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ORIGINAL RESEARCH

Functional Ability Level Development and Validation: Providing Clinical Meaning for Spinal Cord Injury Functional Index Scores

Richa Sinha, MPH, PhD,[a] Mary D. Slavin, PT, PhD,[a] Pamela A. Kisala, MA,[b] Pengsheng Ni, MPH, MD,[a] David S. Tulsky, PhD,[b,c] Alan M. Jette, PT, PhD[a]

From the [a]Health and Disability Research Institute, Boston University School of Public Health, Boston, MA; [b]Center on Assessment Research and Translation, Department of Physical Therapy, College of Health Sciences, University of Delaware, Newark, DE; and [c]Kessler Foundation Research Center, West Orange, NJ.

Abstract

Objectives: To develop functional ability levels for the Spinal Cord Injury Functional Index (SCI-FI) and to validate them using calibration and reliability samples.

Design: Three-phase strategy involved (1) performing quantitative synthesis of SCI-FI data to create item maps; (2) using a panel of experts to identify functional ability levels after the bookmarking and Delphi consensus-building process; and (3) performing quantitative analyses to examine demographic characteristics across 2 samples, assessing the distribution pattern across functional ability levels, and examining concurrent validity using the self-reported functional measure and the observer-rated FIM.

Setting: Inpatient and community settings.

Participants: People 18 years or older with traumatic spinal cord injury (N=1124) were recruited from the Spinal Cord Injury Model Systems programs and stratified by diagnosis, severity, and time since injury (n=855 and n=269 for calibration and reliability samples, respectively).

Interventions: Not applicable.

Main Outcome Measure: SCI-FI.

Results: Five functional ability levels were identified for all SCI-FI domains, except fine motor having 4 functional ability levels. Statistical test results indicated no significant differences in the distribution pattern across the 2 samples across functional ability levels for all domains except for ambulation. Known-group comparisons were able to discern the spinal cord injury population as expected. Basic mobility, self-care, and wheelchair mobility domains had a cluster of persons with paraplegia and incomplete lesions at higher functional ability levels and persons with tetraplegia and complete lesions at lower functional ability levels. For the ambulation domain, the distribution was skewed to the lower end, with a relatively small percentage of persons with incomplete lesions (paraplegia and tetraplegia) at higher functional ability levels. For the fine motor domain, the distribution was skewed to higher functional ability levels, with a high percentage of persons with paraplegia at the highest level (complete and incomplete lesions). Concurrent validity analyses revealed SCI-FI functional levels to be significantly ($P<.001$) positively correlated with both the self-reported functional measure and the observer-rated FIM.

Conclusions: Clinicians can use functional ability levels to discuss patients' functional capabilities with them and their family.

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The need for accurate and sensitive functional measures for spinal cord injury (SCI), emphasized by the International Campaign for Cures of Spinal Cord Injury Paralysis Clinical Guidelines Panel,[1] an international panel established to review the methodology for clinical trials in SCI, and by the 2006 National Institute on Disability and Rehabilitation Research SCI Measures Meeting,[2] led to the development of the Spinal Cord Injury Functional Index (SCI-FI).[1,3] Existing measures are limited in the range of activities being assessed, such as the Spinal Cord Independence Measure,[4,5] which is composed of 19 items that assess 3 domains of functioning (self-care, respiration and sphincter management, mobility), and the FIM,[6] composed of 13 items that assess motor function. The FIM was developed as a generic measure for use in individuals with chronic health conditions and has been shown to have high floor and ceiling effects,[2,7,8] whereas other currently available SCI measures can be used for 1 diagnosis or domain of function. For example, the Quadriplegic Index of Function[9] provides a more detailed assessment of upper extremity functioning but is used only for persons with tetraplegia. Similarly, the Walking Index for Spinal Cord Injury[10] is used only for persons with SCI who ambulate. In summary, current measures used to assess the functioning of persons with SCI have inherent limitations, including an inadequate range of items and limited applicability to all persons with SCI.[11]

The SCI-FI can be administered as a Computerized Adaptive Test (CAT) and uses item banks calibrated with an item response theory approach to hierarchically organize items along a continuum of difficulty in a given domain. CATs use a computer algorithm to select items from the calibrated item bank on the basis of an individual's response to previous items. CAT results provide an estimate of an individual's functional ability on the basis of responses to items appropriate for that individual. Because items are selected from the same calibrated item bank, scores can be compared across individuals even though different sets of items are administered. Initial examination of the SCI-FI demonstrated the measure's validity.[1]

The SCI-FI measures activity limitations in 5 domains: basic mobility (54 items), ambulation (39 items), wheelchair mobility (56 items), self-care (90 items), and fine motor function (36 items). SCI-FI scores provide interval-level data that are useful for research purposes; however, without a functional context, it is difficult to interpret the clinical significance of these numeric scores. Clinicians may not be able to judge the level of functioning implied by SCI-FI numeric scores, which would hinder their ability to use SCI-FI scores to guide clinical practice.[12] Providing meaning to SCI-FI scores in a context that summarizes relevant functional information would enable clinicians to interpret these scores to better understand, communicate, and use the assessment results.

Our approach to interpreting SCI-FI scores identifies hierarchical functional stages, or levels, that characterize a range of scores related to meaningful and distinct functional abilities.[13] This approach has roots in the bookmarking procedure, traditionally used in educational testing to distinguish students of different abilities according to their level of performance.[14] The bookmarking procedure involves ordering items by difficulty, from the easiest to the most difficult, followed by the placement of bookmarks by content experts along the continuum of difficulty to identify the location of the cutoff scores that distinguish different functional levels.[8] Functional levels are simple to understand and provide a clinical context for numeric scores. In this study, we applied the bookmarking procedure to develop item response theory-based functional ability levels for each of the 5 SCI-FI domains. We further examined the known-groups and concurrent validity of SCI-FI functional levels on the basis of the following objectives: (1) to test whether the distribution of persons with SCI across SCI-FI functional levels differs by level of lesion (persons with paraplegia at higher functional levels and persons with tetraplegia at lower functional levels, specifically for fine motor a higher percentage of persons with paraplegia at the highest functioning level) and completeness (persons with incomplete lesions at higher functional levels and persons with complete lesions at lower functional levels, specifically for ambulation a higher percentage of persons with incomplete lesions at the highest functioning level) and (2) to examine whether there are positive correlations between SCI-FI levels and legacy measures (ie, observer-rated FIM and self-reported functional measure).

List of abbreviations:

AIS	**American Spinal Injury Association Impairment Scale**
CAT	**Computerized Adaptive Test**
SCI	**spinal cord injury**
SCI-FI	**Spinal Cord Injury Functional Index**

Methods

Study samples

SCI-FI study participants

Two samples of SCI-FI study participants were used in the study: one from the SCI-FI calibration study (from here on referred to as the calibration sample) and the other from the SCI-FI reliability study (from here on referred to as the reliability sample). The calibration sample was used to develop functional ability levels, and both the calibration and reliability samples were used for the purpose of establishing validity of the functional levels. The SCI-FI calibration study consisted of 855 adults with traumatic SCI.[1] The reliability study consisted of 269 participants. Participants for both studies were recruited by the Spinal Cord Injury Model Systems programs.

Both studies were cross-sectional, and the following inclusion criteria were used for both samples: (1) participants with a traumatic SCI, (2) 18 years or older, and (3) able to read and understand English. Both samples were stratified by level (paraplegia vs tetraplegia) and completeness of injury (complete vs incomplete) and time since injury (<1, 1−3, >3y) to ensure a heterogeneous sample with an adequate representation of functional abilities. The study was approved by the institutional review board of each of the participating Spinal Cord Injury Model Systems programs.

Expert panel participants

The qualitative methodology of the study involved the recruitment of a content expert panel consisting of researchers and/or consumers (people with SCI) involved in disability and SCI research. The expert panel comprised 6 individuals (5 women and 1 man) with professional training in rehabilitation: physical therapy (n=2), occupational therapy (n=1), and public health (n=3). Panel members had experience in SCI research and/or clinical practice. One panel member was an individual with SCI.

Data collection and measures

Calibration sample

For the calibration sample, all SCI-FI items were administered and SCI-FI domain scores were derived. SCI-FI items were administered by trained interviewers either by phone or in person.

Table 1 SCI-FI functional ability levels and descriptions

SCI-FI Domain Levels	Score Interval	Description	
Ambulation			
1	≤50	Unable to ambulate	
2	51—55	A few steps	
3	56—63	Walks for short distances at home	
4	64—75	Walks in some community settings	
5	≥76	Walks in all community settings	
Basic mobility			
1	≤28	Activities involving limited shoulder, head, and supported upper body movement	
2	29—40	Activities involving upright trunk and gross upper extremity movement	
3	41—50	Activities using upper extremities while sitting unsupported and some transfer activities	
4	51—63	Activities involving unsupported sitting, reaching, and level transfers	
5	≥64	Activities involving unsupported sitting and transfers to/from surfaces of different heights	
Fine motor function			
1	≤32	No activities requiring hand function	
2	33—43	Some activities involving gross hand movement	
3	44—51	Some activities requiring dexterity and coordinated upper extremity movement	
4	≥52	Most activities requiring dexterity and coordinated upper extremity movement	
Self-care			
1	≤32	No self-care activities	
2	33—43	Eating and some basic dressing and bathing activities	
3	44—51	Most basic dressing and bathing activities	
4	52—60	Most self-care activities	
5	≥61	All self-care activities	
Wheelchair mobility			
		Power wheelchair	Manual wheelchair
1	≤15	Few basic wheelchair activities	No wheelchair activities
2	16—40	Some wheelchair activities	Unable to do most wheelchair activities
3	41—52	All wheelchair activities	Some basic wheelchair activities
4	53—63	No difficulty with any activities	Most wheelchair activities
5	≥64	NA	All wheelchair activities

Abbreviation: NA, not applicable.

Responses to screener questions (ie, sex, use of wheelchair, ambulation status, living situation, use of bowel and/or bladder program) were used to select appropriate subsets of SCI-FI items. Participants were instructed to respond on the basis of their ability to perform the activity without special equipment or help from another person, except when it was explicitly stated in the item. Participants could skip an item if they were unable to respond. Results from the calibration study[1] demonstrated strong psychometric properties of the SCI-FI.

Reliability sample

Calibrated item banks[1] for the 5 SCI-FI domains (SCI-FI CATs) plus 2 legacy instruments (the self-reported functional measure and the observer-rated FIM) were administered to the reliability sample. The self-reported functional measure and the observer-rated FIM each consist of 13 items measuring motor activities. Items are rated on a 7-point ordinal scale that ranges from total assistance (or complete dependence) to complete independence. The scores range from 13 (lowest) to 91 (highest).

Dimensions assessed include eating, grooming, bathing, upper and lower body dressing, toileting, bladder and bowel management, bed-to-chair transfer, toilet and shower transfer, locomotion (ambulatory or wheelchair level), and stairs. The self-reported functional measure was administered during the interview, and the most recent observer-rated FIM scores were retrieved from the medical record.

For both the samples, data regarding level and completeness of injury were collected by participant self-report at the time of the interview and confirmed by examination of the participant's medical record. After review of the most recent evaluation available in the medical record, the level of lesion was recorded. Completeness was confirmed by recording the most recent American Spinal Injury Association Impairment Scale (AIS) grade. In case of discrepancy between patient self-report and medical record, the medical record reports were used to categorize participants (paraplegia, tetraplegia, complete, incomplete).

Analytic procedure

A 3-phase analytic approach was followed to develop and evaluate SCI-FI functional ability levels.

The first phase involved quantitative synthesis of SCI-FI data from the calibration study. Item responses were used to create item maps,[15,16] which display the pattern of participant responses based on the options (eg, without any difficulty, with a little difficulty, with some difficulty, with much difficulty, unable to do) provided to assess the difficulty level of specific activities. Item calibration and item-fit analyses were performed using PARSCALE and IRTFIT, respectively.[1] SCI-FI item difficulty levels were represented as T-score distributions across the levels. Item maps were generated for each SCI-FI domain where items were ordered along a continuum of difficulty using item response theory[7] methods.

Table 2 Demographic characteristics for calibration and reliability samples

Variable	Mean ± SD or n (%) n=855	n=269	Test Statistics
Age (y)	43.1±15.3	43.8±15.5	$t_{1111}=-0.663$; $P=.507$
Age at injury (y)	36.3±15.7	37±15.6	$t_{1122}=-0.675$; $P=.500$
Time since injury (y)	6.8±9.3	6.8±8.7	$t_{1120}=-0.021$; $P=.983$
Sex			$\chi^2(1, N=1112)=0.334$; $P=.563$
Men	657 (76.8)	193 (71.7)	
Women	198 (23.2)	64 (23.8)	
Missing		12 (4.5)	
Ethnicity			$\chi^2(1, N=1100)=0.246$; $P=.620$
Hispanic	97 (11.3)	26 (9.7)	
Non-Hispanic	751 (87.8)	226 (84.0)	
Unknown/refused	7 (0.8)	17 (6.3)	
Race			$\chi^2(3, N=1103)=3.354$; $P=.340$
White	602 (70.4)	190 (70.6)	
Black	148 (17.3)	48 (17.8)	
Asian	17 (2.0)	3 (1.1)	
Others*			
Missing	9 (1.1)	12 (4.5)	
Level and completeness† of injury			$\chi^2(3, N=1121)=36.626$; $P<.001$
Paraplegia complete	188 (22.0)	64 (23.8)	
Paraplegia incomplete	277 (32.4)	61 (22.7)‡	
Tetraplegia complete	205 (24)	39 (14.5)‡	
Tetraplegia incomplete	185 (21.6)	102 (37.9)‡	
Missing		3 (1.1)	
Central cord syndrome	30 (3.5)	Not available	Not applicable
Etiology			$\chi^2(6, N=1121)=23.194$; $P<.01$
Motor vehicle accident	300 (35.1)	77 (28.6)‡	
Fall	205 (24.0)	53 (19.7)	
Gunshot wound/violence	99 (11.6)	32 (11.9)	
Diving	73 (8.5)	29 (10.8)	
Other sports	75 (8.8)	25 (9.3)	
Medical/surgical complications	42 (4.9)	20 (7.4)	
Other	58 (6.8)	33 (12.3)‡	
Missing	3 (0.4)		
Current living situation			$\chi^2(2, N=1123)=0.458$; $P=.795$
Home	665 (77.8)	213 (79.2)	
Initial rehabilitation	166 (19.4)	49 (18.2)	
Skilled nursing or long-term care	24 (2.8)	6 (2.2)	
Missing		1 (0.4)	
Use a bowel and bladder program	679 (79.4)	204 (76.2)	$\chi^2(1, N=1124)=1.567$; $P=.211$
Walk some or all of the time	228 (26.7)	86 (32.0)	$\chi^2(1, N=1123)=2.823$; $P=.093$
Use a manual wheelchair some or all of the time	438 (51.2)	149 (55.4)	$\chi^2(1, N=1123)=1.380$; $P=.240$
Use a power wheelchair some or all of the time	358 (41.9)	114 (42.4)	$\chi^2(1, N=1123)=0.018$; $P=.894$

* Others include >1 race, other races, refused, and unknown categories.
† Complete: AIS grade A and incomplete: AIS grades B, C, D, and E.
‡ Pairwise group difference significant with Bonferroni correction.

The second phase used qualitative methods and followed the bookmarking procedure to determine the cutoff scores that demarcated different levels of functional abilities. A modified Delphi approach[2] was used with participation from the content expert panel charged with the task of reaching consensus on SCI-FI scores that characterized different functional levels. The bookmarking procedure was explained to the panel members using specific examples. The panel was shown an example of standards[12] for bookmarking to determine the cutoff points, reviewed the process for establishing the optimal number of functional levels for each domain and discussed content expectations for each level. The panel was advised not to have >5 functional levels for each domain, which was guided by the empirical examination of the content and the difficulty levels of each item. The goal was to identify discrete levels that summarize similar capabilities within a single functional level. Next, the panel reviewed the SCI-FI item maps, identified items that characterized clinically meaningful functional differences, and suggested the number of cutoff points needed to define different functional levels. This exercise gave an indication of the number of levels appropriate for a specific domain. After discussion of

Table 3 SCI- FI domain scores for functional ability levels

Domain	Level 1	Level 2	Level 3	Level 4	Level 5	F score
AM-1	48.42±0.37	53.41±1.79	60.34±2.39	68.61±3.25	81.27±4.75	$F_{4,850}$=5436.21; $P<.001$
AM-2	43.10±2.08	0±0	61.01±2.21	67.96±2.26	77.2±2.46	$F_{3,90}$=417.39; $P<.001$
BM-1	23.62±2.59	36.15±3.33	46.29±2.90	55.81±2.98	69.58±5.52	$F_{4,850}$=2087.265; $P<.001$
BM-2	27.20±0.73	34.94±3.18	45.97±3.24	55.88±3.55	66.78±3.41	$F_{4,264}$=421.04; $P<.001$
FM-1	29.31±2.27	38.97±2.73	47.48±2.40	58.36±3.63	NA	$F_{3,846}$=2684.237; $P<.001$
FM-2	27.57±1.32	37.63±2.99	48.08±2.39	58.45±4.78	NA	$F_{3,265}$=490.10; $P<.001$
SC-1	27.26±7.13	39.25±3.05	48.53±2.21	55.87±2.30	63.29±2.01	$F_{4,845}$=2316.510; $P<.001$
SC-2	29.28±2.34	39.67±2.58	48.56±2.25	55.85±2.48	64.22±2.93	$F_{4,264}$=926.72; $P<.001$
WC-1	8.733±5.59	34.22±5.37	47.59±3.43	57.24±2.65	66.85±2.98	$F_{4,704}$=1481.185; $P<.001$
WC-2	0±0	36.62±3.04	48.23±3.11	57.11±2.71	65.62±1.61	$F_{3,213}$=509.14; $P<.001$

NOTE. 1: n=855; 2: n=269. Values are mean ± SD, or as otherwise indicated.
Abbreviations: AM, ambulation; BM, basic mobility; FM, fine motor; NA, not applicable; SC, self-care; WC, wheelchair.

different score values to define cutoff points, the panel arrived at a consensus and identified optimal values to yield different levels associated with abilities that were clinically meaningful. Finally, key functional abilities that defined each functional level were described and refined.

In the third phase, as outlined in the following sections, we examined the characteristics of the established functional levels in the calibration and reliability samples. Because they used the same calibrated item banks, SCI-FI scores could be compared across the 2 samples.

Demographic characteristics

Descriptive analyses of demographic characteristics were performed, and because we examined the distribution of the samples across functional levels, statistical tests were performed to determine whether the samples differed with respect to critical demographic characteristics. We used the *t* test for continuous variables and the chi-square test for categorical variables.

Functional ability levels and sample distribution across levels

To determine whether functional level cutoff points defined different levels of SCI-FI scores, we examined mean SCI-FI scores at each functional level for both the samples. Furthermore, we examined the distribution of participants across the levels in both the samples.

Validation of functional ability levels

Known-group comparisons, with respect to the distribution of the sample by level of lesion and completeness of injury (AIS grade A=complete and AIS grades B, C, D, and E=incomplete), were examined across 4 categories (ie, paraplegia complete, paraplegia incomplete, tetraplegia complete, tetraplegia incomplete). Functional ability levels were examined, and we performed chi-square analyses to determine whether the samples were equally distributed across functional ability levels. Concurrent validity was evaluated for the reliability sample by conducting Spearman correlations to determine the relationship between SCI-FI levels and the legacy measure scores (observer-rated FIM and self-reported functional measure[17]).

Results

Qualitative

Functional ability level development and definitions

The expert panel identified 4 cutoff scores to establish 5 functional levels for all SCI-FI domains, except fine motor function, which

Table 4 Counts and percentages of participants across SCI-FI functional ability levels

Domain	Level 1	Level 2	Level 3	Level 4	Level 5	Missing	Test Statistics
AM-1	596 (69.7)	45 (5.3)	89 (10.4)	110 (12.9)	15 (1.8)	0 (0)	χ^2(4, N=1124)=19.50; $P<.01$
AM-2	185 (68.8)	0 (0)*	28 (10.4)	51 (19.0)*	5 (1.9)	0 (0)†	
BM-1	36 (4.2)	118 (13.8)	249 (29.1)	393 (46.0)	59 (6.9)	0 (0)	χ^2(4, N=1124)=7.185; $P=.126$
BM-2	6 (2.2)	25 (9.3)	85 (31.6)	137 (50.9)	16 (5.9)	0 (0)	
FM-1	70 (8.2)	140 (16.4)	217 (25.4)	423 (49.5)	NA	5 (0.6)	χ^2(3, N=1119)=5.930; $P=.115$
FM-2	12 (4.5)	39 (14.5)	80 (29.7)	138 (51.3)	NA	0 (0)	
SC-1	80 (9.4)	141 (16.5)	211 (24.7)	282 (33.0)	136 (15.9)	5 (0.6)	χ^2(4, N=1119)=4.917; $P=.296$
SC-2	18 (6.7)	35 (13.0)	77 (28.6)	96 (35.7)	43 (16.0)	0 (0)	
WC-1	9 (1.1)	127 (14.9)	272 (31.8)	241 (28.2)	60 (7.0)	146 (17.1)‡	χ^2(4, N=926)=7.720; $P=.102$
WC-2	0 (0)	34 (12.6)	92 (34.2)	81 (30.1)	10 (3.7)	52 (19.3)‡	

NOTE. 1: n=855; 2: n=269. Values are n (%), or as otherwise indicated.
Abbreviations: AM, ambulation; BM, basic mobility; FM, fine motor; NA, not applicable; SC, self-care; WC, wheelchair.
* Pairwise group difference significant with Bonferroni correction.
† People could not ambulate (n=175), and therefore SCI-FI AM domain was not administered. These were considered to be in level 1 of the AM domain.
‡ People did not use a wheelchair and were ambulating; therefore, the WC domain was not administered.

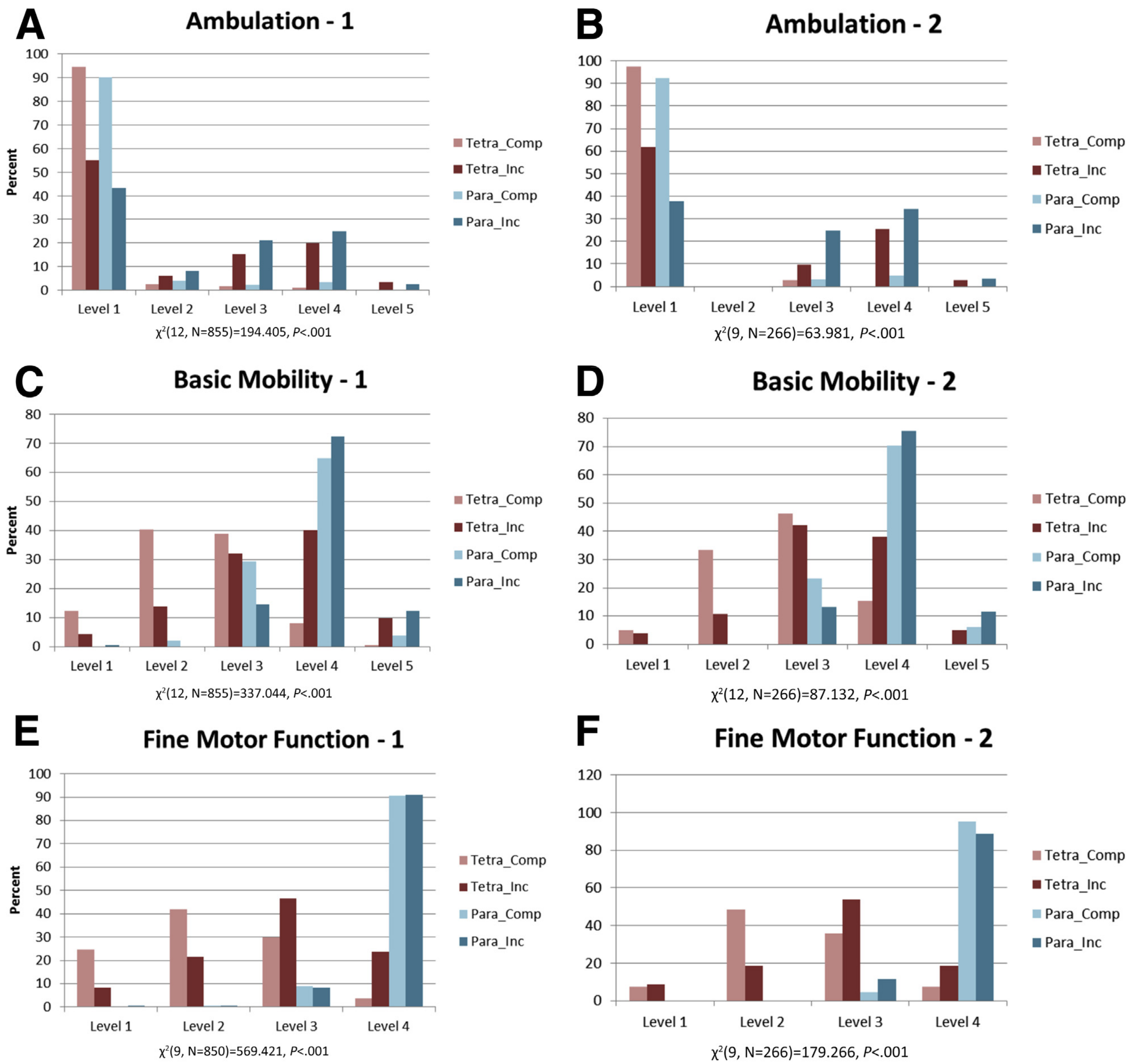

Fig 1 Distribution of participants by completeness across SCI-FI functional ability levels in the 5 domains along with χ^2 test results at the bottom of each figure. NOTE: Bars of 1 specific color add to 100%. 1: Calibration sample (n=855); 2: Reliability sample (n=269). Abbreviations: Comp, complete; Inc, incomplete; Para, paraplegia; Tetra, tetraplegia. (*Continued on next page*)

had 3 cutoff scores, yielding 4 functional levels. Table 1 presents the SCI-FI levels along with the score interval and a clinically relevant description of each level.

Quantitative

Demographic characteristics

Table 2 summarizes demographic characteristics for the calibration (N=855) and reliability (N=269) samples along with test statistics results for group comparisons for demographic characteristics. Significant group differences were found for level and completeness of injury (*P*<.001). The calibration sample included a higher percentage of persons with SCI categorized as paraplegia/incomplete and tetraplegia/complete, whereas the reliability sample had a higher percentage of persons categorized as tetraplegia/incomplete. Despite these differences, the samples were similar to the U.S. National Spinal Cord Injury Statistical Center demographic characteristics with respect to age at injury, sex, ethnicity, and mechanism of injury.[18]

Functional ability levels and sample distribution across levels

Mean SCI-FI scores for each functional level and domain are presented in table 3 (all are significantly different). Table 4 presents the distribution of sample participants across the SCI-FI functional ability levels. Statistical test results indicated no significant differences in the distribution of the 2 samples across the functional levels except for the ambulation domain (reliability sample significantly smaller at level 2 and higher at level 4).

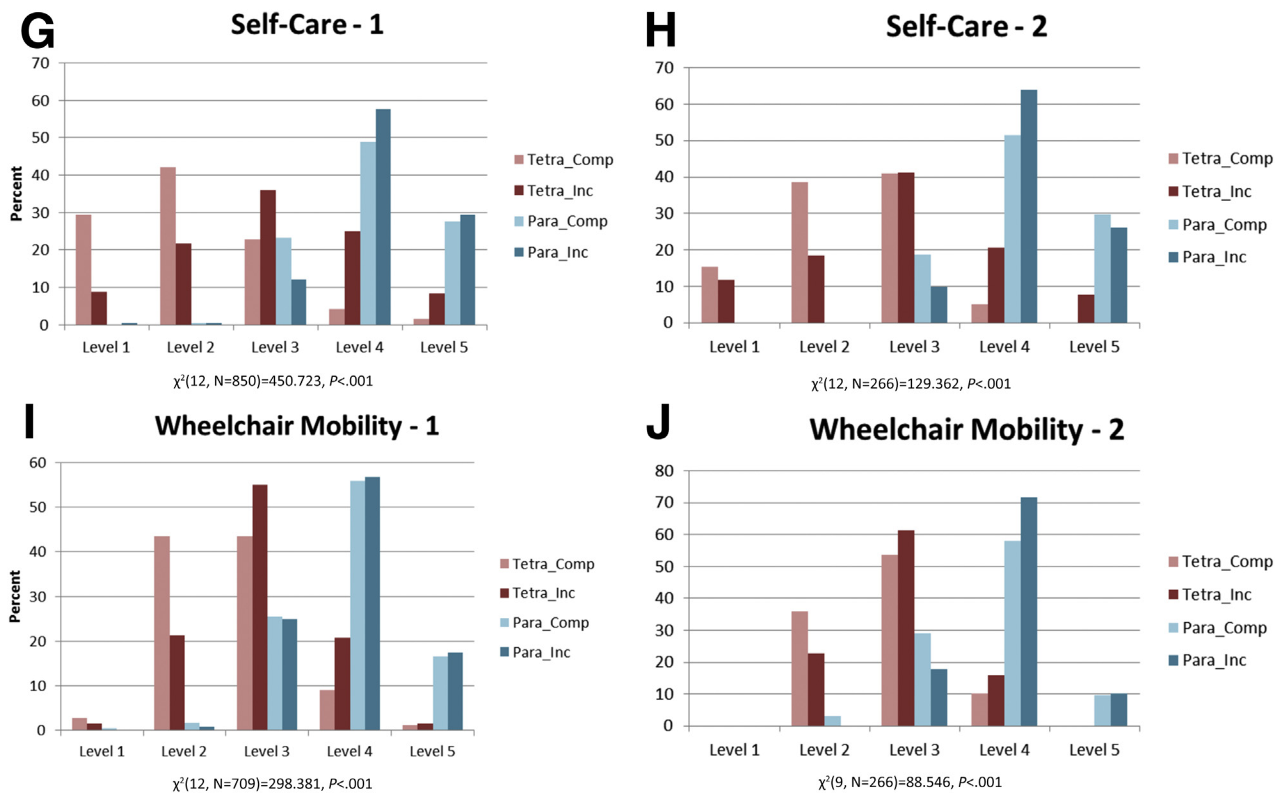

Fig 1 *Continued*

Validation of functional ability levels

Chi-square tests showed significant effects of the level of lesion and completeness in the hypothesized directions (results at the bottom of figs 1A–J). Figures 1A to J demonstrate the distribution of the 2 samples across the SCI-FI levels for each domain based on the level of lesion (blue indicates paraplegia; red, tetraplegia) and completeness (dark indicates incomplete; light, complete). Basic mobility, self-care, and wheelchair mobility domains followed the predicted pattern, with a cluster of persons with paraplegia and incomplete lesions at higher functional levels and persons with tetraplegia and complete lesions at lower functional levels.

Distribution of participants based on level of lesion and completeness was different for ambulation and fine motor domains (compared with other domains), as expected. For the ambulation domain, the distribution was skewed to the lower end, with a relatively small percentage of persons with incomplete lesions (paraplegia and tetraplegia) at higher functional levels. There was almost no representation of complete lesion (paraplegia and tetraplegia) at the highest functional level in the reliability sample. For the fine motor domain, the distribution was skewed to higher functional levels, with a high percentage of persons with paraplegia at the highest level (complete and incomplete lesions). The distribution of the 2 study samples is similar, but reflects the following sample differences: the reliability sample has significantly more paraplegia complete at the highest level for fine motor and self-care domains, and the wheelchair domain has a higher percentage of paraplegia incomplete at level 4 for the reliability sample.

Concurrent validity results demonstrated SCI-FI functional levels to be significantly ($P<.0001$) positively correlated with legacy measures (self-reported functional measure and observer-rated FIM) (table 5). Across all the domains, correlations between SCI-FI functional ability levels and the self-reported functional measure were always higher than those between SCI-FI functional ability levels and the observer-rated FIM. For the ambulation domain, correlations between functional ability levels and the self-reported functional measure and the observer-rated FIM were the lowest, and the difference in correlation between the self-reported functional measure and the observer-rated FIM was the largest.

Discussion

The objectives of this study were to develop functional ability levels for the SCI-FI and to validate those using calibration and reliability samples.

Qualitative

The bookmarking procedure[14] has been envisaged for setting performance standards by means of cutoff scores.[1] We have used this procedure in the present study to identify items that demarcate different levels of functional abilities for persons with SCI. Conceptually, functional levels describe important differences in levels in terms of capabilities. For example, for the basic mobility domain, functional levels identify different abilities related to sitting (supported and unsupported) and transferring (different surfaces). The fine motor domain functional levels identify different levels of ability using the hands and upper extremities (gross motor, dexterity, coordinated movement). Functional levels for the self-care domain describe different abilities related to eating, bathing, and dressing (no activities, some, most, all). For

Table 5 Spearman correlations between SCI-FI functional ability levels and legacy measures (N=269)

SCI-FI Domain Levels	Self-Reported Functional Measure	Observer-Rated FIM
AM	.596	.379
BM	.827	.632
FM	.736	.650
SC	.851	.665
WC	.788	.644

NOTE. All correlations significant at $P<.001$ (2-tailed).
Abbreviations: AM, ambulation; BM, basic mobility; FM, fine motor; SC, self-care; WC, wheelchair.

the ambulation domain, functional levels describe walking in different settings (home and community). Finally, for the wheelchair mobility domain, functional levels describe the ability to do different activities (basic, some, all).

Quantitative

Functional ability levels and sample distribution across levels

Analyses of the distribution of persons with SCI across the SCI-FI functional ability levels is important to determine whether the established cutoff scores are appropriate. Individuals with similar SCI levels of lesion (ie, paraplegia or tetraplegia) and severity of injury (ie, complete or incomplete) should be grouped in similar functional levels. If persons with similar levels of SCI injury and completeness of injury are not grouped by functional level, this may be an indication that the cutoff scores are not precise and, therefore, may need to be reevaluated and adjusted.

We found that the identified functional ability levels characterize functional performance of people with similar levels of SCI and completeness of injury in both the calibration and reliability samples for all domains except ambulation and wheelchair. For ambulation (level 2) and wheelchair (level 1), there was no representation in the reliability sample, which is likely due to the small sample size. Also, very few people ambulated in the reliability sample and there was a higher percentage of participants at levels 3 and 4 for the wheelchair domain. Differences in sample characteristics by level of lesion and completeness of injury may further account for these differences.

Validation of functional ability levels

The obtained functional ability levels are able to discern differences in functioning as per known groups based on the level of lesion and completeness. The distribution of participants categorized as paraplegia/tetraplegia and complete/incomplete for ambulation (see fig 1) is shifted to lower levels, which is consistent with the fact that ambulation is quite a demanding activity for people with SCI. Furthermore, the finding that for the fine motor domain, participants in the paraplegia category are shifted to higher levels demonstrates that these abilities are largely preserved. For the self-care domain, the distribution is clustered around levels 3 and 4, as expected.

As we predicted, the association between observer-rated FIM and SCI-FI functional levels was lower than the association between self-reported functional measure and SCI-FI functional levels. One potential explanation for this difference is that the self-reported functional measure and the SCI-FI are both patient reported while the observer-rated FIM is clinician reported. The smallest correlation was noted for the ambulation domain because the FIM evaluates locomotion and does not differentiate wheelchair mobility and ambulation.

Use in clinical practice

Functional ability levels would be useful for clinicians to monitor patients' functioning in 5 relevant domains. The descriptions provided for the functional levels would ease the explanation regarding what a person is capable of doing within a certain level and facilitate communication between the clinician and the patient and his or her family members. The use of functional levels and the description of capabilities in different domains is demonstrated for a 20-year-old man (table 6) with an injury at thoracic vertebrae 10 and AIS grade A (complete injury). Because the person is not ambulating, the ambulation items were not administered. For basic mobility, the score was 2 SDs higher than the mean at follow-up. When these scores were transformed to functional ability levels, the person had moved 1 functional level higher at follow-up. At discharge, the person could perform basic mobility activities involving unsupported

Table 6 Depiction of change in SCI-FI scores and functional ability levels over a period of 6 months

SCI-FI Discharge Scores		SCI-FI Follow-Up Scores
Ambulation score=not applicable		
Basic mobility score=55 Level 4: Activities involving unsupported sitting, reaching, and level transfers	→	Basic mobility score=72 Level 5: Activities involving unsupported sitting and transfers to/from surfaces of different heights
Self-care score=60 Level 4: Most self-care activities	→	Self-care score=67 Level 5: All self-care activities
Fine motor score=64 Level 4: Most activities requiring dexterity and coordinated upper extremity movement	→	Fine motor score=66 Level 4: Most activities requiring dexterity and coordinated upper extremity movement
Manual wheelchair score=61 Level 4: Most wheelchair activities	→	Manual wheelchair score=72 Level 5: All wheelchair activities

NOTE. Participant was a 20 yr old man, thoracic vertebrae 10, AIS grade A.

sitting, reaching, and level transfers. At follow-up, the person could now perform activities involving unsupported sitting and transfers to/from surfaces of different heights. For self-care and wheelchair domains, the person moved 1 functional level higher as well. For the fine motor domain, the person remained at the highest functional level because these skills are preserved. These levels also provide an indication regarding the environmental modifications required for the person to live independently in the community and the kind of care (nursing/rehabilitation intervention) that would be appropriate, as well as for planning therapy interventions for an individual.

The SCI-FI CATs can either be administered at the point of care or can be completed by the patient at home before the scheduled appointment and the assessment result could be available to the clinicians. The CAT score is a T score with a mean of 50 and an SD of 10 and therefore offers ease in interpretation. A computer program could facilitate assigning the level corresponding to a score, and the descriptions regarding the functional abilities could be provided simultaneously. This information could then be used by the clinicians for patient and family communications, for determining rehabilitation goals, and so forth. At subsequent follow-ups, this procedure could be followed and the (change in) functional levels could be used for monitoring purpose.

Study limitations

Our bookmarking method used a single content expert panel and modified Delphi consensus-building process, which was practical for us considering the objective of the study. However, independent replication of these functional stages would further strengthen these results. We developed item maps using a complete set of items, which provided the panel a good overview for judging the cutoff points precisely.

The fact that the functional levels were developed from the calibration sample and further examined in a separate reliability sample is one of the strengths of the study. The reliability sample had a relatively smaller sample size; therefore, some functional levels did not have adequate representation of persons with SCI. Examining the distribution in other (larger) samples would help further assess whether the selected cutoff scores are optimal for identifying different levels of functioning that are meaningful for the population with SCI. Furthermore, study of functional levels using data from a longitudinal study is needed to examine whether the changes in functional levels over time are meaningful. For example, it would be important to document whether a change in functional levels is congruent with participants' perceived change in functional abilities that may occur due to the natural recovery process or clinical interventions. We would be interested in identifying factors that increase or decrease a person's functional level. A longitudinal study to examine changes in SCI-FI scores and functional levels from discharge to 1-year postdischarge is currently underway. As we examine, characterize, and refine functional abilities/levels, we are particularly interested in studying functional level changes with respect to important patient characteristics, such as level of lesion and completeness of injury. In addition, we want to examine whether changes in functional levels correspond to changes in critical outcomes. For example, rehabilitation interventions may increase a person's functional level. SCI-FI scores and functional levels may also identify environmental factors that result in negative changes, such as decline in wheelchair functioning postdischarge when an individual is required to function in community settings.

Conclusions

Quantitative assessment provides supportive evidence regarding the validity of the identified functional ability levels and the suitability of these levels for profiling functional abilities of persons with SCI. Functional ability levels used to interpret SCI-FI scores would serve as a helpful tool for the clinicians to communicate and explain current functional abilities to patients and their families. These functional levels can also facilitate goal setting among the rehabilitation team members and serve as a guide for clinical practice and interventions. Data collection using a larger sample size is in progress, and we will be able to further examine the similarities and differences in the distribution patterns that we have observed in the 2 samples reported in this study.

Future directions

In the future, SCI-FI scores and functional ability levels can be analyzed in the population with SCI to establish specific functional targets on the basis of the level of lesion, completeness of injury, and other influencing factors.

Keywords

Disability evaluation; Patient outcome assessment; Rehabilitation; Spinal cord injuries

Corresponding author

Richa Sinha, MPH, PhD, Health & Disability Research Institute, Boston University School of Public Health, 715 Albany St, T5W, Boston, MA 02118. *E-mail address:* sinha.richa@hotmail.com.

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