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Rehabilitation length of stay and functional improvement among patients with traumatic spinal cord injury

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STUDY DESIGN:: Retrospective cohort study.

OBJECTIVE: Investigate the association between rehabilitation length of stay (LOS) and motor FIM® (mFIM) between rehabilitation admission and discharge among patients with traumatic spinal cord injury (SCI).

SETTING: Seventeen SCI Model Systems (SCIMS) centers in the United States.

METHODS: A total of 3386 patients with traumatic SCI enrolled in the SCIMS Database from 2011 to 2018. The main outcome measure was the mean change in mFIM (12 items) between rehabilitation admission and discharge by twelve neurological categories (C1-C4 American Spinal Injury Association impairment scale (AIS) A-B, AIS C, AIS D, and C5-C8 AIS A-B, AIS C, AIS D, and T1-T10 AIS A-B, AIS C, AIS D, and T11-S3 AIS A-B, C, D). Linear regression models were applied to estimate changes across rehabilitation LOS groups (shortest LOS, quarter2, quarter3, and longest LOS) after adjusting for covariables for each neurological category.

RESULTS: The mean age of study patients was 44.5 years. Patients were predominantly men (78.5%), non-Hispanic white (64.8%), and had private insurance (57.1%). The median LOS was 42 days across the entire sample. Longer LOS was associated with a higher mFIM score compared to the shortest LOS among patients with C1–C4 AIS D; C5-C8 AIS D; T1–T10 AIS A–B; and T11-S3 AIS A–B, C, and D after adjusting for demographics and clinical characteristics.

CONCLUSION: Among patients with C1–C4 AIS D; C5–C8 AIS D; T1–T10 AIS A–B; and T11-S3 AIS A–B, C, and D injuries, those with longer rehabilitation stays tended to have more motor function improvement.

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INTRODUCTION

The current incidence of traumatic spinal cord injury (SCI) is approximately 17,810 people each year in the United States (US) [1]. Patients with traumatic SCI experience high medical utilization with substantial economic costs [2]. The dominant medical expenditures in the first year after a traumatic SCI, covering over half of expenditures, occurs during the inpatient acute and rehabilitation care [2].

Inpatient medical rehabilitation is a fundamental component of health care delivery, playing a critical role in improving functional status, optimizing independence, and facilitating discharge to the community for individuals after a traumatic SCI [3]. Length of stay (LOS), one of the primary drivers of healthcare costs for individuals with a traumatic SCI, is also used to evaluate the efficiency of health care delivery [4]. Moreover, rehabilitation LOS is a vital predictor of motor function restoration according to a systematic review [5]. However, the average rehabilitation LOS has become progressively shorter over the years in the US. According to the National SCI Statistical Center report, the trend of rehabilitation LOS for patients with traumatic SCI has declined from an average of 98 days in the 1970s, to an average of 31 days in 2020 [1]. Shorter rehabilitation LOS may be desirable from an economic point of view; but, functional improvement by rehabilitation discharge may be impacted for individuals with a traumatic SCI.

Prior studies have reported that earlier rehabilitation may ameliorate traumatic SCI patients' functional status at rehabilitation discharge [6, 7]. Warschausky et al. observed that longer rehabilitation LOS was associated with increased FIM® scores (i.e., better functional abilities recovery) [8]. However, other studies have reported that rehabilitation LOS decreased annually and FIM® scores increased among the traumatic SCI population [9, 10]. Moreover, these studies used data from around a decade ago. Therefore, using recent data to examine the association between LOS and functional improvement among patients with traumatic SCI using recent data is important for patients, clinicians, and policy makers because rehabilitation LOS had declined dramatically since 1970s. In addition, many studies have reported data using four neurological categories (i.e. C1–C4 American Spinal Injury Impairment Scale (AIS) ABC, C5–C8 AIS ABC, T1–S3 AIS ABC, and AIS D) [11]. While these four neurological categories have been used as a standard analysis in SCI rehabilitation for more than 10 years, that does not mean that there are not finer gradations that can be used, especially when large datasets are available. Hence, this study aims to investigate the association between rehabilitation LOS and motor FIM® (mFIM) between

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Table 1. Quarters of rehabilitation LOS across neurological categories ($n = 3386$).

Neurological Category	Total (n)	Rehabilitation LOS (days)			Average Rehabilitation LOS (days) by Quarter[a]			
		25th percentile	Median	75th percentile	Shortest LOS (Quarter 1)	Quarter 2	Quarter 3	Longest LOS (Quarter 4)
C1–C4 AIS A–B	543	45	63	86	35.7 ± 7.7 (143)	54.6 ± 5.2 (132)	75.2 ± 7.1 (135)	119.9 ± 42.7 (133)
C1–C4 AIS C	351	40	53	74	31.1 ± 6.3 (90)	47.0 ± 3.6 (90)	63.1 ± 6.4 (87)	97.4 ± 25.2 (84)
C1–C4 AIS D	498	18	30	43	12.0 ± 3.9 (133)	24.5 ± 3.6 (123)	36.8 ± 3.8 (126)	62.7 ± 19.9 (116)
C5–C8 AIS A–B	308	44	59	77	34.5 ± 8.8 (78)	51.3 ± 4.3 (77)	68.7 ± 5.5 (80)	106.6 ± 36.8 (73)
C5–C8 AIS C	134	38	56	74	30.4 ± 6.0 (34)	48.8 ± 5.3 (37)	64.8 ± 5.1 (30)	93.8 ± 21.5 (33)
C5–C8 AIS D	289	15	23	35	10.3 ± 3.4 (76)	19.5 ± 2.3 (73)	29.5 ± 3.4 (75)	53.5 ± 19.6 (65)
T1–T10 AIS A–B	609	29	42	56	22.4 ± 6.0 (171)	36.5 ± 3.8 (156)	49.3 ± 4.2 (132)	75.8 ± 21.8 (150)
T1–T10 AIS C	109	28	35	51	23.4 ± 4.1 (33)	32.0 ± 2.2 (24)	43.4 ± 5.0 (27)	73.5 ± 30.4 (25)
T1–T10 AIS D	90	16	23	36	11.7 ± 3.4 (24)	20.5 ± 1.7 (22)	29.5 ± 3.8 (24)	50.4 ± 13.5 (20)
T11–S3 AIS A–B	227	25	35	49	18.8 ± 4.9 (59)	30.7 ± 3.4 (61)	42.1 ± 4.2 (55)	69.2 ± 20.7 (52)
T11–S3 AIS C	112	24	34	48	17.9 ± 4.3 (28)	28.9 ± 2.6 (29)	39.8 ± 4.5 (30)	61.0 ± 11.8 (25)
T11–S3 AIS D	116	13	21	29	8.8 ± 2.7 (31)	17.2 ± 2.4 (30)	25.7 ± 2.5 (30)	42.5 ± 17.1 (25)

Overall mean and median of Rehabilitation LOS were 48 and 42 days, respectively.
LOS length of stay.
[a]mean ± SD (*n*).

rehabilitation admission and discharge among the traumatic SCI population across twelve neurological categories using recent data from the National SCI Model Systems (SCIMS) Database.

METHODS

Study design and population

The SCIMS Database currently captures about 6% of new traumatic SCIs every year, and follow-up interviews with these participants occur at regular intervals. The SCIMS Database has standardized data collection methods, measures, and error check mechanisms to assure data quality, which has been previously described [12].

In the SCIMS Database, there were 4833 patients who had a record of rehabilitation admission identified during the period from October 2011 to August 2018. Patients were included beginning in October 2011 because health insurance information was available after October 1, 2011 [13]. We excluded patients with atypical stays, such as program interruption ($n =$ 209), patients deceased during inpatient rehabilitation ($n = 8$), and patients younger than 18 years old ($n = 165$). We also excluded patients who were not covered by private health insurance, Medicare, or Medicaid ($n = 601$) as these stays may be shorter or longer due to insurance coverage status [14]. After excluding records with key data missing or unknown, as follows: sex and race ($n = 31$), neurological category at rehabilitation admission ($n = 268$), and mFIM at either admission or discharge ($n = 165$). In total, 3386 patients were eligible for this study.

Primary outcome measure

The FIM® instrument was developed to assess a person's level of disability in terms of burden of care [15]. Using FIM® data, we created the outcome measure change in mFIM, which included 12 items covering self-care, sphincter control, transfers, and locomotion dimensions [9, 10]. In our study, the tub/shower transfer item was excluded from transfers because scores have been shown to vary based on the environment (use of roll-in shower or tub) and thus may not always reflect a person's level of disability [16]. The FIM® items are coded using a seven-level rating scale. Consistent with most prior research, a code of "0" indicating that an activity did not occur., was re-coded to one. The summed score of the 12 motor items ranged from 12–84, with a higher score indicating more independence. We summed FIM® scores to create our outcome measure, which is a common method used to share such data with clinicians. Additionally, we created a mFIM change score using admission and discharge data. The general formula of mean change in mFIM (ΔmFIM) is

$$\Delta mFIM = mFIM_{Discharge} - mFIM_{Admission}$$

Some studies have transformed data to Rasch measures to try to address the ordinal nature of the data. Although Rasch measures could turn FIM® items into an interval score that is approximately equally sensitive in the middle as at the extreme values, the results from Rasch analysis may not be easily understood by clinicians and patients. Previous research has shown that summed FIM® scores show a higher correlation with minutes of assistance and minutes of paid assistance (ratio-level measures; a square-root of assistance was used to model the curvilinear relationship) than FIM® Rasch measures [17]. In addition, there is a strong linear correlation between raw summed scores and Rasch transformed scores [8], and the variation occurs mostly at the extremes. Therefore, this study measured raw ΔmFIM without a Rasch analysis.

Independent variable of Interest

Rehabilitation LOS was the independent variable of interest. This study calculated rehabilitation LOS in days, and then classified LOS into four equal groups: LOS ≤ 25th percentile (shortest LOS [Quarter 1]), 25th percentile < LOS ≤ median (Quarter 2), median < LOS ≤ 75th percentile (Quarter 3), and LOS > 75th percentile (longest LOS [Quarter 4]). This was done because rehabilitation LOS data were a skewed distribution. Because LOS varied by injury severity, we stratified patients into twelve categories, and the quarter was specifically defined for each neurological category based on the level of injury and AIS grade: C1–C4 AIS A and B, C1–C4 AIS C, C1–C4 AIS D, C5–C8 AIS A and B, C5–C8 AIS C, C5–C8 AIS D, T1–T10 AIS A and B, T1–T10 AIS C, T1–T10 AIS D, T11–S3 AIS A and B, T11–S3 AIS C, and T11–S3 AIS D (Table 1).

Covariables

Patients' demographic and clinical characteristics [6, 11, 18] might associate with functional outcomes at rehabilitation discharge; therefore, we adjusted for several covariables in data analysis. Patient's demographics included age, sex, race/ethnicity (non-Hispanic white, non-Hispanic black, Hispanics, and others [Asian, Hawaiian/Pacific islander, Native American/Aleut, and unspecified]), marital status (never married, married [married and living with significant other], and other [divorced, separated, and widowed]), education level (less than high school, high school or above), family household income (<$25,000, $25,000–$49,999, $50,000–$74,999, and $75,000 or more), and insurance program (private, Medicare, and Medicaid). Clinical characteristics included associated injury (yes/no), spinal surgery (yes/no) [11], and number of days from injury to rehabilitation admission [6]. Associated injury was identified if the patient has any of the co-existing injuries included (1) moderate to severe traumatic brain injury (Glascow Coma Scale Score of 12 or below), (2) non-vertebral fractures requiring surgery, (3) severe facial injuries affecting sensory organs, (4) major chest injury requiring chest-tube or mechanical ventilation, (5) traumatic amputations of an arm or leg, or injuries severe enough to require surgical amputation, (6) severe hemorrhaging, and (7) damage to any internal organ requiring surgery spinal surgery. Regarding spinal surgery, patients who received any of the following procedure during the inpatient hospitalization were identified as having spinal

Table 2. Study patient characteristics overall and by quarters of rehabilitation LOS, 2011–2018.

Variables	Overall	Quarters of rehabilitation length of stay[c]				
		Shortest LOS	Quarter 2	Quarter 3	Longest LOS	P value
	N = 3386	N = 900	N = 854	N = 831	N = 801	
	n (%)	n (%)	n (%)	n (%)	n (%)	
Age, years (mean ± SD)	44.4 ± 18.3	44.1 ± 18.0	44.6 ± 18.7	45.0 ± 18.2	43.9 ± 18.2	0.974
Sex						0.753
Female	728 (21.5)	193 (21.4)	176 (20.6)	189 (22.7)	170 (21.2)	
Male	2658 (78.5)	707 (78.6)	678 (79.4)	642 (77.3)	631 (78.8)	
Race/ethnicity						<0.001
Non-Hispanic White	2194 (64.8)	538 (59.8)	546 (63.9)	563 (67.8)	547 (68.3)	
Non-Hispanic Black	658 (19.4)	204 (22.7)	179 (21.0)	149 (17.9)	126 (15.7)	
Hispanic	394 (11.6)	122 (13.6)	104 (12.2)	79 (9.5)	89 (11.1)	
Others[a]	140 (4.2)	36 (4.0)	25 (2.9)	40 (4.8)	39 (4.9)	
Marital status						0.491
Never married	1421 (42.0)	379 (42.2)	373 (43.7)	326 (39.2)	343 (42.9)	
Married	1430 (42.3)	372 (41.4)	356 (41.7)	363 (43.7)	339 (42.4)	
Others[b]	532 (15.7)	148 (16.5)	125 (14.6)	142 (17.1)	117 (14.6)	
Unknown	3					
Educational level						<0.01
<high school	2128 (63.0)	601 (66.9)	551 (64.7)	503 (60.7)	473 (59.1)	
≥high school	1251 (37.0)	297 (33.1)	301 (35.3)	326 (39.3)	327 (40.9)	
Unknown	7					
Family household income						<0.001
<$25,000	806 (28.6)	257 (33.7)	206 (28.5)	175 (25.5)	168 (25.8)	
$25,000–$49,999	704 (24.9)	212 (27.8)	185 (25.6)	171 (24.9)	136 (20.9)	
$50,000–$74,999	510 (18.1)	128 (16.8)	145 (20.1)	134 (19.5)	103 (15.8)	
≥$75,000	802 (28.4)	166 (21.8)	186 (25.8)	206 (30.0)	244 (37.5)	
Unknown	564					
Insurance type						<0.001
Private	1934 (57.1)	456 (50.7)	471 (55.2)	517 (62.2)	490 (61.2)	
Medicare	545 (16.1)	148 (16.4)	152 (17.8)	133 (16.0)	112 (14.0)	
Medicaid	907 (26.8)	296 (32.9)	231 (27.1)	181 (21.8)	199 (24.8)	
Associated injury						<0.001
No	2265 (67.1)	642 (71.5)	566 (66.5)	563 (68.0)	494 (61.8)	
Yes	1111 (32.9)	256 (28.5)	285 (33.5)	265 (32.0)	305 (38.2)	
Unknown	10					
Spinal surgery						<0.01
No	579 (17.1)	186 (20.7)	150 (17.6)	135 (16.3)	108 (13.5)	
Yes	2805 (82.9)	714 (79.3)	704 (82.4)	695 (83.7)	692 (86.5)	
Unknown	2					
Days from injury to rehab (mean ± SD)	22.9 ± 30.0	24.6 ± 36.6	20.8 ± 26.0	21.0 ± 26.4	25.1 ± 29.0	0.817

LOS length of stay.
[a]Other race includes Asian, Hawaiian/Pacific Islander, Native American/Aleut, and Unspecified.
[b]Other marital status includes divorced, separated, and widowed.
[c]The quarters were specifically defined for each of the 12 neurological categories.

surgery: (1) laminectomy, (2) neural canal restoration, (3) open reduction, (4) spinal fusion, and (5) internal fixation of the spine. These covariables were recorded at admission to the rehabilitation unit.

Statistical Analysis

We used descriptive statistical analysis to calculate the distribution of patient characteristics across neurological category-specific quarters of rehabilitation LOS. The association of patient characteristics with LOS was examined using a chi-squared test for categorical variables and a one-way analysis of variance for continuous variables. A linear trend test was used to evaluate unadjusted ΔmFIM by the quarters of LOS. Multiple linear regression analyses were applied to compare ΔmFIM across quarters of LOS for each injury category while adjusting for covariables. All models were tested using variance inflation factor (VIF) to detect the presence of multi-collinearity. There was no multi-collinearity because VIF scores were less than five. The statistically significant level is 0.05. All analyses were performed using SAS version 9.4 (SAS Institute, Cary, NC).

Table 3. FIM motor scores (unadjusted)[a] at admission, at discharge, and change by quarters of rehabilitation LOS ($n = 3386$).

	Overall	Quarters of Rehabilitation Length of Stay[b]				*P* for trend
		Shortest LOS	Quarter 2	Quarter 3	Longest LOS	
Overall						
Admission	21.8 ± 10.4	26.6 ± 12.9	21.9 ± 9.5	19.8 ± 8.3	18.5 ± 7.7	
Discharge	47.2 ± 20.2	48.8 ± 21.6	47.8 ± 19.5	46.7 ± 19.6	45.3 ± 19.7	
ΔmFIM	25.4 ± 15.5	22.3 ± 14.4	25.9 ± 14.9	26.9 ± 16.0	26.8 ± 16.3	<0.001
C1–C4 AIS A–B						
Admission	13.3 ± 2.3	13.6 ± 3.1	13.0 ± 1.6	13.4 ± 2.2	13.1 ± 1.9	
Discharge	22.7 ± 10.1	21.6 ± 9.6	22.6 ± 9.1	25.2 ± 11.3	21.7 ± 9.8	
ΔmFIM	9.4 ± 9.2	7.9 ± 7.9	9.6 ± 8.7	11.8 ± 10.6	8.6 ± 9.0	0.210
C1–C4 AIS C						
Admission	13.6 ± 3.3	14.4 ± 5.1	13.4 ± 2.4	13.5 ± 2.7	13.1 ± 2.0	
Discharge	31.9 ± 17.0	28.0 ± 17.7	34.1 ± 17.7	34.7 ± 16.9	30.8 ± 14.8	
ΔmFIM	18.2 ± 16.3	13.6 ± 16.1	20.6 ± 17.1	21.1 ± 16.4	17.7 ± 14.3	0.090
C1–C4 AIS D						
Admission	22.7 ± 12.0	34.8 ± 13.3	21.7 ± 8.6	17.2 ± 7.8	16.0 ± 5.3	
Discharge	56.4 ± 17.8	66.5 ± 12.8	55.7 ± 16.8	51.2 ± 19.9	51.1 ± 16.8	
ΔmFIM	33.7 ± 15.3	31.8 ± 12.4	34.0 ± 15.2	34.0 ± 17.7	35.1 ± 15.4	0.100
C5–C8 AIS A–B						
Admission	16.5 ± 5.7	18.6 ± 7.6	17.1 ± 5.2	16.0 ± 4.9	14.2 ± 3.3	
Discharge	36.6 ± 13.9	36.7 ± 15.5	37.8 ± 13.5	36.5 ± 14.2	35.3 ± 12.4	
ΔmFIM	20.1 ± 11.5	18.1 ± 11.4	20.7 ± 10.8	20.5 ± 12.0	21.0 ± 11.7	0.138
C5–C8 AIS C						
Admission	16.4 ± 5.2	18.4 ± 5.5	15.1 ± 3.9	17.4 ± 6.0	14.8 ± 4.7	
Discharge	42.2 ± 17.2	43.6 ± 19.2	38.5 ± 16.4	46.6 ± 15.7	40.6 ± 16.8	
ΔmFIM	25.8 ± 15.9	25.2 ± 17.0	23.4 ± 15.3	29.3 ± 14.5	25.9 ± 16.8	0.526
C5–C8 AIS D						
Admission	26.9 ± 12.7	38.8 ± 12.5	28.2 ± 10.1	22.0 ± 8.7	17.1 ± 6.7	
Discharge	62.7 ± 13.9	69.1 ± 9.0	65.5 ± 11.1	59.0 ± 15.3	56.2 ± 15.8	
ΔmFIM	35.8 ± 13.5	30.3 ± 11.7	37.3 ± 11.8	37.0 ± 14.7	39.1 ± 14.4	
T1–T10 AIS A–B						
Admission	25.8 ± 6.7	28.1 ± 6.9	26.3 ± 6.4	24.6 ± 6.4	23.6 ± 6.2	
Discharge	54.5 ± 12.5	52.4 ± 13.4	55.7 ± 11.2	53.7 ± 13.3	56.6 ± 11.7	
ΔmFIM	28.8 ± 11.7	24.3 ± 11.5	29.4 ± 10.4	29.0 ± 12.5	32.9 ± 10.9	<0.001
T1–T10 AIS C						
Admission	27.4 ± 7.8	28.8 ± 9.4	29.9 ± 8.3	25.6 ± 5.8	25.0 ± 5.9	
Discharge	57.0 ± 13.3	56.5 ± 12.6	58.0 ± 12.9	57.9 ± 13.7	55.8 ± 14.8	
ΔmFIM	29.6 ± 11.6	27.7 ± 12.0	28.1 ± 9.3	32.3 ± 12.1	30.8 ± 12.3	0.163
T1–T10 AIS D						
Admission	31.5 ± 10.5	39.5 ± 10.7	27.5 ± 6.6	30.0 ± 9.7	28.1 ± 10.3	
Discharge	62.7 ± 13.5	67.7 ± 9.3	59.9 ± 10.7	62.3 ± 14.6	60.5 ± 17.7	
ΔmFIM	31.2 ± 12.3	28.2 ± 11.1	32.4 ± 10.8	32.2 ± 10.4	32.4 ± 16.9	0.276
T11–S3 AIS A–B						
Admission	28.2 ± 7.9	32.6 ± 8.4	28.3 ± 6.3	26.2 ± 6.8	25.5 ± 8.4	
Discharge	59.4 ± 12.0	59.5 ± 11.6	59.4 ± 11.7	60.5 ± 11.1	57.9 ± 13.6	
ΔmFIM	31.1 ± 12.1	27.0 ± 12.7	31.1 ± 11.2	34.3 ± 11.5	32.5 ± 12.2	0.006
T11–S3 AIS C						
Admission	30.8 ± 9.5	36.5 ± 9.7	31.5 ± 10.1	26.7 ± 6.4	28.5 ± 8.8	
Discharge	62.9 ± 11.2	64.1 ± 10.6	61.7 ± 11.2	60.9 ± 12.8	65.2 ± 9.6	
ΔmFIM	32.1 ± 11.7	27.7 ± 11.5	30.2 ± 11.8	34.2 ± 12.2	36.7 ± 9.6	0.002
T11–S3 AIS D						
Admission	35.5 ± 10.0	43.8 ± 8.7	36.2 ± 9.1	32.0 ± 7.3	28.5 ± 7.8	

Table 3 continued

	Overall	Quarters of Rehabilitation Length of Stay[b]				P for trend
		Shortest LOS	Quarter 2	Quarter 3	Longest LOS	
Discharge	65.7 ± 10.0	68.5 ± 9.0	65.6 ± 8.7	64.8 ± 11.2	63.2 ± 10.6	
ΔmFIM	30.2 ± 11.3	24.7 ± 10.5	29.4 ± 9.6	32.8 ± 10.1	34.8 ± 13.0	<0.001

Admission, Discharge and Change are expressed in points as the sum of item scores.
ΔmFIM mean change of mFIM, *LOS* length of stay.
*Mean ± SD.
[§]The quarters were specifically defined for each of the 12 neurological categories.

This study protocol was reviewed and approved by the institutional review board at Louisiana State University Health Sciences Center New Orleans and University of Alabama at Birmingham.

RESULTS

The demographic characteristics of the patients with traumatic SCI ($n = 3386$), summarized in Table 2, show that 900 (26.6%), 854 (25.2%), 831 (24.5%), and 801 (23.7%) patients were included in the shortest to longest rehabilitation LOS groups, respectively. Among the entire sample, the mean age was 44.4 years (SD = 18.3), men comprised 78.5% of the patients, 64.8% of patients were non-Hispanic white, and 57.1% of patients had private insurance. Furthermore, 32.9% and 82.9% of patients had an associated injury and received spinal surgery, respectively. The average number of days from injury to rehabilitation admission was 22.9 (SD = 30.0) days. Across LOS groups, there were significant differences in several characteristics: race/ethnicity, education level, family household income, insurance type, associated injury, and spinal surgery. Compared to the shortest quarter of rehabilitation LOS, a greater percentage of patients in the upper quarter were non-Hispanic white (59.8% vs 68.3%), had a higher education level (33.1% vs 40.9%) and family household income (21.8% vs 37.5%), had private insurance (50.7% vs 61.2%), had an associated injury (28.5% vs 38.2%), and had spinal surgery (79.3% vs 86.5%).

Table 3 presents the unadjusted summed mFIM scores at rehabilitation admission and discharge as well as mFIM changes between admission and discharge. The overall ΔmFIM was 25.4 (SD = 15.5) and scores increased when rehabilitation LOS increased (P for trend <0.001). A significant positive association between rehabilitation LOS and ΔmFIM was found among patients with C5-C8 AIS D; T1-T10 AIS A-B; T11-S3 AIS A-B, T11-S3 AIS C, and T11-S3 AIS D, respectively (P for trend <0.01).

The results from the linear regressions evaluating the effect of rehabilitation LOS and covariables on ΔmFIM are presented in Table 4. After adjusting for covariables, compared to patients in the shortest quarter of rehabilitation LOS, those who were in the second, third, and longest quarter of rehabilitation LOS had a significant higher ΔmFIM among overall SCI patients (adjusted coefficient = 3.22, 4.80, and 5.20, respectively). After analyzing patients in each injury category independently, compared to the shortest quarter group, there was a statistically significant increase in ΔmFIM for the second, third, and longest quarter groups among patients with C5-C8 AIS D (adjusted coefficient = 7.55, 7.75, and 11.94) and T1–T10 AIS A-B (adjusted coefficient = 4.22, 3.70, and 7.04). Among patients with C1–C4 AIS D, T11–S3 AIS A–B, and T11–S3 AIS D, higher ΔmFIM for the third and longest quarter groups was observed compared to those in the shortest quarter group (adjusted coefficient = 4.84 and 5.52; adjusted coefficient = 5.57 and 5.86, and adjusted coefficient = 8.12 and 13.17, respectively). However, compared to the patients in the shortest LOS group, patients in the second quarter group had a tendency of improvement in ΔmFIM (adjusted coefficient = 3.77, 2.67, and 5.65, respectively) without statistical significance. Patients with C1–C4 AIS A–B in the third quarter group were observed to have a significant improvement in ΔmFIM (adjusted coefficient = 3.57) when compared to those who were in the shortest quarter group. In addition, patients with T11–S3 AIS C in the longest quarter group showed a higher improvement of ΔmFIM than those in the shortest quarter group (adjusted coefficient = 9.41). Among patients with C5–C8 AIS A–B, C5–C8 AIS C, T1–T10 AIS C, and T1–T10 AIS D, there were no significant positive associations between LOS and ΔmFIM in these neurological categories.

DISCUSSION

Using recent data from the National SCIMS Database, this study examined the association between rehabilitation LOS and mFIM for adult patients with traumatic SCI. The findings of this study revealed that longer rehabilitation LOS was associated with higher mFIM improvement in patients with traumatic SCI. Patients with a lower mFIM score at admission were observed in the longer LOS groups which may lead to a higher ΔmFIM scores. Additionally, this study classified patients into twelve groups based on their neurological categories at the time of rehabilitation admission to demonstrate the relationship between LOS and mFIM. Among patients with C1–C4 AIS D, C5–C8 AIS D, T1–T10 AIS A–B, T11–S3 AIS A–B, T11–S3 AIS C, and T11–S3 AIS D, those with longer rehabilitation stays have greater mFIM gain. In the C1–C4 AIS A–B and C1–C4 AIS C injury groups, patients who were in the 3rd LOS quarter showed the highest ΔmFIM. In addition, mFIM improvement increased with a longer rehabilitation LOS among patients with C5–C8 AIS A–B, C5–C8 AIS C, T1–T10 AIS C, and T1–T10 AIS D injuries.

Previous studies have shown wide ranges of LOS in rehabilitation across the world. Our study showed that the average rehabilitation LOS is 48 days (median is 42 days) among patients with traumatic SCI, which was close to but shorter than another US study (mean, 55 days) [4]. However, the rehabilitation LOS in the US was lower than studies that were conducted in other countries, including Canada (median, 81 days) [3], Australia (median, 83 days) [19], Norway (mean, 105 days) [20], Netherlands and Flanders (mean, 183.3 days; median, 155.5 days) [21], Israel (mean, 239 days) [22], and Japan (mean, 185.6 days for patients with early rehabilitation; and 267.8 days for patients with delayed rehabilitation) [7]. Future studies are encouraged to explore what kind of factors cause the variation of rehabilitation LOS around the world. Additionally, the effect of rehabilitation LOS on function improvement for SCI patients has been a long-standing discussion with inconsistent findings. Osterthum et al. reported that there is no statistically significant association between LOS and function outcome [21]. In contrast, Ronen and colleagues reported a high correlation ($r = 0.81$) between LOS and Spinal Cord Independence Measure (SCIM) scores when analyzing LOS between 30 and 70 days, indicating a longer stay in the rehabilitation may be associated with higher SCIM scores at discharge. However, no significant correlation was detected when LOS ≥ 70 days despite a trend of slightly increased SCIM gain [22]. Our findings are consistent with Ronen's study. On average, patients who are in the

Table 4. Association between LOS and change in FIM motor score using regression models.

Quarters of rehabilitation LOS[b]	Unadjusted models		Adjusted models[a]	
	Coeff (95% CI)	*P* value	Coeff (95% CI)	*P* value
Overall				
Quarter 2	3.63 (2.18, 5.07)	<0.001	3.22 (1.70, 4.74)	<0.001
Quarter 3	4.68 (3.22, 6.13)	<0.001	4.80 (3.25, 6.34)	<0.001
Quarter 4 (Longest)	4.52 (3.06, 5.99)	<0.001	5.20 (3.62, 6.78)	<0.001
C1–C4 AIS A–B				
Quarter 2	1.63 (−0.53, 3.79)	0.138	1.34 (−0.92, 3.60)	0.246
Quarter 3	3.85 (1.70, 5.99)	0.001	3.57 (1.24, 5.90)	0.003
Quarter 4 (Longest)	0.65 (−1.50, 2.80)	0.554	0.12 (−2.26, 2.51)	0.918
C1–C4 AIS C				
Quarter 2	7.07 (2.36, 11.77)	0.003	6.66 (1.60, 11.72)	0.010
Quarter 3	7.57 (2.83, 12.32)	0.002	7.39 (2.34, 12.45)	0.004
Quarter 4 (Longest)	4.09 (−0.70, 8.88)	0.094	3.38 (−1.69, 8.45)	0.191
C1–C4 AIS D				
Quarter 2	2.20 (−1.55, 5.95)	0.249	3.77 (−0.08, 7.62)	0.055
Quarter 3	2.25 (−1.48, 5.98)	0.236	4.84 (1.12, 8.56)	0.011
Quarter 4 (Longest)	3.30 (−0.51, 7.11)	0.090	5.52 (1.59, 9.44)	0.006
C5–C8 AIS A–B				
Quarter 2	2.61 (−1.02, 6.24)	0.158	0.12 (−3.85, 4.09)	0.951
Quarter 3	2.44 (−1.16, 6.03)	0.184	1.26 (−2.83, 5.36)	0.544
Quarter 4 (Longest)	2.95 (−0.73, 6.63)	0.116	1.50 (−2.71, 5.72)	0.483
C5–C8 AIS C				
Quarter 2	−1.74 (−9.25, 5.76)	0.647	−0.09 (−8.24, 8.07)	0.983
Quarter 3	4.09 (−3.82, 12.00)	0.308	5.86 (−2.46, 14.18)	0.165
Quarter 4 (Longest)	0.70 (−7.02, 8.42)	0.858	5.40 (−3.53, 14.32)	0.233
C5–C8 AIS D				
Quarter 2	7.02 (2.77, 11.27)	0.001	7.55 (3.16, 11.95)	<0.001
Quarter 3	6.74 (2.52, 10.96)	0.002	7.75 (3.34, 12.16)	<0.001
Quarter 4 (Longest)	8.83 (4.45, 13.21)	<0.001	11.94 (7.18, 16.70)	<0.001
T1–T10 AIS A–B				
Quarter 2	5.03 (2.57, 7.48)	<0.001	4.22 (1.57, 6.87)	0.002
Quarter 3	4.70 (2.12, 7.27)	<0.001	3.70 (0.90, 6.50)	0.010
Quarter 4 (Longest)	8.60 (6.11, 11.08)	<0.001	7.04 (4.27, 9.82)	<0.001
T1–T10 AIS C				
Quarter 2	0.36 (−5.79, 6.51)	0.909	0.75 (−6.92, 8.42)	0.847
Quarter 3	4.57 (−1.38, 10.52)	0.131	7.03 (−0.03, 14.08)	0.051
Quarter 4 (Longest)	3.07 (−3.01, 9.15)	0.319	5.55 (−1.63, 12.73)	0.128
T1–T10 AIS D				
Quarter 2	4.16 (−3.11, 11.42)	0.259	4.94 (−4.09, 13.98)	0.278
Quarter 3	4.00 (−3.11, 11.11)	0.266	4.12 (−4.40, 12.64)	0.337
Quarter 4 (Longest)	4.14 (−3.31, 11.60)	0.273	8.19 (−0.89, 17.28)	0.076
T11–S3 AIS A–B				
Quarter 2	4.15 (−0.13, 8.43)	0.058	2.67 (−1.60, 6.95)	0.219
Quarter 3	7.31 (2.91, 11.70)	0.001	5.57 (1.08, 10.06)	0.015
Quarter 4 (Longest)	5.48 (1.02, 9.94)	0.016	5.86 (1.28, 10.44)	0.013
T11–S3 AIS C				
Quarter 2	2.56 (−3.42, 8.54)	0.398	3.79 (−3.75, 11.33)	0.319
Quarter 3	6.52 (0.59, 12.45)	0.032	6.01 (−1.83, 13.86)	0.131
Quarter 4 (Longest)	9.00 (2.79, 15.21)	0.005	9.41 (1.64, 17.19)	0.018
T11–S3 AIS D				
Quarter 2	4.72 (−0.73, 10.18)	0.089	5.65 (−1.09, 12.40)	0.099

Table 4 continued

Quarters of rehabilitation LOS[b]	Unadjusted models		Adjusted models[a]	
	Coeff (95% CI)	*P* value	Coeff (95% CI)	*P* value
Quarter 3	8.06 (2.60, 13.52)	0.004	8.12 (1.38, 14.85)	0.019
Quarter 4 (Longest)	10.05 (4.32, 15.78)	<0.001	13.17 (6.42, 19.92)	<0.001

Reference group: The shortest LOS quarter (Quarter 1) of rehabilitation LOS
LOS length of stay
[a]Adjusted for age, sex, race/ethnicity, marital status, education level, family household income, insurance type, associated injury, spinal surgery, and days from injury to rehabilitation admission.
[b]The quarters were specifically defined for each of the 12 neurological categories.

longest LOS group (mean LOS: 62.7 [C1–C4 AIS D], 53.5 [C5–C8AIS D], 75.8 [T1–T10 AIS A–B], 50.4 [T1–T10 AIS D], 69.2 [T11–S3 AIS A-B], 61.0 [T11–S3 AIS C], and 42.5 [T11–S3 AIS D] days, respectively) showed the highest mFIM improvement; this was not observed for patients with C1–C4 AIS A–B, C1–C4 AIS C, and T1–T10 AIS C. Among these patients, the highest mFIM gain was observed in the 3rd LOS quarter group (mean LOS: 75.2, 63.1, and 43.4 days).

Our study, consistent with most prior studies, demonstrated that longer LOS is associated with improvement in mFIM among patients with traumatic SCI. A study conducted in Israel found that longer LOS was associated with increased functional ability in patients with SCI [22]. Vervoordeldonk et al. observed that rehabilitation LOS was associated with changes in FIM® motor scores for patients with non-traumatic SCI in the Netherlands [23]. A Saudi Arabia study found a positive association between rehabilitation LOS and mFIM change score among people with traumatic SCI [24]. One study has also shown that longer rehabilitation LOS was associated with a lower likelihood of rehospitalizations after discharge for patients with traumatic SCI who lived in six geographically dispersed rehabilitation centers in the US [25]. Therefore, it may be a beneficial to not only optimize mFIM improvement, but also reduce healthcare utilization (i.e., readmissions) [26] if patients stay longer in the rehabilitation. Longer rehabilitation LOS does benefit some people with traumatic SCI in terms of more functional abilities by discharge. Longer LOS provides more time and opportunities for interdisciplinary treatments and identification of medical vulnerabilities, additional education about recovery and health promotion, which can lead to improvements in patients' functional activities at discharge and reductions in the risk of rehospitalizations after discharge [26]. Another reason a longer rehabilitation LOS can be beneficial is because it provides time for patients to learn more about taking care of themselves and staying healthy after discharge.

Patients with C5–C8 AIS A–B, C5–C8 AIS C, T1–T10 AIS C, and T1–T10 AIS D injuries exhibited a tendency to gain more mFIM recovery with a longer rehabilitation stay but there were no statistically significant associations between rehabilitation LOS and higher levels of functioning at discharge. A possible reason for this finding might be unmeasured patient complexity (e.g., co-morbidities, complications) and coping strategies. Another reason might be that FIM® activities are not sensitive for this subpopulation with tetraplegia [27]. Moreover, the floor effect of the FIM® instrument may result in only small improvements for patients with tetraplegia (i.e., C5–C8 AIS A–B and C5–C8 AIS C) [28]. For patients with T1–T10 AIS C and T1–T10 AIS D injuries, the small group for T1–T10 AIS C ($n = 109$) and T1–T10 AIS D ($n = 90$) may have led to the marginally significant results. Furthermore, some patients may have a longer stay in rehabilitation due to discharge plan challenges such as waiting for completion of home adaptations or delivery of assistive devices [29].

There are several strengths for this study. This study applied a retrospective cohort design using the SCIMS Database to provide stronger evidence of the association between rehabilitation LOS and motor functional improvement among patients with traumatic SCI. In addition, large samples from the SCIMS Database allowed our study to utilize a more detailed classification of neurological categories than previous studies and control for many confounders. Our findings support the positive association between rehabilitation LOS and motor functional improvement after controlling for demographic characteristics and clinical factors. Moreover, raw summed mFIM score was used in this study because it not only has a highly linear correlation with Rasch transformed scores [8], but can also be used directly by clinicians and practitioners. There are some limitations of this study. First, the readers should be aware of the limited representation of SCIMS Database participants, because the database is not a nationally representative sample of the SCI population across the country; nor is the data weighted, which may limit the generalizability of results [12]. Second, some potential confounders that have been previously associated with rehabilitation LOS, such as comorbidities [18], were not available in the database. Moreover, LOS could have been influenced by many external factors, such as health care policies like Medicare's inpatient rehabilitation facility prospective payment system [9], or financial considerations due to local economic and social policies [22]. Fourth, we included patients with private insurance, Medicare, or Medicaid only, and excluded 433 patients (approximately 10% of the sample) who did not have a reported neurological category, injury level, or mFIM (admission/discharge) data. Therefore, generalization of results with regard to other populations with SCI should be made with caution. Lastly, ceiling and floor effects have been reported for specific FIM® items among patients in the paraplegic group and in the tetraplegic group with a high FIM® score or low FIM® score on admission to rehabilitation [28].

In summary, this study shows a positive association between rehabilitation LOS and the mFIM improvement by discharge among most patients with traumatic SCI. Patients with C1–C4 AIS A–B and C1–C4 AIS C who were in the 3rd quarter of rehabilitation LOS as well as with C1–C4 AIS D, C5–C8 AIS D, T1–T10 AIS A–B, T11–S3 AIS A–B, T11–S3 AIS C and T11–S3 AIS D who had the longest rehabilitation LOS achieved a significant improvement in motor functional recovery. However, patients with C5–C8 AIS A–B, C5–C8 AIS C, T1–T10 AIS C, and T1–T10 AIS D did not show the significant association between LOS and mFIM improvement. Although statistical significance was not detected among these patients, longer LOS exhibited a tendency for more mFIM improvement. Therefore, when possible, patients with traumatic SCI should be encouraged to have a longer rehabilitation LOS in order to improve functional recovery.

DATA AVAILABILITY

The data that support the findings of this study are available from the National Spinal Cord Injury Statistical Center on request.

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AUTHOR CONTRIBUTIONS

Y.K. designed the study, analyzed data and interpreted results, drafted the article, revised the article, and finally approved of the version to be published. YC designed the study, interpreted results, critically revised the article, and finally approved of the version to be published. A.D. designed the study, interpreted results, critically revised the article, and finally approved of the version to be published. H.W. interpreted results, revised the article, and finally approved of the version to be published. T.T. designed the study, interpreted results, drafted the article, critically revised the article, and finally approved of the version to be published.

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COMPETING INTERESTS

The authors declare no competing interests.

ETHICS

This protocol study was approved by the Institutional Review Board of Louisiana State University Health Sciences Center New Orleans (IRB-10028) and University of Alabama at Birmingham (IRB-070419004).

ADDITIONAL INFORMATION

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