JOURNAL-BASED CME ARTICLE (ARTICLE 2 OF 2)

Development and Initial Evaluation of the Spinal Cord Injury-Functional Index

Alan M. Jette, PT, PhD, David S. Tulsky, PhD, Pengsheng Ni, MD, MPH, Pamela A. Kisala, MA, Mary D. Slavin, PT, PhD, Marcel P. Dijkers, PhD, Allen W. Heinemann, PhD, Denise G. Tate, PhD, Gale Whiteneck, PhD, Susan Charlifue, PhD, Bethlyn Houlihan, MSW, MPH, Steve Williams, MD, Steven Kirshblum, MD, Trevor Dyson-Hudson, MD, Jeanne Zanca, MPT, PhD, Denise Fyffe, PhD

Both articles below must be read to complete the one 2-hour CME activity.

Article 1: Spinal Cord Injury-Functional Index: Item Banks to Measure Physical Functioning of Individuals With Spinal Cord Injury

David S. Tulsky, PhD; Alan M. Jette, PT, PhD; Pamela A. Kisala, MA; Claire Kalpakjian, PhD; Marcel P. Dijkers, PhD; Gale Whiteneck, PhD; Pengsheng Ni, MD, MPH; Steven Kirshblum, MD; Susan Charlifue, PhD; Allen W. Heinemann, PhD; Martin Forchheimer, MPP; Mary D. Slavin, PT, PhD; Bethlyn Houlihan, MSW, MPH; Denise G. Tate, PhD; Trevor Dyson-Hudson, MD; Denise Fyffe, PhD; Steve Williams, MD; Jeanne Zanca, MPT, PhD

Article 2: Development and Initial Evaluation of the Spinal Cord Injury-Functional Index

Alan M. Jette, PT, PhD; David S. Tulsky, PhD; Pengsheng Ni, MD, MPH; Pamela A. Kisala, MA; Mary D. Slavin, PT, PhD; Marcel P. Dijkers, PhD; Allen W. Heinemann, PhD; Denise G. Tate, PhD; Gale Whiteneck, PhD; Susan Charlifue, PhD; Bethlyn Houlihan, MSW, MPH; Steve Williams, MD; Steven Kirshblum, MD; Trevor Dyson-Hudson, MD; Jeanne Zanca, MPT, PhD; Denise Fyffe, PhD

Statement of Need

A major treatment goal in the rehabilitation of persons with spinal cord injury (SCI) is to maximize the restoration of physical functioning. Documenting the extent of recovery is imperative for: 1) assessing treatment efficacy; 2) evaluating the cost-effectiveness of treatment interventions; 3) examining the impact of policy changes on patient outcomes; 4) evaluating the quality of care being provided; and 5) providing appropriate, long-term prognostic information to patients and their families, as well as to insurance carriers. In order to document recovery of rehabilitation interventions, reliable and valid tools are necessary to assess physical functioning outcomes in the SCI population.

Several outcomes measures are currently used to assess physical functioning in SCI. The most commonly used scales (e.g., Functional Independence Measure) have 2 important shortcomings with respect to their use in this population: comprehensiveness of the measure's content to assess the full range of SCI severity and the breadth of content to ensure all important aspects of physical functioning are covered, including the perspective of individuals with SCI in assessing outcomes. It is difficult for any single instrument to include the large number of items necessary to cover the range of severity levels seen among persons with SCI.

These 2 articles will describe the development and evaluation of the Spinal Cord Injury-Functional Index (SCI-FI) a new comprehensive outcomes measurement tool for persons with SCI.

Accreditation Statement

This journal-based activity has been planned and developed in accordance with the Essential Areas and policies of the Accreditation Council for Continuing Medical Education (ACCME) through the sponsorship of Professional Education Services Group (PESG).

PESG is accredited by the ACCME to provide continuing medical education (CME) for physicians.

Credit Designation Statement

PESG designates this Journal-based CME activity for a maximum of 2.0 *AMA PRA Category 1 Credit(s)*™. Physicians should claim only the credit commensurate with the extent of their participation in the activity.

All other health care professionals completing continuing education credit for this activity will be issued a certificate of participation.

Educational Objectives

To support the attainment of knowledge, competence, and performance, the learner should be able to achieve the following objectives:

1. Describe the current outcomes measurement tools being used with persons with SCI.
2. Discuss the limitations of the current outcomes measurement tools being used with persons with SCI.
3. Describe the development of a new outcome measurement tool with the item content and structure being designed specifically for persons with SCI.
4. Explain how the Spinal Cord Injury-Functional Index (SCI-FI) outcomes measurement tool improves upon existing outcome measurement tools used with persons with SCI.

Planning Committee

Susan Charlifue, PhD; Marcel P. Dijkers, PhD; Trevor Dyson-Hudson, MD; Martin Forchheimer, MPP; Denise Fyffe, PhD; Allen W. Heinemann, PhD; Bethlyn Houlihan, MSW, MPH; Alan M. Jette, PT, PhD; Claire Kalpakjian, PhD; Steven Kirshblum, MD; Pamela A. Kisala, MA; Pengsheng Ni, MD, MPH; Mary D. Slavin, PT, PhD; Denise G. Tate, PhD; David S. Tulsky, PhD; Gale Whiteneck, PhD; Steve Williams, MD, Jeanne Zanca, MPT, PhD; PESG staff.

Faculty Profiles & Disclosure Information

As a sponsor accredited by the ACCME, it is the policy of PESG to require the disclosure of anyone who is in a position to control the content of an educational activity. All relevant financial relationships with any commercial interests and/or manufacturers must be disclosed to participants at the beginning of each activity. The faculty of this educational activity disclose the following:

Susan Charlifue, PhD

Craig Hospital, Englewood, CO

No financial conflicts to disclose.

Marcel P. Dijkers, PhD

Mt. Sinai School of Medicine, New York, NY

No financial conflicts to disclose.

Trevor Dyson-Hudson, MD

University of Medicine and Dentistry of New Jersey-New Jersey Medical School, Department of Physical Medicine and Rehabilitation, Newark, NJ

No financial conflicts to disclose.

Martin Forchheimer, MPP

University of Michigan Medical School, Department of Physical Medicine and Rehabilitation, Ann Arbor, MI

No financial conflicts to disclose.

Denise Fyffe, PhD

University of Medicine and Dentistry of New Jersey-New Jersey Medical School, Department of Physical Medicine and Rehabilitation, Newark, NJ

No financial conflicts to disclose.

Allen W. Heinemann, PhD

Northwestern University and Rehabilitation Institute of Chicago, Department of Physical Medicine and Rehabilitation, Chicago, IL

No financial conflicts to disclose.

Bethlyn Houlihan, MSW, MPH

Boston University School of Public Health, Health and Disability Research Institute, Boston, MA

No financial conflicts to disclose.

Alan M. Jette, PT, PhD

Boston University School of Public Health, Health and Disability Research Institute, Boston, MA

No financial conflicts to disclose.

Claire Kalpakjian, PhD

University of Michigan Medical School, Department of Physical Medicine and Rehabilitation, Ann Arbor, MI

No financial conflicts to disclose.

Steven Kirshblum, MD

Kessler Institute for Rehabilitation, West Orange, NJ

No financial conflicts to disclose.

Pamela A. Kisala, MA

University of Michigan Medical School, Department of Physical Medicine and Rehabilitation, Ann Arbor, MI

No financial conflicts to disclose.

Pengsheng Ni, MD, MPH

Boston University School of Public Health, Health and Disability Research Institute, Boston, MA

No financial conflicts to disclose.

Mary D. Slavin, PT, PhD

Boston University School of Public Health, Health and Disability Research Institute, Boston, MA

No financial conflicts to disclose.

Denise G. Tate, PhD

University of Michigan Medical School, Department of Physical Medicine and Rehabilitation, Ann Arbor, MI

No financial conflicts to disclose.

David S. Tulsky, PhD

University of Michigan Medical School, Department of Physical Medicine and Rehabilitation, Ann Arbor, MI

No financial conflicts to disclose.

Gale Whiteneck, PhD

Craig Hospital, Englewood, CO

No financial conflicts to disclose.

Steve Williams, MD

Boston Medical Center, New England Regional Spinal Cord Injury Center, Boston, MA
No financial conflicts to disclose.

Jeanne Zanca, MPT, PhD

Mt. Sinai School of Medicine, New York, NY
No financial conflicts to disclose.

PESG Staff

No financial conflicts to disclose.

Resolution of Conflict of Interest

PESG has implemented a process to resolve conflict of interest for each CME activity. In order to help ensure content objectivity, independence, and fair balance, and to ensure that the content is aligned with the interest of the public, PESG has resolved the conflict by external content review.

Unapproved/Off-Label Use Disclosure

PESG requires CME faculty to disclose to the participants:

1. When products or procedures being discussed are off-label, unlabeled, experimental, and/or investigational (not US Food and Drug Administration [FDA] approved); and
2. Any limitations on the information presented, such as data that are preliminary or that represent ongoing research, interim analyses, and/or unsupported opinion. Faculty may discuss information about pharmaceutical agents that is outside of FDA-approved labeling. This information is intended solely for CME and is not intended to promote off-label use of these medications. If you have questions, contact the medical affairs department of the manufacturer for the most recent prescribing information.

Intended Audience

This program is intended for physicians and healthcare professionals responsible for the comprehensive care for individuals with chronic illness and disabilities.

Method of Participation

In order to claim credit, participants must complete the following:

1. Pre-activity self-assessment questions
2. Read the 2 articles included in this activity.
3. Complete the CME Test and Evaluation. Participants must achieve a score of 70% on the CME Test.

Participants can complete the pre-activity self-assessment and CME Test and Evaluation online by logging on to http://acrm.cds.pesgce.com. Upon successful completion of the online tests and evaluation form, you can instantly download and print your certificate of credit.

To better define and meet the CME needs of health care professionals and enhance future CME activities, PESG will conduct an outcomes-measurement survey following the conclusion of the program. This follow-up survey is designed to measure changes to participants' practice behaviors as a result of their participation in this CME activity. You will be contacted by email 60 days following the conclusion of this activity with an outcomes measurement survey. We would greatly appreciate your participation.

CME Inquiries

For all CME certificate inquiries, please contact us at support@pesgce.com.

This continuing education activity is active starting October 1, 2012 and will expire September 30, 2013.

Estimated Time to Complete This Activity: . . . . . **2.0 hours**

ABSTRACT. Jette AM, Tulsky DS, Ni P, Kisala PA, Slavin MD, Dijkers MP, Heinemann AW, Tate DG, Whiteneck G, Charlifue S, Houlihan B, Williams S, Kirshblum S, Dyson-Hudson T, Zanca J, Fyffe D. Development and initial evaluation of the Spinal Cord Injury-Functional Index. Arch Phys Med Rehabil 2012;93:1733-50.

Objectives: To describe the calibration of the Spinal Cord Injury-Functional Index (SCI-FI) and report on the initial psychometric evaluation of the SCI-FI scales in each content domain.

Design: Cross-sectional survey followed by calibration data simulations.

Setting: Inpatient and community settings.

Participants: A sample of participants (N=855) with traumatic spinal cord injury (SCI) recruited from 6 SCI Model Systems and stratified by diagnosis, severity, and time since injury.

Interventions: None.

Main Outcome Measure: SCI-FI instrument.

Results: Item response theory analyses confirmed the unidimensionality of 5 SCI-FI scales: basic mobility (54 items), fine motor function (36 items), self-care (90 items), ambulation (39 items), and wheelchair mobility (56 items). All SCI-FI scales revealed strong psychometric properties. High correlations of scores on simulated computer adaptive testing (CAT) with the overall SCI-FI domain scores indicated excellent potential for CAT to accurately characterize functional profiles of adults with SCI. Overall, there was very little loss of measurement reliability or precision using CAT compared with the full item bank; however, there was some loss of reliability and precision at the lower and upper ranges of each scale, corresponding to regions where there were few questions in the item banks.

Conclusions: Initial evaluation revealed that the SCI-FI achieved considerable breadth of coverage in each content domain and demonstrated acceptable psychometric properties. The use of CAT to administer the SCI-FI will minimize assessment burden, while allowing for the comprehensive assessment of the functional abilities of adults with SCI.

Key Words: Activities of daily living; Outcome assessment (health care); Psychometrics; Rehabilitation; Spinal cord injuries.

THE COMPLEX PATTERN of a person's functioning after spinal cord injury (SCI) can challenge accurate assessment, and important limitations exist in measures currently being used. There is growing recognition that limitations of current SCI outcome measures pose a serious impediment to conducting research and evaluating clinical interventions and programs. Two prominent groups—the International Campaign for Cures of SCI Paralysis Clinical Guidelines Panel[1] and the 2006 National Institute on Disability and Rehabilitation Research SCI Measures Meeting[2]—emphasized the urgent need to improve SCI outcome measures.

The FIM, the most commonly administered functional status measure developed for generic individuals with chronic health conditions, does not capture the full range nor the unique aspects of functioning after SCI.[2-4] The FIM's lack of specificity for persons with SCI results in unacceptable measurement ceiling and floor effects.[2-4] A measure that is unable to differentiate at high and low levels of functioning makes it difficult for clinicians to detect restoration or loss of functioning over time after SCI.[2-4] Other measures developed specifically for SCI limit their assessment to the type of injury (eg, Quadriplegic Index of Function) or select specific functional domains (eg, Walking Index for Spinal Cord Injury). Different methods of administration (eg, self-report or nurse/therapist rated) and the extensive amount of time needed to administer functional measures (eg, Spinal Cord Independence Measure III) present further constraints on research and clinical practice.[2-4] Finally, previous measures of functioning have been developed primarily from the perspective of clinicians or researchers,[4] rendering the information less meaningful to those living with SCI.

There is a need to develop functional status measures for persons with SCI that are comprehensive, psychometrically sound, relevant to the needs of those with SCI, yet feasible for use in clinical practice and research. CAT combined with the psychometric foundation of item response theory (IRT) holds promise to meet this need.[5,6] In CAT administration, an iterative computer program uses information from a person's previous responses to tailor item selection, thereby eliminating questions on tasks that are too difficult or too easy for a particular patient and therefore not informative. CAT methods dramatically reduce the time to administer a comprehensive measure while maintaining its psychometric qualities.[7] However, CAT requires the prior development of unidimensional item banks that contain items corresponding to the full range of functioning of the populations that will be measured.

The Spinal Cord Injury-Functional Index (SCI-FI) was designed to measure activity limitations, as defined by the International Classification of Functioning, Disability and Health

List of Abbreviations

AIS	American Spinal Injury Association Impairment Scale
CAT	computer adaptive testing
DIF	differential item functioning
ICF	International Classification of Functioning, Disability and Health
IRT	item response theory
SCI	spinal cord injury
SCI-FI	Spinal Cord Injury-Functional Index

From the Health and Disability Research Institute, Boston University School of Public Health, Boston, MA (Jette, Ni, Slavin); Department of Physical Medicine and Rehabilitation, University of Michigan, Ann Arbor, MI (Tulsky, Kisala, Tate); Mount Sinai School of Medicine, New York, NY (Dijkers, Zanca); Department of Physical Medicine and Rehabilitation, Feinberg School of Medicine, Northwestern University, Chicago, IL (Heinemann); Rehabilitation Institute of Chicago, Chicago, IL (Heinemann); Craig Hospital, Englewood, CO (Whiteneck, Charlifue); New England Regional Spinal Cord Injury Center, Boston Medical Center, Boston, MA (Houlihan, Williams); Kessler Institute for Rehabilitation, West Orange, NJ (Kirshblum); Department of Physical Medicine and Rehabilitation, University of Medicine and Dentistry of New Jersey-New Jersey Medical School, Newark, NJ (Kirshblum, Dyson-Hudson, Fyffe); and Kessler Foundation Research Center, West Orange, NJ (Dyson-Hudson, Fyffe).

Supported by the U.S. Department of Education, National Institute of Disability and Rehabilitation Research (grant nos. H133N060022, H133N060024, H133N060014, H133N060005, H133N060027, and H133N060032).

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit on the authors or on any organization with which the authors are associated.

Reprint requests to Alan M. Jette, PT, PhD, Health and Disability Research Institute, Boston University School of Public Health, 715 Albany St T5W, Boston, MA 02118, e-mail: *ajette@bu.edu*.

In-press corrected proof published online on Jul 30, 2012, at www.archives-pmr.org.

0003-9993/12/9310-00192$36.00/0
http://dx.doi.org/10.1016/j.apmr.2012.05.008

(ICF), that reflect the overall physical functioning of a person with SCI and that can impact a person's overall quality of life.[8-10] An initial item pool across several functional domains was developed from a review of current measures used in SCI assessments and extensive focus groups conducted with persons with SCI and clinicians.[8] The final item pool consisted of 188 core items deemed relevant to all persons with SCI and 140 supplemental items to be administered based on responses to screener questions (eg, power and/or manual wheelchair, walking), living situation (eg, home, inpatient rehabilitation), and use of a bowel and bladder program.

In previous work, we conducted factor analyses that revealed a structure of the SCI-FI items that was consistent with the ICF framework as well as with the themes revealed in patient and clinician focus groups.[9] The goal of this article is to describe the calibration of the items, the development of scales in each content domain, and initial psychometric evaluation of the SCI-FI instrument. It also evaluates the potential of using CAT to administer the SCI-FI, through evaluation of the agreement between simulated CAT and scores based on the total item set for a domain.

METHODS

Participants

The study included a stratified sample of 855 participants with traumatic SCI recruited from 6 SCI Model Systems: Rocky Mountain Regional Spinal Cord Injury Center, Northern New Jersey Model Systems Program, Mount Sinai Spinal Cord Injury Model System, New England Regional Spinal Cord Injury Center, Midwest Regional Spinal Cord Injury Center, and the University of Michigan Spinal Cord Injury System. Institutional review boards at each institution reviewed and approved the study. Eligibility criteria included age of 18 or older and the ability to speak and understand English fluently. The sample was stratified to include approximately equal numbers based on the following characteristics: level of injury (paraplegia vs tetraplegia), completeness of injury (complete vs incomplete), and time since injury ($<$1y, 1–3y, $>$3y) to ensure heterogeneity. The same sample was used for SCI-FI factor analytic work.[9]

Data Collection Procedures

Trained personnel completed interviews either by phone or in person. We collected demographic information (age, sex, ethnicity, race), descriptors related to the SCI (date of injury, age at injury, mechanism of injury, grade of lesion, and American Spinal Injury Association Impairment Scale [AIS] score). Responses to screener questions were used to select appropriate sets of supplemental items (use of wheelchair, ambulation status, living situation, use of bowel and bladder program). Participants were asked to respond to SCI-FI questions based on their capacity to perform the activity without special equipment or help from another person, except where explicitly stated in the item. Participants could skip an item if unable to respond.

Data Analytic Procedures

We used a graded response model to calibrate data separately for the 5 item pools (basic mobility, self-care, fine motor function, ambulation, and wheelchair mobility) that were produced using confirmatory factor analysis, as described in Tulsky et al.[9] Calibration refers to using iterative methods to estimate the place on a scale that corresponds to a participant's level of ability and to produce an item estimate corresponding to the difficulty of successfully completing that specific task. Item fit was tested based on S-chi-square[11,12] and Stone's chi-square test.[13-15] The sample's scores were estimated using weighted likelihood estimation; item calibration was conducted using PARSCALE[a]; and item fit was calculated using IRTFIT.[b]

Differential item functioning (DIF) was assessed by applying logistic regression modeling,[16] where the dependent variable was the item score and the independent variables were background variables of interest (sex, white/nonwhite race, Hispanic/non-Hispanic ethnicity, complete/incomplete injury, tetraplegia/paraplegia, time since injury $<$1y/1–3y/$>$3y), ability level (participant's score estimated from the graded response model), and background variable and ability level interaction. In DIF analysis, if the background effect was significant and the interaction effect was not, then the item demonstrated uniform DIF; if the interaction effect was significant, the item demonstrated nonuniform DIF. Model comparison was based on the likelihood ratio test. We used Bonferroni corrected P values for significance testing and used the R^2 change to qualify the effect size of both uniform and nonuniform DIF based on Jodoin and Gierl's[17] criteria. Items with DIF were removed from the final item banks. For each final item bank, the breadth of coverage was evaluated by examining the score distribution, which was created by mapping the item response category's expected value onto the sample's score on each scale.

CAT algorithms were created for 5 domains using specialized software developed at Boston University. CAT was designed to select the first question from the middle of the difficulty range; weighted likelihood estimation analysis was used to estimate the participant's score and its SE, and the program selected the next item with the maximum item information matrix at the current score level. The CAT program updated a participant's score after each response and continued until a preset maximum number of items had been administered or a minimum SE was reached. The final scores were transformed into a scale with a mean $\pm$ SD of 50 ± 10; lower scores indicate more activity limitation.

To evaluate the SCI-FI CAT's performance, we used the calibration study data to compare scores produced by simulated 5- or 10-item CAT with the full item bank scores in each domain. The CAT selected questions according to the algorithm, and participant responses were fed to the CAT as they were selected, thus creating a score and SE for each participant for a 5- or 10-item CAT for each scale. The psychometric properties, measurement accuracy, precision, and internal consistency reliability of each CAT scale were assessed using the Pearson correlation coefficient to evaluate degree of agreement between scores generated by the CAT and those of the full item bank. Precision was assessed by calculating the SEs across the range of scores for each CAT. Conditional reliability was estimated across the scale as $1/[1+(SE)^2]$.[18] Areas with reliabilities $<$.70 were considered insufficient. Because of the heterogeneous nature of the SCI population, we reported results separately for individuals with tetraplegia and paraplegia. Finally, we calculated the floor and ceiling effect using the response data at the participant level. Participants responding at the highest or lowest SCI-FI response category for all items were grouped at the ceiling or floor, respectively.

RESULTS

Table 1 displays the background characteristics of the study sample: 54% had a diagnosis of tetraplegia; 46% had incomplete injuries; 27% walked some or all of the time; and 77% were men. The sample was representative of persons with SCI

Table 1: Demographic and Clinical Characteristics of the Sample

Variable	Level of Lesion: Tetraplegia (n=465, 54.4%)	Level of Lesion: Paraplegia (n=390, 45.6%)	Total (N=855)
Current age (y)	43 (15.04)	43 (15.24)	43 (15.32)
Age at injury (y)	37 (16.54)	36 (14.68)	36 (15.71)
Time since injury (y)	7 (9.45)	7 (9.23)	7 (9.34)
Sex			
Male	78.9	74.4	77.0
Female	21.1	25.6	23.0
Ethnicity			
Hispanic	10.1	12.8	11.3
Non-Hispanic	88.8	86.7	87.8
Unknown/refused	1.1	0.5	0.8
Race			
White	72.9	67.4	70.4
Black	14.8	20.3	17.3
Asian	3.0	0.8	2.0
American Indian/Alaskan Native	0.4	0.8	0.6
More than 1 race	7.3	9.7	8.4
Unknown/refused	1.5	1.0	1.3
Type of injury			
Complete	40.6	52.3	46.0
Incomplete	59.4	47.7	54.0
Central cord syndrome	5.6	1.0	3.5
Mechanism of injury			
Motor vehicle accident	38.5	31.0	35.1
Fall	23.4	24.6	24.0
Gunshot wound/violence	7.1	16.9	11.6
Diving	14.4	1.5	8.5
Other sports	9.0	8.5	8.8
Medical/surgical complication	1.9	8.5	4.9
Other	5.4	8.5	6.8
Living situation			
Home	74.2	82.1	77.8
Inpatient rehabilitation facility	21.9	16.4	19.4
Skilled nursing or long-term care	3.9	1.5	2.8
Uses a bowel and bladder program	79.8	79.0	79.4
Walks some or all of the time	25.6	28.0	26.7
Uses a manual wheelchair some or all of the time	32.5	73.8	51.3
Uses a power wheelchair some or all of the time	62.2	17.7	41.9

NOTE. Values are percentages or mean ± SD.

on the key demographic variables reported by the National Spinal Cord Injury Statistical Center.[19]

Of the 328 items included in the calibration study, 22 were removed after the unidimensional confirmatory factor analyses because of local independence (10 items), missing data (7 items), and content concerns (5 items). A total of 306 items were retained and examined with IRT analyses, which confirmed the unidimensionality of the 5 SCI-FI scales. The IRT analyses were performed separately for 5 scales. Initial item fit was examined based on a chi-square value $<.01$. A total of 12 items were removed because of misfitting the model. DIF was assessed in the 5 SCI-FI scales across 6 demographic and clinical variables. A total of 18 items were removed because of DIF. One item was removed because of

Table 2: SCI-FI Item Bank Refinement—Items Removed

Domain	Initial	Misfitting Items	DIF	Total Removed	Final Item Bank
Basic mobility	65	4	7 (completeness=1, sex=1, level of injury=4, race=1)	11	54
Self-care	99	1	8 (completeness=1, level of injury=7)	9	90
Fine motor function	39	1	1 (level of injury)	3*	36
Ambulation	40	1	0	1	39
Wheelchair mobility	63	5	2 (sex=1, level of injury=1)	7	56
Total items	306	12	18	30	275

*1 additional item was removed because of a high percentage of missing data.

Table 3: Accuracy of 5- and 10-Item CAT by Content Domains by Neurologic Level: Pearson Correlations With the Full-Scale Score

Domains	Level	n	5-Item CAT	10-Item CAT
Basic mobility	Tetraplegia	465	0.89	0.97
	Paraplegia	389	0.88	0.96
	Full sample	854	0.90	0.97
Self-care	Tetraplegia	463	0.94	0.98
	Paraplegia	387	0.90	0.96
	Full sample	850	0.95	0.98
Fine motor function	Tetraplegia	462	0.96	0.98
	Paraplegia	387	0.93	0.98
	Full sample	849	0.98	0.99
Ambulation	Tetraplegia	119	0.95	0.98
	Paraplegia	109	0.94	0.97
	Full sample	228	0.95	0.97
Manual wheelchair	Tetraplegia	150	0.92	0.96
	Paraplegia	285	0.93	0.97
	Full sample	435	0.94	0.97
Power wheelchair	Tetraplegia	288	0.96	0.99
	Paraplegia	67	0.98	0.99
	Full sample	355	0.97	0.99

a high percentage of missing data. Table 2 summarizes the item removal process.

We ended up with 39 items in the ambulation scale, 54 items in the basic mobility scale, 36 items in the fine motor function scale, 90 items in the self-care scale, and 56 items in the wheelchair mobility scale. Response options, item content, and item parameters are presented in appendix 1.

Manual (41 items) and power (15 items) wheelchair items were calibrated into 1 unidimensional wheelchair mobility scale based on our factor analytic work.[9] However, to achieve a fair comparison between the CAT and full item banks in our data simulations, we separated the wheelchair scale into manual wheelchair and power wheelchair subscales.

Table 3 displays the accuracy of the 5- and 10-item CAT compared with the overall item banks. Correlations of the CAT with the total item banks reached or exceeded 0.9 in all but 2 cases (basic mobility for tetraplegia and paraplegia, .89 and .88, respectively). There was little difference in accuracy between the 5- and 10-item CAT.

Table 4 illustrates the breadth of coverage of the 10-item CAT and full item banks in each content domain. Among participants with paraplegia, there are minimal floor effects across all scales, but there are some ceiling effects in the self-care, fine motor function, and power wheelchair mobility domains, where 10% to 28% of the sample is at the ceiling of the distribution. In contrast, there are minimal ceiling effects across all domains for those with tetraplegia. However, in the basic mobility, fine motor function, and manual wheelchair mobility domains, 5% to 10% of the sample displays floor effects.

Reasons for the observed ceiling and floor effects are illustrated in figure 1, which provides the distribution of the SCI-FI response categories across items in the bank for each of the 6 content domains. Consistent with the findings displayed in table 3, figure 1 illustrates the relative paucity of categories/items above 2 SDs on the SCI-FI scale in the domains of self-care, fine motor function, and power wheelchair mobility, and the small number of categories/items below 2 SDs for the fine motor function, basic mobility, and manual wheelchair mobility scales.

Figure 2 displays a functional profile of the sample by diagnostic group across all content domains. Each domain scale is represented as a spoke of the spiderweb. Scores range from a low of 30 in the center of the web to 70 at the periphery. Figure 2 illustrates the expected functional differences between participants with paraplegia and those with tetraplegia. The exception is the ambulation domain, where there is little difference in average function between individuals with paraplegia and tetraplegia, which is likely because completeness of injury (ie, AIS grade D) has more impact on ambulation than grade of lesion.

Figures 3 to 8 display the precision (SE of the measure) and reliability of each domain scale. The line graphs represent the precision and reliability values for each domain across the functional continuum. The precision and reliability data are presented for the full item bank (solid line) and for a 10-item simulated CAT (dotted line) in each domain. The histograms shown in each figure illustrate the distribution of the sample across each functional scale for those with paraplegia (white) or tetraplegia (gray). Figures 3 to 8 reveal that although there is some loss of reliability and precision using a 10-item CAT compared with the full item bank, the loss is modest for each scale, with increasing loss of precision and reliability at the lower and upper ranges, absolute and relative to the full scale. The data also illustrate that across each domain, except for ambulation, those with paraplegia are functioning at a higher level than those with tetraplegia. Using a 10-item CAT, in the basic mobility, self-care, and manual wheelchair mobility scales, 95% of the

Table 4: Breadth of Coverage for a 10-Item CAT and Full Item Bank for Each Content Domain by Neurologic Level

		Tetraplegia					Paraplegia				
Domain	Mode	n	Mean ± SD	Range	% Ceiling	% Floor	n	Mean ± SD	Range	% Ceiling	% Floor
Basic mobility	10-item CAT	465	45.9±11.1	22.9–3.6	3.4	9.9	389	54.93±6.5	22.9–73.6	3.1	0.3
	Full item bank	465	45.7±11.4	18.7–77.1	2.4	4.5	389	54.93±6.6	18.7–77.1	1.8	0.3
Self-care	10-item CAT	463	44.1±10.8	0–63.8	5.8	0.9	387	56.40±5.2	19.5–63.8	17.6	0.0
	Full item bank	463	44.0±10.5	0–66.1	3.9	0.7	387	56.74±5.6	13.9–66.3	10.6	0.0
Fine motor function	10-item CAT	462	43.5±8.8	27.2–63.1	3.7	9.3	387	57.55±4.6	27.4–63.1	28.7	0.3
	Full item bank	462	43.5±8.7	26.7–63.3	3.0	6.7	387	57.71±4.7	26.7–63.3	28.4	0.3
Ambulation	10-item CAT	119	65.7±7.5	48.8–87.9	2.5	2.5	109	64.75±6.7	48.8–87.9	0.9	0.9
	Full item bank	119	65.6±7.5	48.3–87.9	2.5	2.5	109	64.65±6.7	48.3–87.9	0.9	0.9
Manual wheelchair	10-item CAT	150	47.8±10.2	3.0–72.9	1.3	5.3	285	57.37±6.3	41.6–72.9	2.5	0.0
	Full item bank	150	48.1±9.4	3.1–73.6	0.7	3.4	285	57.37±6.2	40.9–73.6	1.8	0.0
Power wheelchair	10-item CAT	288	41.7±9.8	2.6–61.2	3.1	1.4	67	53.29±8.5	2.6–61.2	20.9	1.5
	Full item bank	288	41.8±9.8	2.6–61.5	3.1	1.4	67	53.30±8.6	2.6–61.5	20.9	1.5

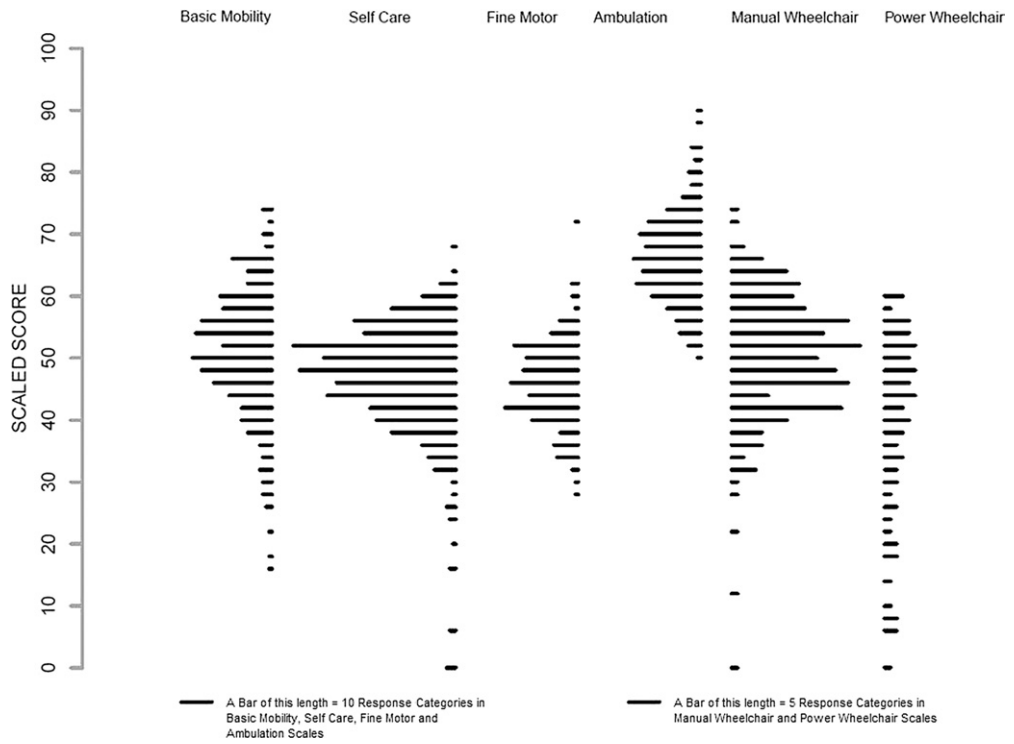

Fig 1. Distribution of SCI-FI item/categories for each content domain.

sample would achieve a reliability ≥0.7; in the fine motor function scale, 82% of the sample would achieve a reliability ≥0.7; in the ambulation scale, almost 100% of the sample would attain a reliability ≥0.7; in the power wheelchair mobility scale, 80% of the sample would realize a reliability ≥0.7.

DISCUSSION

Developing a multidimensional activity limitation measure appropriate for all persons with SCI, regardless of the grade or severity of lesion, is an ambitious yet important goal. CAT methodology is ideally suited for the complexity of assessing functional abilities of those with SCI and overcomes many of the challenges associated with traditional measurement approaches. A CAT can assess multiple functional domains with a common metric, instead of using multiple measures, and can employ filter questions to select appropriate items that match an individual's sex, living situation, and/or method of locomotion, thus avoiding inappropriate or redundant questions.

The SCI-FI revealed strong psychometric properties for all functional scales in a sample of adults with paraplegia or tetraplegia. High correlations of simulated CAT with the overall SCI-FI item bank score indicated high accuracy of the CAT scales in characterizing functional profiles of adults with SCI. There was very little loss of measurement reliability or preci-

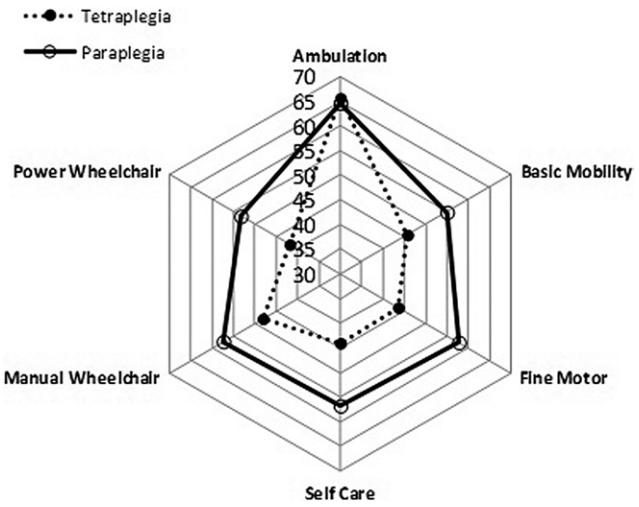

Fig 2. SCI-FI functional profiles by neurologic level.

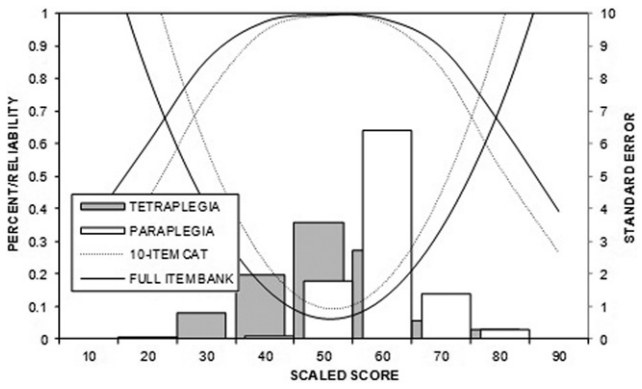

Fig 3. SCI-FI basic mobility 10-item CAT and full item bank precision and reliability by neurologic level.

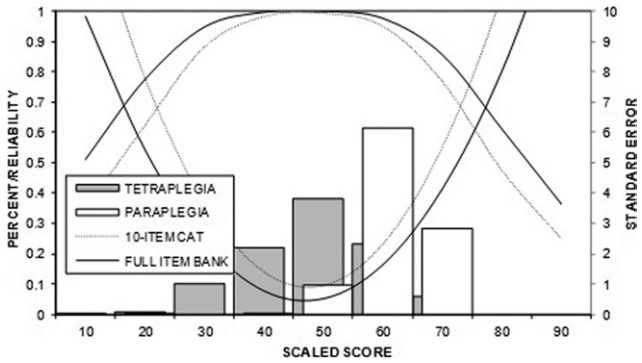

Fig 4. SCI-FI self-care 10-item CAT and full item bank precision and reliability by neurologic level.

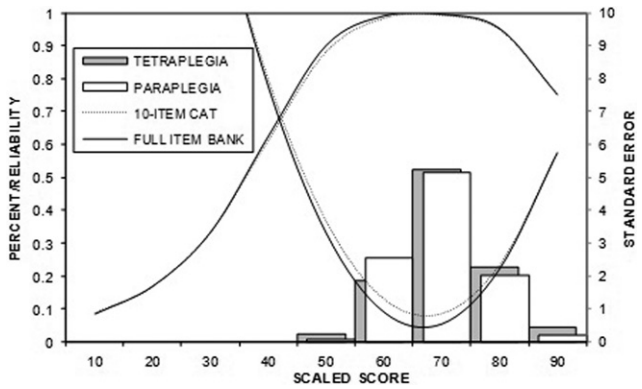

Fig 6. SCI-FI ambulation domain 10-item and full item bank precision and reliability by neurologic level.

sion using a 5- or 10-item CAT compared with the full item bank; however, there was some loss of reliability and precision at the lower and upper ranges of each scale where there were fewer questions in the item banks.

The SCI-FI contains several conceptual advancements over previous instruments, including items that assess ability to manage a bowel and bladder program, in contrast to FIM[20] items that assess bowel and bladder physiologic function, and a distinct fine motor function domain that addresses important aspects of upper extremity functioning.[21] The Quadriplegic Index of Functioning is the only existing measure that includes a range of items that assess upper extremity functioning.[22] In addition, the SCI-FI ambulation domain includes items that assess walking on different surfaces and under a variety of conditions, which is relevant to people with incomplete SCI.

Many current SCI measures give limited attention to wheelchair mobility and ambulation. Most of their items focus on mobility in controlled settings and are limited to 1 type of wheelchair, while many individuals use a power wheelchair in the community and a manual wheelchair at home.[23] The SCI-FI contains distinct power and manual wheelchair domains that assess a comprehensive range of activities, including mobility on different surfaces and activities such as weight shifting for pressure relief, reaching, and dressing. The inclusion of 2 separate domains for ambulation and wheelchair mobility is another unique feature of the SCI-FI. Instruments such as the Spinal Cord Independence Measure III[24] and FIM[20] subsume wheelchair functioning and ambulation under a general mobility score, resulting in a need for separate tools to assess ambulation (eg, Walking Index for Spinal Cord Injury II)[25] or wheelchair function (eg, Functional Evaluation in a Wheelchair Questionnaire).[26]

Study Limitations

Although the SCI-FI includes items across the spectrum of functional ability that allow both low-functioning and high-functioning people to complete the same assessment instrument, the analysis found some areas where the scale could be improved. For those with paraplegia, the breadth of coverage could be improved by including more difficult items, because there was evidence of some ceiling effects in the fine motor function, self-care, and power wheelchair mobility domains. For those with tetraplegia, additional items tapping into low levels of functioning could lower the floor of the basic mobility, fine motor function, and manual wheelchair mobility item banks. Adding new items and recalibration of the scales would increase the breadth of coverage in these content areas and minimize floor and ceiling problems. The fact that these analyses were conducted on the same sample used to develop the factor structure is a limitation,[27] but additional validation data studies are currently underway to demonstrate the SCI-FI's concurrent and discriminant validity as well as the scales' responsiveness to change in independent samples.

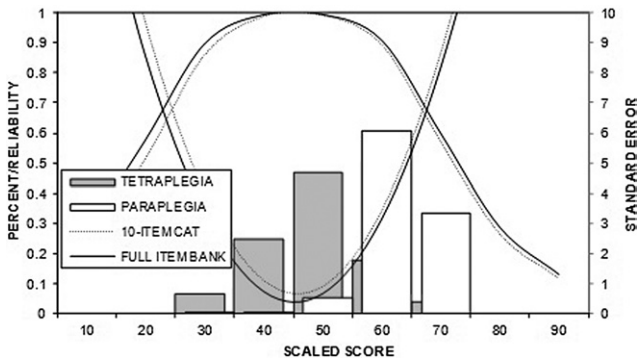

Fig 5. SCI-FI fine motor function 10-item CAT and full item bank precision and reliability by neurologic level.

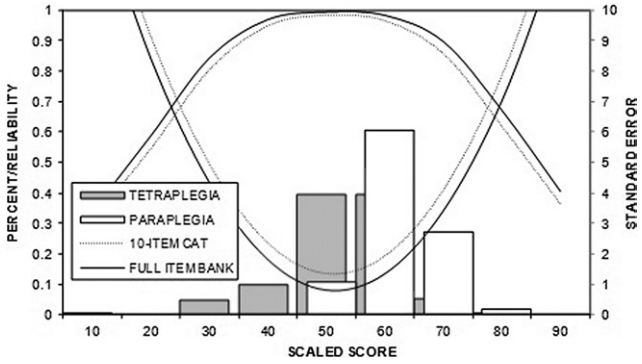

Fig 7. SCI-FI manual wheelchair 10-item CAT and full item bank precision and reliability by neurologic level.

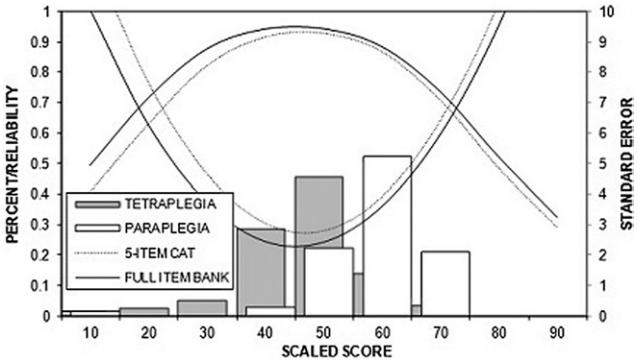

Fig 8. SCI-FI power wheelchair 5-item CAT and full item bank precision and reliability by neurologic level.

CONCLUSIONS

The findings from this study provide significant evidence of the SCI-FI's validity. In developing the SCI-FI, we emphasized content validity by using rigorous qualitative methodology[8] and item writing methodology. We conducted detailed factor analyses to reveal a factor structure underlying the SCI-FI that was consistent with themes revealed in patient and clinician focus groups.[9] The calibration study demonstrated the reliability of the instrument and allowed us to identify and remove misfitting items and those that displayed DIF. Finally, the SCI-FI scales revealed clinically meaningful group differences in functional profiles of individuals with paraplegia and tetraplegia. All of these data provide us with strong evidence of the SCI-FI's construct validity.

The use of CAT minimizes assessment burden while achieving comprehensive assessment of the functioning of adults living with SCI, thus facilitating standardized functional assessment in busy clinical and research settings. The simulated CAT's success in providing an accurate estimate of participants' capacities bodes well for future CAT use to administer the SCI-FI; however, this needs to be confirmed through further research. In summary, the SCI-FI contributes important conceptual clarity to measuring the functional status of adults with SCI. Initial evaluation reveals that the SCI-FI has considerable breadth of coverage in each content domain and demonstrates noteworthy psychometric properties. Our simulation study suggested that with the use of CAT, especially those that consist of 10-items, very little information is lost. Future research needs to assess the SCI-FI's ability to detect clinically meaningful change.

APPENDIX 1: ITEM PARAMETERS FOR EACH SCI-FI CONTENT DOMAIN

Items use 3 different response options.
Response option 1
Item stem: Are you able to . . .
Responses: (1) Unable to do; (2) With much difficulty; (3) With some difficulty; (4) With a little difficulty; (5) Without any difficulty
Response option 2
Item stem: How much difficulty do you have . . .
Responses: (1) Can't do; (2) A lot of difficulty; (3) Some difficulty; (4) A little difficulty; (5) No difficulty
Response option 3
Item stem: How much help from another person do you need . . .
Responses: (1) Total; (2) A lot; (3) A little; (4) None

Basic Mobility Domain

Item	Discrimination*	Threshold 1†	Threshold 2†	Threshold 3†	Threshold 4†
Are you able to get in and out of bed?	5.180	−0.273	−0.139	0.124	0.521
Are you able to move your upper body while lying down in bed?	2.127	−1.475	−0.999	−0.365	0.185
When I am in bed, I can roll from my back to my side . . .	3.346	−0.666	−0.396	−0.043	0.432
Once in bed, I can pull up my sheets and blankets . . .	2.734	−1.146	−0.865	−0.469	0.063
When you are in bed, are you able to turn your lower body?	3.150	−0.174	−0.005	0.321	0.752
When you are in bed, are you able to position pillows for pressure relief?	3.664	−0.442	−0.266	0.037	0.377
Are you able to move from lying down to sitting up (legs straight in front) in a regular bed?	3.184	−0.238	−0.038	0.310	0.758
When you are in bed, are you able to turn your body for pressure relief?	4.048	−0.545	−0.345	0.061	0.457
When sitting on the edge of my bed, I can lean forward to reach for something . . .	2.889	−0.375	−0.144	0.239	0.739
When in my bed, I can roll from my back onto my belly . . .	3.424	−0.237	0.053	0.421	0.805
How much difficulty do you currently have moving from sitting at the side of the bed to lying down on your back?	3.600	−0.664	−0.407	−0.042	0.445
Are you able to reach for a book on a table when sitting in a chair with a firm seat and a back?	2.371	−1.213	−0.930	−0.490	0.056

APPENDIX 1: ITEM PARAMETERS FOR EACH SCI-FI CONTENT DOMAIN (Cont'd)

Item	Discrimination*	Threshold 1†	Threshold 2†	Threshold 3†	Threshold 4†
When sitting, are you able to reach down to pick up a shoe from the floor while using 1 arm for support?	3.433	−0.426	−0.219	0.095	0.483
Are you able to sit in a car going around a corner, without losing your balance?	1.935	−1.126	−0.826	−0.355	0.275
Are you able to sit on a bench without a back, when you can't use your arms for support?	2.364	−0.257	0.075	0.435	0.878
Are you able to sit on a bench without a back, when you are able to use your arms for support?	2.378	−0.856	−0.607	−0.151	0.281
Are you able to sit in a chair with a firm seat and a back, when you can't use your arms for support?	1.913	−1.162	−0.918	−0.491	0.032
Are you able to sit in a chair with a firm seat and a back when you can use your arms for support?	2.145	−1.428	−1.239	−0.900	−0.435
Are you able to stand without any support for 1min, eg, long enough to brush your teeth?	2.029	0.711	0.816	0.979	1.184
Are you able to stand supported in a standing frame?	1.185	−1.723	−1.272	−0.739	−0.048
Are you able to stand without any support for 5min, eg, long enough to wash dishes?	2.261	0.851	0.957	1.119	1.344
Are you able to get on and off the toilet?	5.561	0.028	0.162	0.326	0.592
I can move onto a shower chair . . .	7.15	−0.206	−0.045	0.177	0.425
Are you able to get out of a chair into bed?	7.451	−0.294	−0.128	0.053	0.341
Are you able to get down on the floor (eg, to play with a child or pet)?	4.188	0.215	0.454	0.710	0.967
Are you able to get out of bed into a chair?	7.566	−0.289	−0.129	0.057	0.335
When transferring into bed, are you able to get your legs onto the bed?	6.672	−0.289	−0.123	0.096	0.428
I can move off of a shower chair . . .	7.837	−0.196	−0.034	0.184	0.430
Are you able to get up off the floor from lying on your back without help?	4.106	0.360	0.628	0.857	1.144
Are you able to get on and off the toilet without an elevated toilet seat?	4.946	0.158	0.301	0.406	0.656
I can move into a tub . . .	4.743	0.345	0.541	0.748	0.992
I can move out of a tub . . .	4.301	0.395	0.619	0.819	1.080
How much difficulty do you currently have sitting down on a low, soft couch?	2.326	−0.596	−0.074	0.327	0.771
How much difficulty do you currently have standing up from a low, soft couch?	2.456	0.432	0.809	1.127	1.728
How much difficulty do you currently have getting into and out of a kneeling position?	2.972	0.458	0.800	1.134	1.561
How much difficulty do you currently have sitting down on an armless straight chair (eg, dining room chair)?	3.379	−0.294	−0.036	0.323	0.687
How much difficulty do you currently have sitting down and standing up from a chair with arms?	2.503	0.230	0.361	0.568	0.915
How much difficulty do you currently have standing up from an armless straight chair (eg, dining room chair)?	2.484	0.350	0.523	0.770	1.067
Are you able to crawl on the floor?	2.587	0.361	0.665	0.955	1.317
How much difficulty do you currently have picking up a gallon carton of milk with 1 hand and setting it on the table?	2.692	−0.674	−0.316	0.034	0.516
Are you able to carry 1 bag of groceries out of the store?	1.718	−0.705	−0.538	−0.098	0.420
Are you able to push a shopping cart?	2.289	−0.180	0.083	0.440	0.871
Are you able to hold a small child in your arms?	1.839	−0.855	−0.521	0.005	0.488
Are you able to reach to take a box of cereal from the top shelf at the grocery store?	2.208	0.187	0.395	0.726	1.137
Are you able to push open a heavy door?	2.181	−0.825	−0.383	0.194	0.780
Are you able to get in and out of a car?	3.915	−0.251	−0.061	0.237	0.587
Are you able to drive from a regular car seat?	2.834	0.195	0.236	0.337	0.506
When sitting on the seat of a car, I can take my seat belt off . . .	3.133	−0.731	−0.584	−0.412	−0.100
Exercise means doing an activity like biking, swimming, or arm cycling for at least 20min. I can exercise . . .	1.294	−1.194	−0.874	−0.193	0.426

APPENDIX 1: ITEM PARAMETERS FOR EACH SCI-FI CONTENT DOMAIN (Cont'd)

Item	Discrimination*	Threshold 1†	Threshold 2†	Threshold 3†	Threshold 4†
How much help from another person do you currently need to get in and out of bed?‡	5.467	−0.581	−0.248	0.177	NA
How much help from another person do you currently need to push open a heavy door?‡	2.366	−1.187	−0.593	0.274	NA
How much help from another person do you currently need to use public transportation?‡	1.682	−1.552	−0.805	0.165	NA
Are you able to touch/hug a partner?	1.739	−2.150	−1.87	−1.378	−0.724
Are you able to move your body into position for sexual activity?	2.686	−0.497	−0.234	0.178	0.682

Abbreviation: NA, not applicable.
*Item discrimination parameter.
†Threshold 1–Threshold 4 are the threshold parameters; the values are increasing.
‡Item with 4 categories.

Self-Care Domain

Item	Discrimination	Threshold 1	Threshold 2	Threshold 3	Threshold 4
I can wash my hands at a sink with soap and water . . .	3.892	−1.122	−0.949	−0.574	−0.257
Are you able to wash your face with a washcloth?	3.723	−1.282	−1.107	−0.779	−0.457
Are you able to shampoo your hair?	3.741	−0.721	−0.575	−0.308	−0.021
Are you able to wash and dry your body?	4.494	−0.579	−0.345	0.000	0.315
Are you able to bathe yourself in your accessible shower in your own home?	3.898	−0.431	−0.291	−0.072	0.244
Are you able to bathe yourself in a standard bathtub, using a tub bench?	3.562	−0.134	0.033	0.280	0.568
Are you able to bathe yourself in a roll-in shower?	3.864	−0.469	−0.310	−0.081	0.225
I can scratch my face . . .	2.831	−1.693	−1.534	−1.357	−1.006
I can dry my hair with a towel . . .	3.593	−1.062	−0.887	−0.631	−0.269
Are you able to rinse your mouth after brushing your teeth?	2.375	−1.529	−1.441	−1.213	−0.947
Are you able to use a long handled mirror to inspect your skin for breakdown?	3.579	−0.694	−0.532	−0.207	0.123
Are you able to cut your toe nails?	4.542	0.123	0.278	0.473	0.734
Are you able to wipe/blow your nose?	3.872	−1.353	−1.169	−0.839	−0.514
Are you able to comb your hair?	4.617	−0.857	−0.716	−0.530	−0.208
Are you able to brush your hair?	4.675	−0.889	−0.747	−0.525	−0.214
Are you able to apply lotion or other skincare products to your body?	3.925	−0.851	−0.633	−0.172	0.181
Are you able to brush your teeth?	3.936	−1.280	−1.174	−0.857	−0.511
Are you able to floss your teeth?	3.889	−0.712	−0.539	−0.338	−0.129
Are you able to squeeze a new tube of toothpaste?	4.166	−1.057	−0.880	−0.562	−0.260
How much difficulty do you currently have putting a Band-Aid or gauze pad on yourself?	4.485	−0.658	−0.351	−0.012	0.269
How much difficulty do you currently have cleaning yourself after a bowel movement?	4.484	−0.224	−0.002	0.260	0.535
How much difficulty do you currently have pulling up and fastening your pants after a bowel movement?	4.002	−0.206	0.046	0.371	0.743
Are you able to dress your upper body?	4.853	−0.801	−0.582	−0.257	0.096
Are you able to dress your lower body?	4.424	−0.221	0.027	0.329	0.678
Are you able to open and close a zipper?	4.481	−0.523	−0.332	−0.079	0.154
Are you able to put on stockings/tights/compression hose?	4.766	−0.039	0.157	0.361	0.627
Are you able to tie your shoelaces?	5.074	−0.022	0.150	0.349	0.575
Are you able to take off a heavy winter jacket?	5.149	−0.649	−0.392	0.008	0.351
Are you able to take your shoes off?	4.46	−0.307	−0.161	0.079	0.391
Are you able to fasten (eg, button, zip) your jeans?	5.353	−0.237	−0.097	0.078	0.332

APPENDIX 1: ITEM PARAMETERS FOR EACH SCI-FI CONTENT DOMAIN (Cont'd)

Item	Discrimination	Threshold 1	Threshold 2	Threshold 3	Threshold 4
Are you able to pull on trousers? (Note to interviewer: This item refers to regular, nonadaptive trousers.)	4.944	−0.230	−0.034	0.268	0.575
Are you able to put on a heavy winter jacket?	5.328	−0.515	−0.323	0.046	0.375
Are you able to take your socks off?	5.339	−0.253	−0.098	0.140	0.400
Are you able to put on pants using adaptive clothing (eg, clothing with loops or Velcro)?	4.926	−0.325	−0.169	0.080	0.315
I can put on my socks . . .	5.575	−0.162	0.004	0.219	0.503
I can put on a belt . . .	4.841	−0.240	−0.109	0.122	0.388
How much difficulty do you currently have taking off a pullover shirt?	4.139	−0.901	−0.519	−0.172	0.292
How much difficulty do you currently have putting on a pullover shirt?	4.321	−0.856	−0.578	−0.185	0.238
How much difficulty do you currently have using a fork to eat a meal?	3.237	−1.228	−0.941	−0.642	−0.24
How much difficulty do you currently have opening previously opened jars?	5.083	−0.685	−0.416	−0.144	0.197
How much difficulty do you currently have using a spoon to eat a meal?	3.583	−1.258	−0.929	−0.616	−0.263
How much difficulty do you currently have chopping or slicing vegetables (eg, onions or peppers)?	4.229	−0.523	−0.234	0.030	0.311
How much difficulty do you currently have applying spreads to bread using a knife?	4.441	−0.684	−0.382	−0.151	0.089
I can open a bag of chips (with mouth, hands) . . .	3.43	−1.117	−0.718	−0.353	−0.028
Are you able to order food for home delivery?	1.805	−2.133	−2.051	−1.694	−1.232
I can use a spoon to eat soup . . .	3.594	−1.127	−0.851	−0.624	−0.354
Are you able to grasp a fork or spoon?	3.818	−0.928	−0.727	−0.487	−0.215
Are you able to cut your food using eating utensils?	3.831	−0.545	−0.356	−0.115	0.116
Are you able to drink liquids from a smooth glass without a handle?	3.902	−1.037	−0.819	−0.501	−0.204
Are you able to drink liquids from a cup with a handle?	4.033	−1.235	−0.999	−0.726	−0.415
Are you able to hold a plate full of food?	3.312	−0.808	−0.601	−0.222	0.103
Are you able to chew and swallow your food (if someone else feeds you)?	0.898	−5.048	−4.962	−4.434	−3.381
Are you able to peel fruit?	3.909	−0.444	−0.229	0.058	0.269
I can shake salt and pepper on my food . . .	4.940	−1.026	−0.891	−0.622	−0.363
Are you able to pour liquid out of a container like a half gallon milk carton?	4.570	−0.657	−0.510	−0.235	0.042
When sitting up, are you able to bring your hand to your mouth?	2.592	−1.753	−1.632	−1.458	−1.122
Are you able to drink liquids through a straw?	1.167	−3.797	−3.749	−3.540	−3.093
I can check the skin on my bottom . . .	3.282	−0.296	−0.073	0.194	0.547
How much help from another person do you currently need to groom yourself?*	4.212	−1.175	−0.548	0.108	NA
How much help from another person do you currently need to bathe yourself in a regular shower?*	2.649	−0.602	−0.071	0.360	NA
How much help from another person do you currently need to bathe in bed?*	3.299	−0.697	−0.063	0.471	NA
Are you able to use adaptive equipment to bathe yourself (eg, long-handled brush)?	2.874	−1.672	−1.112	−0.353	0.279
Are you able to clean yourself after a bladder accident?	4.215	−0.221	−0.039	0.180	0.463
Are you able to insert a suppository with an assistive device?	4.985	−0.023	0.077	0.194	0.355
Are you able to use a device to perform digital stimulation?	4.607	−0.007	0.110	0.244	0.388
Are you able to catheterize yourself during the night?	5.365	−0.088	0.010	0.102	0.282
Are you able to clean your leg bag?	5.640	−0.231	−0.148	0.011	0.222
Are you able to insert a suppository?	5.703	0.004	0.091	0.200	0.378
Are you able to use an electric leg bag clamp?	2.235	−0.467	−0.419	−0.312	−0.190
Are you able to clean yourself after a bowel accident?	4.272	−0.025	0.213	0.496	0.748
Are you able to carry out your bowel program in bed?	1.937	−0.246	0.057	0.335	0.589

APPENDIX 1: ITEM PARAMETERS FOR EACH SCI-FI CONTENT DOMAIN (Cont'd)

Item	Discrimination	Threshold 1	Threshold 2	Threshold 3	Threshold 4
Are you able to position a urinal for use from your wheelchair? (men only)	3.043	−0.375	−0.247	−0.051	0.216
Are you able to catheterize yourself using an assistive device (eg, a splint, brace, or special clothing adaptation)?	4.337	−0.163	−0.095	0.000	0.124
Are you able to perform digital stimulation?	5.144	−0.003	0.072	0.197	0.384
Are you able to open and close a manual leg bag?	4.782	−0.385	−0.281	−0.136	0.008
Are you able to apply a condom catheter? (men only)	4.410	−0.256	−0.121	0.031	0.200
Are you able to carry out your bowel program on the toilet?	2.359	−0.115	0.074	0.325	0.538
Are you able to attach (eg, with tape, glue) your leg bag yourself?	5.729	−0.237	−0.112	0.021	0.198
Including fixing my clothes, setup, and clean up, I can complete my bowel program . . .	5.035	−0.026	0.109	0.298	0.508
Including fixing my clothes, setup, and clean up, I can catheterize myself . . .	4.848	−0.134	−0.019	0.088	0.272
After someone has helped with my clothes and setup, I can catheterize myself . . .	4.484	−0.199	−0.133	−0.005	0.146
How much difficulty do you currently have shaving your neck and face safely and thoroughly with an electric razor?	3.335	−0.972	−0.689	−0.460	−0.130
Are you able to apply shaving cream to your face?	3.814	−0.980	−0.803	−0.534	−0.271
Are you able to shave your face with a manual razor?	3.950	−0.618	−0.376	−0.211	0.027
Are you able to insert and remove a tampon?	3.676	−0.143	−0.016	0.193	0.453
Are you able to change your pad (for menstruation)?	4.029	−0.307	−0.164	0.023	0.297
Are you able to put lipstick on?	3.740	−1.142	−0.917	−0.772	−0.486
Are you able to apply cream to your face?	3.993	−1.283	−1.101	−0.838	−0.630
Are you able to take a bra off?	4.367	−0.344	−0.172	−0.004	0.205
Are you able to put a bra on?	5.078	−0.317	−0.166	0.047	0.270

Abbreviation: NA, not applicable.
*Item with 4 categories.

Fine Motor Function Domain

Item	Discrimination	Threshold 1	Threshold 2	Threshold 3	Threshold 4
Using both of my hands together, I can turn the pages of a book . . .	3.432	−1.323	−1.163	−0.771	−0.400
Using only 1 hand, I can turn the pages of a book . . .	3.350	−1.242	−0.937	−0.630	−0.251
Are you able to hold a book?	4.386	−1.047	−0.897	−0.612	−0.282
Are you able to write with a pen or pencil?	4.324	−1.013	−0.645	−0.354	−0.046
Using only 1 hand to use a remote, I can change TV channels . . .	3.465	−1.072	−0.812	−0.628	−0.398
Are you able to make and receive calls on a cell phone?	3.198	−1.295	−1.112	−0.856	−0.516
Are you able to make and receive calls using a phone that you hold in your hands?	5.125	−1.087	−0.894	−0.658	−0.406
Are you able to make a phone call using a touch tone keypad?	4.643	−1.278	−1.123	−0.828	−0.544
Are you able to type on a standard computer keyboard with your fingers?	3.734	−0.892	−0.632	−0.336	−0.035
Are you able to type on a standard computer keyboard using your knuckles, a pointer, or the end of a pen?	2.750	−1.450	−1.169	−0.753	−0.376
Are you able to type on a laptop (small, flat keys)?	2.986	−1.145	−0.869	−0.498	−0.115
I can turn the knob on a door . . .	6.449	−0.674	−0.523	−0.255	−0.006
Are you able to water a houseplant?	5.433	−0.749	−0.615	−0.306	−0.022
Are you able to cut a piece of paper with scissors?	6.592	−0.592	−0.368	−0.241	0.016
Are you able to pick up coins from a table top?	5.352	−0.883	−0.606	−0.232	0.053
Are you able to use a bottle opener?	6.772	−0.513	−0.400	−0.204	0.022
Are you able to swipe your card in an ATM or credit card machine?	6.493	−0.699	−0.497	−0.293	−0.068
Are you able to change the bulb in a table lamp?	5.475	−0.500	−0.374	−0.137	0.115

APPENDIX 1: ITEM PARAMETERS FOR EACH SCI-FI CONTENT DOMAIN (Cont'd)

Item	Discrimination	Threshold 1	Threshold 2	Threshold 3	Threshold 4
Are you able to press with your index finger (eg, ringing a doorbell)?	4.124	−0.966	−0.818	−0.592	−0.339
Are you able to pick up a small object (eg, pack of gum)?	4.440	−1.194	−1.001	−0.622	−0.245
I can take dollars out of my wallet or purse . . .	6.915	−0.878	−0.712	−0.386	−0.100
Are you able to pick up a piece of paper?	4.182	−1.146	−0.911	−0.525	−0.140
Are you able to remove something from your back pocket?	3.618	−0.378	−0.191	0.082	0.404
Are you able to get your wallet out of your purse?	6.217	−0.991	−0.795	−0.446	−0.180
Are you able to wring out a wet washcloth?	6.248	−0.660	−0.485	−0.208	0.055
Are you able to change a light bulb overhead?	1.951	0.234	0.483	0.744	1.046
Are you able to turn a key in a lock?	6.961	−0.645	−0.422	−0.216	0.014
I can put a DVD or CD into the player . . .	6.358	−0.894	−0.713	−0.477	−0.238
Are you able to open mail?	6.741	−0.839	−0.616	−0.384	−0.112
How much difficulty do you currently have playing cards or Bingo or other light recreational activities?	3.964	−1.194	−0.780	−0.326	0.111
How much difficulty do you currently have holding a screw and screwing it in tight with a manual screwdriver?	6.066	−0.356	−0.035	0.174	0.535
How much difficulty do you currently have removing wrappings from small objects?	5.194	−1.011	−0.509	−0.131	0.193
How much difficulty do you currently have pounding a nail with a hammer to hang a picture?	4.687	−0.246	0.020	0.271	0.597
How much difficulty do you currently have reaching behind your back to put a belt through a loop?	3.541	−0.381	−0.012	0.275	0.678
How much difficulty do you currently have opening medications or vitamin containers (eg, childproof containers, small bottles)?	5.651	−0.557	−0.339	−0.097	0.220
How much help from another person do you currently need to use the phone?*	2.960	−1.817	−1.444	−0.878	NA

Abbreviation: NA, not applicable.
*Item with 4 categories.

Ambulation Domain

Item	Discrimination	Threshold 1	Threshold 2	Threshold 3	Threshold 4
I can take a step with each foot . . .	3.232	0.478	0.766	1.010	1.323
Are you able to walk for 5min inside?	3.721	0.843	1.010	1.178	1.542
Are you able to walk for 5min outside?	3.869	0.921	1.101	1.334	1.640
I can change direction by turning around while walking . . .	3.569	0.798	0.999	1.310	1.640
Are you able to go for a walk of at least 15min?	3.453	1.152	1.371	1.578	1.85
How much difficulty do you currently have walking around 1 floor of your home?	3.578	0.786	0.923	1.137	1.509
How much difficulty do you currently have running up and down an incline?	3.338	1.919	2.205	2.492	2.778
How much difficulty do you currently have walking on uneven surfaces (eg, grass, dirt road, or sidewalk)?	5.423	1.109	1.404	1.814	2.244
How much difficulty do you currently have walking 45min on an even surface?	6.206	1.381	1.639	1.900	2.188
How much difficulty do you currently have running 45min?	3.866	2.371	2.778	3.174	3.339
How much difficulty do you currently have walking in a dark room without falling?	5.502	1.247	1.496	1.700	1.963
How much difficulty do you currently have stopping when walking at a brisk pace?	5.607	1.266	1.354	1.580	1.763
How much difficulty do you currently have walking in a busy place (eg, crowded store) without losing your balance?	6.193	1.240	1.397	1.680	1.965
How much difficulty do you currently have crossing the road at a 4-lane traffic light with curbs?	7.289	1.274	1.493	1.711	1.921

APPENDIX 1: ITEM PARAMETERS FOR EACH SCI-FI CONTENT DOMAIN (Cont'd)

Item	Discrimination	Threshold 1	Threshold 2	Threshold 3	Threshold 4
How much difficulty do you currently have taking a 20-min brisk walk without stopping to rest?	5.969	1.460	1.682	1.897	2.206
How much difficulty do you currently have walking on a slippery surface outdoors?	6.086	1.385	1.834	2.194	2.654
How much difficulty do you currently have going up and down a flight of stairs inside, using a handrail?	5.207	1.034	1.323	1.650	1.998
How much difficulty do you currently have climbing stairs step over step without a handrail (alternating feet)?	6.401	1.388	1.737	1.948	2.239
How much difficulty do you currently have going up and down 3 flights of stairs inside, using a handrail?	6.066	1.161	1.550	1.780	2.144
How much difficulty do you currently have using an escalator?	5.147	1.149	1.295	1.456	1.681
Are you able to go up and down 3 steps, using a handrail?	4.850	1.005	1.035	1.179	1.409
Are you able to jump up and down?	3.768	1.741	2.047	2.183	2.470
I can walk down a ramp or steep hill . . .	5.247	1.211	1.475	1.804	2.090
Are you able to run for 5min?	4.778	2.132	2.328	2.459	2.784
I can walk up a ramp or steep hill . . .	4.628	1.206	1.483	1.782	2.082
I can walk on a dirt path or hiking trail . . .	6.124	1.276	1.456	1.813	2.137
Are you able to run or jog for 10min?	4.564	2.180	2.360	2.618	2.850
Are you able to run at a fast pace for 2 miles?	3.474	2.576	2.769	3.075	3.350
I can hold a door open while moving into a room . . .	5.671	1.104	1.214	1.365	1.605
Are you able to step up and down curbs?	6.485	1.196	1.307	1.429	1.752
How much difficulty do you currently have descending 3–5 stairs without a handrail with your walking aid?	3.982	0.843	1.110	1.428	1.756
How much difficulty do you currently have walking on uneven surfaces (eg, grass, dirt road, or sidewalk) with your walking aid?	3.960	0.663	0.929	1.299	1.793
How much difficulty do you currently have going up and down 3 flights of stairs, using a handrail with your walking aid?	4.139	0.880	1.155	1.410	1.802
How much difficulty do you currently have going up and down 3 flights of stairs with your walking aid?	4.041	0.808	1.002	1.286	1.732
How much difficulty do you currently have sitting down or standing up from a low, soft couch with your walking aid?	3.715	0.786	1.064	1.395	1.798
How much difficulty do you currently have sitting down and standing up from a chair with arms with your walking aid?	3.936	0.583	0.684	0.997	1.415
Are you able to go for a walk of at least 15min with your walking aid?	3.989	0.951	1.082	1.366	1.612
Are you able to walk from room to room in your house with your walking aid?	4.213	0.646	0.693	0.816	1.148
Are you able to walk from your car into a building with your walking aid?	4.184	0.698	0.814	0.978	1.330

Wheelchair Mobility Domain

Item	Discrimination	Threshold 1	Threshold 2	Threshold 3	Threshold 4
Are you able to use sip and puff controls to propel your chair?	1.095	−3.788	−3.199	−2.469	−1.573
How much difficulty do you currently have sitting down on an armless straight chair using a wheelchair?	2.848	−0.352	−0.114	0.253	0.765
How much difficulty do you currently have propelling/driving a wheelchair for at least 15min?	2.812	−0.994	−0.480	−0.077	0.397
How much difficulty do you currently have getting into and out of a truck, bus, shuttle van, or sport utility vehicle from your wheelchair?	2.079	−0.040	0.297	0.831	1.476
Are you able to get on and off the toilet from your wheelchair?	2.983	0.027	0.193	0.449	0.788
Are you able to transfer from your chair to a shower bench in a standard bathtub?	4.308	−0.063	0.049	0.343	0.726

APPENDIX 1: ITEM PARAMETERS FOR EACH SCI-FI CONTENT DOMAIN (Cont'd)

Item	Discrimination	Threshold 1	Threshold 2	Threshold 3	Threshold 4
Are you able to transfer from a shower bench in a standard tub to your chair?	4.266	−0.050	0.089	0.360	0.746
Are you able to remove your wheelchair armrests and footrests?	3.598	−0.352	−0.204	0.017	0.313
Are you able to fold your chair?	3.695	0.130	0.306	0.484	0.781
When sitting in your manual wheelchair, are you able to lift a backpack from your lap and place it on a table?	3.071	−0.987	−0.760	−0.376	0.062
How much difficulty do you currently have removing the wheels from your wheelchair?	4.048	0.055	0.251	0.456	0.770
Are you able to put your wheelchair in the car?	3.420	0.331	0.529	0.729	1.093
Are you able to remove your seat cushion?	4.100	−0.281	−0.211	−0.028	0.222
Are you able to lift your foot from the footrest?	2.321	−0.571	−0.345	−0.093	0.276
Are you able to push your chair over rough or uneven surfaces?	3.732	−0.684	−0.184	0.419	0.972
In your manual wheelchair, are you able to go up and down a slight incline?	3.510	−0.702	−0.262	0.068	0.548
Are you able to dress your lower body while sitting in your wheelchair?	3.122	0.113	0.381	0.646	1.111
When sitting in my manual wheelchair, I can bend forward to pick something up off the floor . . .	3.498	−0.309	−0.077	0.223	0.675
When sitting in my manual wheelchair, I can fix and straighten my pants . . .	3.415	−0.413	−0.141	0.273	0.781
For this question, hooking means to hold your arm to the wheelchair to keep your balance. I can hook my arm on my manual wheelchair . . .	2.370	−1.323	−1.154	−0.685	−0.210
Are you able to use a sports wheelchair?	2.622	−0.332	−0.215	0.023	0.345
From the floor, I can get into my manual wheelchair . . .	2.753	0.466	0.858	1.269	1.645
When sitting in my manual wheelchair, I can bring my foot up, like when I put on socks or shoes . . .	2.947	−0.101	0.137	0.336	0.687
After reaching the floor, I can come back up to sit in my manual wheelchair . . .	2.513	−0.334	−0.144	0.190	0.667
In my manual wheelchair, I can lean forward to reach for something in front of me . . .	2.616	−1.124	−0.800	−0.303	0.307
In a wheelie position, I can push my manual wheelchair . . .	3.212	0.217	0.411	0.618	0.865
On a flat surface, I can stop my manual wheelchair before I hit something . . .	3.171	−1.366	−0.983	−0.555	−0.148
In my manual wheelchair, I can turn corners indoors without hitting walls . . .	2.707	−1.365	−1.012	−0.678	−0.120
In my manual wheelchair, I can cross the street at a traffic light . . .	3.894	−0.624	−0.482	−0.179	0.224
I can push my manual wheelchair in a busy hallway with a lot of people . . .	3.477	−1.014	−0.622	−0.277	0.242
I can push my manual wheelchair all day . . .	3.380	−0.300	−0.016	0.346	0.665
I can push my manual wheelchair down a ramp . . .	3.462	−0.835	−0.547	−0.167	0.129
I can stop my manual wheelchair . . .	3.349	−1.234	−0.963	−0.662	−0.239
I can push my manual wheelchair up a curb . . .	2.856	0.035	0.307	0.668	1.126
In my manual wheelchair, I can maintain a wheelie position . . .	3.374	0.345	0.478	0.640	0.852
I can push my manual wheelchair up a ramp . . .	3.708	−0.589	−0.219	0.188	0.637
I can push my manual wheelchair down a curb . . .	2.793	−0.140	0.043	0.340	0.731
In my manual wheelchair, I can lock the brakes . . .	3.167	−1.226	−1.078	−0.827	−0.446
I can push my manual wheelchair on a rug . . .	3.379	−0.961	−0.540	−0.075	0.338
I can put my manual wheelchair into the car . . .	3.557	0.342	0.538	0.784	1.063
Are you able to get in and out of a car from a wheelchair?	3.922	−0.234	−0.055	0.256	0.627
Are you able to propel your wheelchair on a rough gravel driveway?	2.926	−0.475	0.174	0.651	1.164

APPENDIX 1: ITEM PARAMETERS FOR EACH SCI-FI CONTENT DOMAIN (Cont'd)

Item	Discrimination	Threshold 1	Threshold 2	Threshold 3	Threshold 4
When sitting in your power wheelchair, are you able to lift a backpack from your lap and place it on a table?	3.316	−0.868	−0.693	−0.400	−0.081
Are you able to remove your wheelchair armrests?	3.194	−0.537	−0.405	−0.226	0.065
Are you able to remove your seat cushion?	3.388	−0.032	0.092	0.173	0.406
In my power wheelchair, I can lean forward to reach for something in front of me.	3.244	−1.092	−0.885	−0.513	−0.064
In my power wheelchair, I can sit without losing my balance . . .	1.282	−2.411	−2.186	−1.725	−1.001
After reaching the floor, I can come back up to sit in my power wheelchair . . .	3.265	−0.353	−0.258	0.058	0.381
For this question, hooking means to hold your arm to the wheelchair then keep your balance. I can hook my arm on my power wheelchair . . .	2.455	−1.263	−1.123	−0.936	−0.632
In my power wheelchair, I can do a weight shift for pressure relief . . .	1.335	−1.979	−1.853	−1.459	−0.979
When sitting in my power wheelchair, I can bend forward to pick something off the floor . . .	3.554	−0.271	−0.167	0.134	0.447
When sitting in my power wheelchair, I can put my feet on the foot plates . . .	3.125	−0.512	−0.329	−0.087	0.192
I can move my power wheelchair down a ramp . . .	1.566	−2.912	−2.793	−2.338	−1.685
In my power wheelchair, I can move on flat surfaces . . .	1.895	−2.958	−2.906	−2.692	−2.257
Before getting into bed, I can put my power wheelchair next to the bed . . .	1.186	−2.413	−2.367	−2.154	−1.771
I can move my power wheelchair onto a power lift . . .	0.895	−3.661	−3.529	−3.085	−2.232

References

1. Steeves JD, Lammertse D, Curt A, et al. Guidelines for the conduct of clinical trials for spinal cord injury (SCI) as developed by the ICCP panel: clinical trial outcome measures. Spinal Cord 2007;45:206-21.
2. Anderson K, Aito S, Atkins M, et al. Functional recovery measures for spinal cord injury: an evidence-based review for clinical practice and research. J Spinal Cord Med 2008;31:133-44.
3. Furlan JC, Noonan V, Singh A, Fehlings MG. Assessment of disability in patients with acute traumatic spinal cord injury: a systematic review of the literature. J Neurotrauma 2011;28:1413-30.
4. Hall KM, Cohen ME, Wright J, Call M, Werner P. Characteristics of the Functional Independence Measure in traumatic spinal cord injury. Arch Phys Med Rehabil 1999;80:1471-6.
5. Haley SM, Ni P, Ludlow LH, Fragala-Pinkham MA. Measurement precision and efficiency of multidimensional computer adaptive testing of physical functioning using the Pediatric Evaluation of Disability Inventory. Arch Phys Med Rehabil 2006;87:1223-9.
6. Jette AM, Haley SM. Contemporary measurement techniques for rehabilitation outcomes assessment. J Rehabil Med 2005;37:339-45.
7. Wise SL, Kingsbury GG. Practical issues developing and maintaining a computerized adaptive testing program. Psicologica 2000;21:135-55.
8. Slavin MD, Kisala PA, Jette AM, Tulsky DS. Developing a contemporary functional outcome measure for spinal cord injury research. Spinal Cord 2010;48:262-7.
9. Tulsky DS, Jette AM, Kisala PA, et al. Spinal Cord Injury-Functional Index: item banks to measure physical functioning in individuals with spinal cord injury. Arch Phys Med Rehabil 2012; 93:1722-32.
10. World Health Organization. International Classification of Functioning, Disability and Health: ICF. World Health Organization: Geneva; 2001.
11. Orlando M, Thissen D. Likelihood-based item-fit indices for dichotomous item response theory models. Appl Psychol Measur 2000;24:50-64.
12. Orlando M, Thissen D. Further investigation of the performance of S-X2: an item fit index for use with dichotomous item response theory models. Appl Psychol Meas 2003;27:289-98.
13. Stone CA. Monte Carlo based null distribution for an alternative goodness-of-fit test statistic in IRT models. J Educ Meas 2000; 37:58-75.
14. Stone CA. Empirical power and type I error rates for an IRT fit statistic that considers the precision of ability estimates. Educ Psychol Meas 2003;63:566-86.
15. Stone CA, Zhang B. Assessing goodness of fit of item response theory models: a comparison of traditional and alternative procedures. J Educ Meas 2003;4:331-52.
16. Crane P, Gibbons L, Ocepek-Welikson K, et al. A comparison of three sets of criteria for determining the presence of differential item functioning using ordinal logistic regression. Qual Life Res 2007;16:69-84.
17. Jodoin MG, Gierl MJ. Evaluating type I error and power rates using an effect size measure with the logistic regression procedure for DIF detection. Appl Meas Educ 2001;14:329-49.
18. Mâsse LC, Heesch KC, Eason KE, Wilson M. Evaluating the properties of a stage-specific self-efficacy scale for physical activity using classical test theory, confirmatory factor analysis and item response modeling. Health Educ Res 2006;21:i33-46.
19. National Spinal Cord Injury Statistical Center. Spinal cord injury facts and figures at a glance. 2011. Available at: https://www.nscisc.uab.edu/PublicDocuments/nscisc_home/pdf/Facts%202011%20Feb%20Final.pdf. Accessed May 21, 2012.
20. Guide for the Uniform Data Set for Medical Rehabilitation (including the FIM instrument), Version 5.1. Buffalo: State University of New York at Buffalo; 1997.
21. Marino RJ. Domains of outcomes in spinal cord injury for clinical trials to improve neurological function. J Rehabil Res Dev 2007;44:113-22.

22. Gresham GE, Labi ML, Dittmar SS, Hicks JT, Joyce SZ, Stehlik MA. The Quadriplegia Index of Function (QIF): sensitivity and reliability demonstrated in a study of thirty quadriplegic patients. Paraplegia 1986;24:38-44.
23. Mortenson WB, Miller WC, Auger C. Issues for the selection of wheelchair-specific activity and participation outcome measures: a review. Arch Phys Med Rehabil 2008;89:1177-86.
24. Itzkovich M, Gelernter I, Biering-Sorensen F, et al. The Spinal Cord Independence Measure (SCIM) version III: reliability and validity in a multi-center international study. Disabil Rehabil 2007;29:1926-33.
25. Dittuno PL, Ditunno JF Jr. Walking Index for Spinal Cord Injury (WISCI II): scale revision. Spinal Cord 2001;39:654-6.
26. Mills T, Holm MB, Trefler E, Schmeler M, Fitzgerald S, Boninger M. Development and consumer validation of the Functional Evaluation in a Wheelchair (FEW) instrument. Disabil Rehabil 2002; 24:38-46.
27. Messick, S. Test validity and the ethics of assessment. Am Psychol 1980;35:1012-27.

Suppliers

a. Scientific Software, 7383 N Lincoln Ave #100, Lincolnwood, IL 60712.
b. Quality Metric Inc, 24 Albion Rd, Lincoln, RI 02865.