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ORIGINAL REPORT

A RASCH-BASED COMPARISON OF THE FUNCTIONAL INDEPENDENCE MEASURE AND SPINAL CORD INDEPENDENCE MEASURE FOR OUTCOME AND QUALITY IN THE REHABILITATION OF PERSONS WITH SPINAL CORD INJURY

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Objective: **The Functional Independence Measure (FIM™) and spinal cord injury (SCI)-specific Spinal Cord Independence Measure (SCIM) are commonly used tools for outcome measurement and quality reporting in rehabilitation. The objective of this study was to investigate the psychometric properties of FIM™ and SCIM and to equate the 2 scales.**

Methods: **First, content equivalence of FIM™ and SCIM was established through qualitative linking with the International Classification for Functioning, Disability and Health (ICF). Secondly, a Rasch analysis of overlapping contents determined the metric properties of the scales and provided the empirical basis for scale equating. Furthermore, a transformation table for FIM™ and SCIM was created and evaluated.**

Subjects: **Patients with SCI in Swiss inpatient rehabilitation in 2017–18.**

Results: **The ICF linking and a separate Rasch analysis of FIM™ restricted the analysis to the motor scales of FIM™ and SCIM. The Rasch analysis of these scales showed good metric properties. The co-calibration of FIM™ and SCIM motor scores was supported with good fit to the Rasch model. The operational range of SCIM is larger than for FIM™ motor scale.**

Discussion: **This study supports the advantage of using SCIM compared with FIM™ for assessing the functional independence of patients with SCI in rehabilitation.**

Key words: spinal cord injury; Functional Independence Measure; Spinal Cord Independence Measure; activities of daily living; Rasch measurement model; psychometrics; outcome assessment (healthcare); quality in healthcare; rehabilitation.

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LAY ABSTRACT

In our study we compared two rehabilitation outcome assessment tools commonly used to measure functional independence in Spinal Cord Injury: the Functional Independence Measure (FIM™), a general tool, and the Spinal Cord Independence Measure (SCIM), a tool specifically developed for Spinal Cord Injury rehabilitation. We first compared the content of the two tools using the International Classification of Functioning Disability and Health (ICF). Then we tested their measurement properties and put them on a common measurement scale, which allows to directly compare scores of the two tools. The common measurement scale was obtained by mean of a so-called Rasch analysis. The results showed that the FIM™ motor items can be compared to the SCIM items from a content but also from a metric point of view. The study showed an advantage in using the SCIM compared to the FIM™ for assessing the functional independence of patients in Spinal Cord Injury rehabilitation.

Over the last decade, health systems have established national quality monitoring systems to strengthen quality assurance and quality management by providing a strategy for performance comparison across healthcare providers (1). To measure and ensure an adequate depiction of quality, these systems need to rely on important determinants to describe case complexity, such as diagnosis, treatment, and functioning information (2).

In the context of rehabilitation, the Functional Independence Measure (FIM™) has been established in several countries as a standard for measuring change at patient level and outcome quality at institutional or national level (e.g. in Australia or Canada) (3–6).

In Switzerland, the National Association for Quality Development (ANQ) (7), an organization mandated by the Swiss cantons, health insurances, and clinics, has also established a quality monitoring system including FIM™ for musculoskeletal and neurological rehabilitation.

Quality monitoring of rehabilitation services for rehabilitation outcomes has its merits, including the possibility to learn from best practices. Nevertheless, the imposition of an instrument such as the FIM™ as a standard patient assessment instrument can pose challenges for the adequate depiction of case complexity of relevant subgroups and subsequent reporting of outcome quality.

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Patients with spinal cord injury (SCI) differ from those with neurological and musculoskeletal disorders in terms of their rehabilitation needs (8). They exhibit higher medical complexity, which requires treatment in specialized rehabilitation centres with the corresponding infrastructure, personnel, and processes (9). In order to consider the medical and rehabilitative characteristics of this group of patients, specific survey instruments are required to ensure a complete and meaningful illustration of the patients' functioning.

For rehabilitation patients with SCI, the FIM™ was found to be unsatisfactory for assessment and follow-up of functional independence (10, 11). Consequently, a SCI-specific assessment instrument, the Spinal Cord Independence Measure (SCIM) was developed (12). Compared with the FIM™, the SCIM does not include cognitive items, but instead it addresses several issues typical for SCI, such as respiration problems, bladder and bowel management, and transfer and walking ability, including usage of SCI-related mobility aids.

In Switzerland, the specialized rehabilitation clinics for SCI have conducted a project to examine whether it would be possible to calculate functioning scores equally to FIM™ scores based on SCIM. As the SCIM can be expected to suit the SCI population better than the FIM™, using the SCIM in SCI rehabilitation would enable collecting more clinically meaningful data on the one hand, and, through an equating of the 2 metrics, provide data comparable to the FIM™ for the national quality management on the other hand. The Swiss SCI centres also hypothesized that the daily independence of patients with a lower level of functioning would be better assessed with the SCIM than with the FIM™ and, consequently, reduce bias against clinics with highly dependent patients for which the FIM™ can be expected to show a floor effect.

The objective of this study was to investigate the psychometric properties of FIM™ and SCIM and to equate the 2 scales for outcome measurement and quality management in SCI. This would help to examine whether SCIM can replace FIM™ for outcome measurement and quality management purposes.

METHODS

Design

Rasch-based score equating based on a common person design.

Sample

From May 2017 to March 2018, all specialized SCI clinics in Switzerland collected FIM™ and SCIM III data in parallel for the same patients with SCI. The data collection was part of a larger investigation for the development of a new reimbursement system in rehabilitation, which aims to include the same assessment tools already used for national quality reporting (13). A total of 663 patients with SCI were assessed 1–6 times for 6 weeks, resulting in a total of 985 observations. Approximately 66% of the patients participated in 1 wave of data collection, 22.3% in 2 waves, 8.5% in 3 waves, and 2.5% in 4 waves of data collection. Only 2 participants underwent 5 and 6 measurements, respectively. To avoid repeated person measures in the sample, only data from 1 assessment time-point was randomly selected from each individual (14).

Assessment tools

The FIM™ was developed in the 1980s (3) and is currently one of the most commonly used functioning assessment instruments in neurological and musculoskeletal rehabilitation (10). The instrument consists of 18 items, with 13 items on motor and 5 items on cognitive abilities. The motor domain is further divided into 4 subscales: "self-care", "continence", "transfer", and "locomotion" (mobility). The cognitive domain consists of 2 subscales: "communication" and "cognition". For each item, 7 response options, from "total assistance" to "complete independence" evaluate the degree of dependence in everyday autonomy.

The psychometric properties of FIM™ have been extensively studied (15). Studies comparing FIM™ with similar instruments designed to address functional independence in SCI, showed that, despite FIM™ sharing many similarities with these instruments, they often do not cover all areas equally well (10, 16–20).

The SCIM was developed in the mid-1990s as the first outcome measure for everyday independence in SCI. Since then, the SCIM has been widely used in SCI rehabilitation (12). The current version of the SCIM is SCIM III (21). The SCIM comprises a total of 18 items, divided into 4 subscales: "self-care", "respiration and sphincter management", "mobility in rooms", and "mobility indoors and outdoors" (mobility). The response scales vary between 0–2 and 0–15 points. The total score, which covers only motor functioning, ranges from 0 "total assistance" to 100 "complete independence".

SCIM and FIM™ are both reliable and valid assessment tools for measuring everyday independence (10). Studies support the good correlation of the FIM™ with the SCIM III. Still, there is also some evidence that the SCIM III has a higher sensitivity and responsiveness for patients with SCI (22, 23).

Data analysis

Qualitative linking: ICF-based content comparison. Scale equating refers to methods establishing equivalence of total scores from different assessment tools so that the scores are interchangeable (24). Qualitative linking was applied to determine the conceptual overlap and similarities, of FIM™ and SCIM. Equality of constructs is an essential requirement for scale equating (24). The International Classification of Functioning, Disability and Health (ICF) (25) is a WHO classification that provides a standardized and international language to describe health and functioning. The ICF was used for qualitative linking, as both FIM™ and SCIM assess functioning information. Concepts identified in both assessment tools were linked by 2 researchers to the most precise ICF category, using the current version of the standardized ICF linking rules (26).

Furthermore, selections of relevant ICF categories for different settings and health conditions, so-called ICF Core Sets, can be consulted to discuss the relevance of assessed functioning information. In a second step, the content of the FIM™ and the SCIM identified through the ICF linking was contrasted with the content of the ICF Generic-30 Set, representing relevant

functioning categories for neurological, musculoskeletal, and cardiovascular rehabilitation (27).

Quantitative equating: metric equivalence. Metric properties of total scores of assessment instruments, such as SCIM and FIM™, can be evaluated with a modern probabilistic measurement approach. Rasch analysis, applying the partial credit model (PCM), was used in the current study. The PCM is a model developed for the psychometric analysis of ordinal response scales (28). Previous studies have shown that PCM is suitable to calibrate the FIM™ (15).

A Rasch analysis examines critical assumptions for reliable measurement with ordinal scales, such as the underlying dimensionality, the monotonicity of the response options, or the conditional independence of items when having conditioned out the total score (29). If the outcome of a Rasch analysis fulfils the model's assumptions, it can be concluded that the total scores are interval scaled and applicable for quantifying change and making comparisons (30).

It has been shown that FIM™ (15), as well as SCIM III (31), are multidimensional assessment instruments, exhibiting local dependencies within subscales. Thus, the redundant information within domains often enters the analysis as testlets, i.e. as a sum score aggregating the respective subscale items. For this study, 3 testlets were formed for the motor items of the FIM™ and SCIM: "self-care", "continence", and "mobility". Furthermore, 1 testlet was formed with all the cognitive items of the FIM™, incorporating the two areas: "communication" and "cognition".

Some response options of SCIM III items are coded in a non-uniform and non-equidistant manner, such as the SCIM's breathing item with 6 non-uniform options (0-2-4-6-8-10) or the SCIM's bowel management item with 4 non-equidistant options (0-5-8-10). For the metric analysis presented in this study, the non-uniform non-equidistant response options of the SCIM have been recoded to represent incremented values starting from 0 with directly consecutive integers. Without this modification, the Rasch model would estimate more thresholds than available by considering the response gaps as missing information. As the PCM does allow thresholds to be non-equidistant, the increase in difficulty of response thresholds will be estimated by the model directly.

Only if the qualitative linking confirms the construct equality and the metric properties of the scales show fit to the Rasch model, can scale equating be conducted.

In the current analysis, FIM™ and SCIM data were collected for all participants (common person design). In a common person equating procedure, given that the scales to equate fit the Rasch model, a co-calibration of the row scores of the scales can be undertaken. The fit of the respective scales to the Rasch model is given by the total-Item χ^2 test. When co-calibrating two scales or subscales by their total scores, the quality of the model fit, i.e. a good adaptation of the data to the model, is given with a conditional χ^2 fit statistic (32).

In a Rasch analysis, the reliability of the model can be measured with the Cronbach α and the Person Separation Index (PSI). A PSI > 0.85 indicates high reliability for measurements at individual levels. A PSI > 0.8 still indicates good reliability of the instrument for measurements at the population level (29). Cronbach α is interpreted similarly. A scale equating, based on total scores of two scales, is comparable, technically speaking, to an analysis with testlets, but represents a bi-factor equivalent solution. In a Rasch analysis that uses testlets instead of items, the change in reliability, given by the PSI or the Cronbach α, can be described by mean of the A-score. The A-score is understood as the percentage of the remaining variance observed after aggregation of the items. A-scores above 90% indicate that more than 90% of the unique variance of the items is retained by a testlet formation. The interpretation of the A-score is similar to the Explained Common Variance used in bi-factor analysis, where values of 80% would indicate a strong first factor (33). According to Quinn (34), A-values above 90% are a minimum threshold and A-values < 70% indicate that a multidimensional model is needed.

A dimensionality analysis was used to evaluate whether testlets measure the same latent construct. Ability estimates derived from oppositely loading testlets on the first principal component are compared individually with a *t*-test for each participant, and the number of significant deviations is determined. In the presence of unidimensionality, the proportion of significant *t*-tests should not exceed 5%, meaning that the lower boundary of the 95% confidence interval (95% CI) should not be above 5% (35).

If the metric properties of FIM™ and SCIM allowed for it, a co-calibration of the scales would deliver a transformation table, indicating how a total score from one assessment tool can be translated into the total score of the other tool. Information from the entire population ($n = 985$) was used to analyse the quality of a SCIM to FIM™ motor total score transformations. The equivalence of the transformed FIM™ motor scores, as derived from SCIM with the observed FIM™ motor scores, was compared with the Spearman's rank correlation, the Wilcoxon signed-rank test (36), and Cohen's D effect size (37). The validity of the transformation table was then determined by comparing the FIM™ motor scores resulting from the transformation table, as derived from SCIM with the truly observed FIM™ motor scores, as assessed with the scale. Likewise, the accuracy, in terms of correctly predicted FIM™ scores, can be described.

In addition, the Leunbach's model for direct equating has been applied (38), to test whether the two scales measure the same latent construct by relating the respective total scores to a common metric. This analysis provides, among other key values, a Cohen's kappa and a mean weighted standard error of equating (SEQ) (39). A Cohen's kappa of zero indicates that the agreement is equivalent to chance. Values of 0.4–0.6 represent moderate agreement, 0.6–0.8 substantial agreement, 0.8–0.99 near-perfect agreement, and 1 perfect agreement. An SEQ mean below 0.91 is acceptable (40).

Due to a very small percentage of missing values in a few cognitive items of the FIM™ and the ability of the Rasch model to handle missing values, no data were imputed. The Rasch analyses were performed with the software RUMM2030 (34). Leunbach's model analyses for scale equating were conducted with DIGRAM (41), and all further quantitative analyses with R (42).

RESULTS

Descriptive statistics of FIM™ and SCIM scores, including frequencies and proportions for the complete dataset and the analysis sample, are shown in Appendices 1 and 2. Further sample characteristics, such as age, sex, lesion level, etc., were not provided in the dataset for the current study.

Qualitative linking: ICF-based content comparison

The ICF linking of SCIM and FIM™ (Table I) showed that the items of both assessment tools contain ICF

Table I. International Classification for Functioning, Disability and Health (ICF) linking

ICF-Code	Titel	Bereich	FIM™	FIM™ Item No.	SCIM	SCIM Item No.
b144	Memory functions	Cognitive	x	FIM R		
b440	Respiration functions	Continence			x	SCIM 7
b525	Defecation functions	Continence	x	FIM H	x	SCIM 8
b620	Urination functions	Continence	x	FIM G	x	SCIM 9
d175	Solving problems	Cognitive	x	FIM Q		
d310	Communicating with - receiving - spoken messages	Cognitive	x	FIM N		
d315	Communicating with - receiving - nonverbal messages	Cognitive	x	FIM N		
d320	Communicating with - receiving - formal sign language messages	Cognitive	x	FIM N		
d325	Communicating with - receiving - written messages	Cognitive	x	FIM N		
d330	Speaking	Cognitive	x	FIM O		
d335	Producing nonverbal messages	Cognitive	x	FIM O		
d340	Producing messages in formal sign language	Cognitive	x	FIM O		
d345	Writing messages	Cognitive	x	FIM O		
d410	Changing basic body position	Mobility			x	SCIM 11, 12
d420	Transferring oneself	Mobility	x	FIM I, J, K	x	SCIM 12, 13, 18, 19
d450	Walking	Mobility	x	FIM L, M	x	SCIM 14, 15, 16, 17
d465	Moving around using equipment	Mobility	x	FIM L	x	SCIM 14,15, 16
d510	Washing oneself	Self-care	x	FIM B, C	x	SCIM 2, 3, 6
d520	Caring for body parts	Self-care	x	FIM B	x	SCIM 6
d530	Toileting	Self-care	x	FIM F, G	x	SCIM 8, 9, 10
d540	Dressing	Self-care	x	FIM D, E	x	SCIM 4, 5
d550	Eating	Self-care	x	FIM A	x	SCIM 1
d560	Drinking	Self-care	x	FIM A	x	SCIM 1
d710	Basic interpersonal interactions	Cognitive	x	FIM P		

FIM™: Functional Independence Measure; SCIM: Spinal Cord Independence Measure.

categories of the chapters d4 – *Mobility* and d5 – *Self-care*, b5 – *Functions of the digestive, metabolic and endocrine systems*, and b6 – *Functions of the urogenital and reproductive systems*. Except for the categories b440 *Respiration* and d410 *Changing basic body position*, the same ICF categories are addressed through the motor items of FIM™ and SCIM. ICF categories from chapters b1 – *Mental functions*, d1 – *Learning and application of knowledge*, d3 – *Communication* and d7 – *Interpersonal interactions and relationships* occur only for the FIM™ and correspond to the cognitive items of the FIM™ (items N–R). The SCIM does not capture cognitive limitations. However, with the exception of 3 SCIM items (items1, 7 and 8), which are linked to b525 *Defecation functions*, b440 *Respiration functions*, and d560 *Drinking*, all other items can be mapped to the ICF Generic-30, in comparison with the FIM™, where 5 (H, N, O, Q and R) of 18 items cannot be linked to the Generic-30, including mostly its cognitive items.

Quantitative equation: metric equivalence

The results of the Rasch analyses are shown in Table II. Rasch analysis of the FIM™ scale, including motor and cognitive domains, clearly supported its multidimensionality with 13.28% (11.5%–15%) significant *t*-tests. The multidimensionality is further confirmed with an A-score below 90% (87.65%). Together with the fact that SCIM does not assess cognitive domains, the decision was made to create a transformation metric that only includes the motor domains of FIM™.

The individual analyses of FIM™ motor and SCIM scale with a testlet-based approach, i.e. by aggregating the items by subscales of the motor domain, resulted in good model fit and targeting, without floor and ceiling

Table II. Sample size, number (%) of floor and ceiling effects in the total scores, model adjustment, targeting with the mean item difficulty and the ability of persons, their standard errors and the dimensionality and reliability of individual and common Rasch analyses of Spinal Cord Independence Measure (SCIM) and Functional Independence Measure (FIM™) ($n = 663$)

				Modelfit					Dimensionality				Reliability		
	Domain	Floor *n* (%)	Ceiling *n* (%)	Total-Item χ^2	DF	*p*-value	Item difficulty M (SE)	Person ability M (SE)	N sign. T-tests**	N without extreme	% sign. T-tests	CI % sign. T-tests	PSI	Cron-bach α	A-Score %
Rasch analysis															
FIM™*	Motor & Cognitive	1 (0.15)	2 (0.3)	272.52	36	<0.001	0 (0.31)	0.04 (0.37)	77	580	13.28	11.5–15	0.82	0.79	87.65
FIM™*	Motor	26 (3.92)	4 (0.6)	36.70	27	0.10	0 (0.18)	−0.18 (0.66)	12	663	1.81	0.2–3.5	0.86	0.87	92.19
SCIM*	Motor	7 (1.06)	6 (0.9)	46.72	27	0.01	0 (0.51)	−0.01 (0.81)	28	650	4.31	2.6–6%	0.90	0.84	93.99
Co-calibration				[a]											
SCIM-FIM™*	Motor	6 (0.9)	1 (0.15)	113.67	136	0.92	0 (0)	−0.11 (0.58)	21	656	3.20	1.4–4.7	0.92	0.93	98.82

[a]Conditional test-of-fit χ^2. N: sample size; DF: Degrees of Freedom; M: mean; SE: standard error: Sign: significant; CI: confidence interval.

Table III. Comparison of transformed and observed total scores with rank correlation, Wilcoxon signed-rank test, and Cohen's D measure of effect intensity

Co-calibration	Rank correlation	Wilcoxon rank test *p*-value	Expected values Mean (SD)	Observed scores Mean (SD)	Cohen's D	Effect
SCIM to FIM™ Motor	0.917	0.534	33.84 (23.59)	32.88 (22.94)	0.041	Negligible

FIM™: Functional Independence Measure; SCIM: Spinal Cord Independence Measure; SD: standard deviation.

effects (Table II). The assessment instruments' motor scales are one-dimensional and show good reliability (PSI >0.85). Based on these findings, an equating of the motor total scores was justified.

The equating of FIM™ motor and SCIM by mean of a co-calibration of their total scores, resulted in good model fit with good targeting and high reliability (PSI >0.9). Also, in the co-calibration context, the one-dimensionality assumption was fulfilled. The A-value of the co-calibration was 98.82%, indicating that less than 2% of the variance had to be discarded to achieve a unidimensional latent estimate. An equivalence of the constructs and the equivalence of the latent trait being assessed by FIM™ motor and SCIM scale were supported statistically.

A person-item map visualizing the distribution of the ability estimates and of the difficulty thersholds from the co-calibration of the SCIM and the FIM™ is shown in Appendix 3. The person-item map shows that the SCIM has additional difficulty thresholds for lower levels of functional independence.

The co-calibrations enabled total scores to be transformed from one scale to another. The transformed values can then be compared with the observed total score. The tables with the SCIM scores and the corresponding Rasch transformed FIM™ motor scores are shown in Appendix 4. The score transformation is based on the sum of re-scored items, as specified in Appendices 2a–c. The derived and observed total scores correlated very highly (r >0.9). A direct comparison with the Wilcoxon signed-rank test showed no significant mean deviation between the total motor scores. Cohen's D values also supported that the observed deviations of the means are negligible (Table III).

Furthermore, the direct raw score equating under the Leunbach's model also supports that SCIM and FIM™ motor items measure a common latent construct. The Cohens' kappa statistic under Leunbach indicated substantial agreement among the raw scores (κ=0.79). The mean weighted SEQ of 0.61 indicated that the scale equating results are acceptable.

The confusion matrix regarding the precision of the total score quantile transformation from SCIM to FIM™ motor score showed the correctly equated total scores on the diagonal. The derivation of the FIM™ motor scores from the SCIM scores had a precision of 68.12% (Table IV). Notably, a substantial part of the unprecise transformations is adjacent to the diagonal in the next quantile, indicating that the observed departures from the correct transformation quantile are not excessive.

DISCUSSION

Qualitative linking with the ICF as a reference system enabled the content overlap between SCIM and FIM™ to be determined. Further separate quantitative testing of the FIM™ motor and SCIM scale with Rasch analysis revealed good metric properties and supported their co-calibration and creation of a transformation table. Co-calibration with Rasch showed that FIM™ motor scores could be derived from observed SCIM scores with sufficient reliability. The Leunbach's approach of direct test equating supported that the 2 scales measure a common latent construct. Statistical comparison of the observed and transformed FIM™ motor scores showed negligible differences. However, the precision of a transformation into FIM™ quantile scores was 68.12%, indicating that 68.12% of the FIM™ scores transformed from the observed SCIM scores were correctly found in the observed FIM™ quantiles. The direction of the equating error, meaning systematic over- or under-estimation of the observed FIM™ score when transforming from SCIM is not found in this analysis.

This study further showed that the SCIM scores have a broader measurement range than the FIM™ motor scores, being more able to determine limitations in functioning, especially in presence of low functional independence, regarding the mobility, self-care, and sphincter control independence experienced by more severely injured patients with SCI.

Table IV. Spinal Cord Independence Measure (SCIM) to Functional Independence Measure (FIM™) motor score derivation vs FIM™ motor score quantile (Precision: 68.12%; misclassification in the next quantile: 30.36%)

		Expected FIM™ Score				
	Quantile (Scores)	0% (<13)	25% (13-27)	50% (28-53)	75% (54-77)	100% (>77)
Observed FIM™ Score	0% (<12)	10 (1.02%)	32 (3.25%)	0 (0%)	0 (0%)	0 (0%)
	25% (13-27)	2 (0.2%)	174 (17.66%)	41 (4.16%)	3 (0.3%)	3 (0.3%)
	50% (28-53)	0 (0%)	44 (4.47%)	134 (13.6%)	47 (4.77%)	5 (0.51%)
	75% (54-77)	0 (0%)	4 (0.41%)	57 (5.79%)	130 (13.20%)	58 (5.89%)
	100% (<78)	0 (0%)	0 (0%)	0 (0%)	18 (1.83%)	223 (22.64%)

This advantage can be explained by the differences of the content addressed by the SCIM subscales. For example, the continence subscale of the SCIM includes an item about respiration in addition to bowel and bladder management. "Respiration" is an item, which becomes particularly relevant with high levels of SCI where pulmonary functions are impaired due to the injury. Having more thresholds to differentiate lower levels of functioning means, concretely, that clinics treating a more severely affected patient population will be enabled to better report improvements achieved at the lower end of the continuum.

As all Swiss specialized SCI centres contributed to the collection of information on functional independence with SCIM and FIM™, the results are expected to be representative for the Swiss setting and can therefore be used to inform further developments of the Swiss ANQ quality reviews in SCI rehabilitation.

Study limitations

This study is based on secondary data analysis of a sample of persons with SCI. Information on sex, age, time since injury, lesion type and lesion level were not provided in the dataset. Therefore, a more refined analysis that could also determine the invariance of the scales across sample subgroups was not possible. Evidence from another Rasch analysis of the FIM™, with data from the Swiss national quality reports in a neurological and musculoskeletal population, supported the absence of differential item functioning for sex, age, nationality, insurance status of patients, rehabilitation group, clinic language, and time-point of measurement (4). More advanced research is needed in order to improve the precision of the score transformation. Availability of clinical cut-points for the scale score comparisons instead of using data driven cut-points (quantiles) may be of the highest benefit in that regard (43). Ultimately, the Rasch analyses of this report are based on a random sample of 663 participants with SCI.

Applicability of results

The study results support some advantages in using the SCIM III to assess independence in patients with SCI. When functional independence data is required for national quality reports or reimbursement purposes, SCIM scores could be transformed to FIM™ motor scores using a metrically sound transformation table. Furthermore, the Rasch analysis can be used to transform the ordinal-level scaled data to interval-scale level, which allows for sound comparisons and calculation of change scores in everyday independence.

Future research could focus on transformations at the subscale level, which could be more beneficial for monitoring in clinical practice. Furthermore, analysis of the invariance of the total scores for subgroups of the SCI sample, such as lesion level or age groups, may further improve the accuracy of the transformation. Considering injury and person characteristics would allow deriving group-specific reference values. These could be used in clinical practice to discuss the everyday independency of individuals in the light of normative scores.

Conclusion

This study allows us to equate and compare FIM™ motor and SCIM III scores. The results showed that SCIM III has a more comprehensive operational range, supporting the use of the SCIM III for SCI rehabilitation, as it provides more information for patients with lower functional abilities.

With respect to the motor domains, evaluations based uniquely on SCIM can be expected to result in a comparable benchmarking in comparison with other rehabilitation populations, in which the FIM™ has been used as outcome measure. In this regard, the assessment of patients with SCI based on SCIM instead of FIM™ may have a positive impact and result in more precise description of rehabilitation outcomes of SCI-specialized centres for quality reports.

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Appendix 1a: Descriptive statistics, frequencies and percentages of responses to Functional Independence Measure (FIM™) self-care items with original and transformed coding of response options for the entire and the analysis sample

Domain	Question		Response Option	Original Coding	Coding for the Rasch analysis	Complete sample *n* (%)	Analysis sample *n* (%)
Self Care	FIM A	Eating	Total assistance with helper	1	0	90 (9.1)	59 (8.9)
			Maximal assistance with helper	2	1	35 (3.6)	17 (2.6)
			Moderate assistance with helper	3	2	19 (1.9)	10 (1.5)
			Minimal assistance with helper	4	3	51 (5.2)	35 (5.3)
			Supervision or setup with helper	5	4	160 (16.2)	109 (16.4)
			Modified independence with no helper	6	5	134 (13.6)	87 (13.1)
			Complete independence with no helper	7	6	496 (50.4)	346 (52.2)
	FIM B	Grooming	Total assistance with helper	1	0	120 (12.2)	72 (10.9)
			Maximal assistance with helper	2	1	57 (5.8)	33 (5.0)
			Moderate assistance with helper	3	2	59 (6.0)	39 (5.9)
			Minimal assistance with helper	4	3	64 (6.5)	50 (7.5)
			Supervision or setup with helper	5	4	150 (15.2)	99 (14.9)
			Modified independence with no helper	6	5	172 (17.5)	117 (17.6)
			Complete independence with no helper	7	6	363 (36.9)	253 (38.2)
	FIM C	Bathing	Total assistance with helper	1	0	251 (25.5)	165 (24.9)
			Maximal assistance with helper	2	1	217 (22.0)	148 (22.3)
			Moderate assistance with helper	3	2	129 (13.1)	84 (12.7)
			Minimal assistance with helper	4	3	101 (10.3)	71 (10.7)
			Supervision or setup with helper	5	4	63 (6.4)	40 (6.0)
			Modified independence with no helper	6	5	144 (14.6)	93 (14.0)
			Complete independence with no helper	7	6	80 (8.1)	62 (9.4)
	FIM D	Dressing Upper Body	Total assistance with helper	1	0	240 (24.4)	159 (24.0)
			Maximal assistance with helper	2	1	66 (6.7)	46 (6.9)
			Moderate assistance with helper	3	2	55 (5.6)	35 (5.3)
			Minimal assistance with helper	4	3	103 (10.5)	68 (10.3)
			Supervision or setup with helper	5	4	95 (9.6)	55 (8.3)
			Modified independence with no helper	6	5	168 (17.1)	113 (17.0)
			Complete independence with no helper	7	6	258 (26.2)	187 (28.2)
	FIM E	Dressing Lower Body	Total assistance with helper	1	0	543 (55.1)	363 (54.8)
			Maximal assistance with helper	2	1	84 (8.5)	50 (7.5)
			Moderate assistance with helper	3	2	50 (5.1)	35 (5.3)
			Minimal assistance with helper	4	3	75 (7.6)	42 (6.3)
			Supervision or setup with helper	5	4	40 (4.1)	29 (4.4)
			Modified independence with no helper	6	5	95 (9.6)	66 (10.0)
			Complete independence with no helper	7	6	98 (9.9)	78 (11.8)
	FIM F	Toileting	Total assistance with helper	1	0	572 (58.1)	374 (56.4)
			Maximal assistance with helper	2	1	50 (5.1)	28 (4.2)
			Moderate assistance with helper	3	2	16 (1.6)	13 (2.0)
			Minimal assistance with helper	4	3	31 (3.1)	20 (3.0)
			Supervision or setup with helper	5	4	40 (4.1)	26 (3.9)
			Modified independence with no helper	6	5	122 (12.4)	85 (12.8)
			Complete independence with no helper	7	6	154 (15.6)	117 (17.6)
Sphincter Control	FIM G	Bladder Management	Total assistance with helper	1	0	469 (47.6)	303 (45.7)
			Maximal assistance with helper	2	1	39 (4.0)	25 (3.8)
			Moderate assistance with helper	3	2	34 (3.5)	22 (3.3)
			Minimal assistance with helper	4	3	30 (3.0)	19 (2.9)
			Supervision or setup with helper	5	4	78 (7.9)	55 (8.3)
			Modified independence with no helper	6	5	253 (25.7)	171 (25.8)
			Complete independence with no helper	7	6	82 (8.3)	68 (10.3)
	FIM H	Bowel Management	Total assistance with helper	1	0	508 (51.6)	327 (49.3)
			Maximal assistance with helper	2	1	50 (5.1)	35 (5.3)
			Moderate assistance with helper	3	2	27 (2.7)	17 (2.6)
			Minimal assistance with helper	4	3	65 (6.6)	39 (5.9)
			Supervision or setup with helper	5	4	59 (6.0)	42 (6.3)
			Modified independence with no helper	6	5	194 (19.7)	138 (20.8)
			Complete independence with no helper	7	6	82 (8.3)	65 (9.8)

Appendix 1b: Descriptive statistics, frequencies and percentages of responses to Functional Independence Measure (FIM™) mobility items with original and transformed coding of response options for the entire and the analysis sample.

Domain	Question		Response Option	Original Coding	Coding for the Rasch analysis	Complete sample *n* (%)	Analysis sample *n* (%)
Mobility	FIM I	Transfers - bed/chair/ wheelchair	Total assistance with helper	1	0	368 (37.4)	242 (36.5)
			Maximal assistance with helper	2	1	73 (7.4)	42 (6.3)
			Moderate assistance with helper	3	2	81 (8.2)	54 (8.1)
			Minimal assistance with helper	4	3	66 (6.7)	48 (7.2)
			Supervision or setup with helper	5	4	92 (9.3)	59 (8.9)
			Modified independence with no helper	6	5	144 (14.6)	94 (14.2)
			Complete independence with no helper	7	6	161 (16.3)	124 (18.7)
	FIM J	Transfers - toilet	Total assistance with helper	1	0	464 (47.1)	297 (44.8)
			Maximal assistance with helper	2	1	55 (5.6)	37 (5.6)
			Moderate assistance with helper	3	2	59 (6.0)	44 (6.6)
			Minimal assistance with helper	4	3	78 (7.9)	54 (8.1)
			Supervision or setup with helper	5	4	82 (8.3)	51 (7.7)
			Modified independence with no helper	6	5	134 (13.6)	94 (14.2)
			Complete independence with no helper	7	6	113 (11.5)	86 (13.0)
	FIM K	Transfers - bath/shower	Total assistance with helper	1	0	487 (49.5)	317 (47.8)
			Maximal assistance with helper	2	1	61 (6.2)	43 (6.5)
			Moderate assistance with helper	3	2	57 (5.8)	34 (5.1)
			Minimal assistance with helper	4	3	67 (6.8)	46 (6.9)
			Supervision or setup with helper	5	4	82 (8.3)	55 (8.3)
			Modified independence with no helper	6	5	130 (13.2)	92 (13.9)
			Complete independence with no helper	7	6	100 (10.2)	76 (11.5)
	FIM L	Walk/wheelchair	Total assistance with helper	1	0	199 (20.2)	124 (18.7)
			Maximal assistance with helper	2	1	25 (2.5)	16 (2.4)
			Moderate assistance with helper	3	2	26 (2.6)	13 (2.0)
			Minimal assistance with helper	4	3	24 (2.4)	19 (2.9)
			Supervision or setup with helper	5	4	92 (9.3)	58 (8.7)
			Modified independence with no helper	6	5	558 (56.6)	387 (58.4)
			Complete independence with no helper	7	6	61 (6.2)	46 (6.9)
	FIM L(1)	Specification: walk/ wheelchair	Walk	1	0	76 (7.7)	64 (9.7)
			Wheelchair	2	1	833 (84.6)	547 (82.5)
			Both	3	2	76 (7.7)	52 (7.8)
	FIM M	Stairs	Total assistance with helper	1	0	876 (88.9)	575 (86.7)
			Maximal assistance with helper	2	1	17 (1.7)	14 (2.1)
			Moderate assistance with helper	3	2	9 (0.9)	6 (0.9)
			Minimal assistance with helper	4	3	4 (0.4)	4 (0.6)
			Supervision or setup with helper	5	4	23 (2.3)	17 (2.6)
			Modified independence with no helper	6	5	45 (4.6)	37 (5.6)
			Complete independence with no helper	7	6	11 (1.1)	10 (1.5)

Appendix 1c: Descriptive statistics, frequencies and percentages of responses to Functional Independence Measure (FIM™) bowel and bladder items with original and transformed coding of response options for the entire and the analysis sample

Domain	Question		Response Option	Original Coding	Coding for the Rasch analysis	Complete sample *n* (%)	Analysis sample *n* (%)
Communication	FIM N	Comprehension	Total assistance with helper	1	0	5 (0.5)	4 (0.6)
			Maximal assistance with helper	2	1	6 (0.6)	6 (0.9)
			Moderate assistance with helper	3	2	5 (0.5)	3 (0.5)
			Minimal assistance with helper	4	3	12 (1.2)	8 (1.2)
			Supervision or setup with helper	5	4	33 (3.4)	24 (3.6)
			Modified independence with no helper	6	5	170 (17.3)	111 (16.7)
			Complete independence with no helper	7	6	754 (76.5)	507 (76.5)
	FIM N(1)	Specification: Comprehension	Auditory	1	0	299 (30.4)	195 (29.5)
			Visual	2	1	3 (0.3)	3 (0.5)
			Both	3	2	682 (69.3)	464 (70.1)
	FIM O	Expression	Total assistance with helper	1	0	8 (0.8)	5 (0.8)
			Maximal assistance with helper	2	1	9 (0.9)	8 (1.2)
			Moderate assistance with helper	3	2	9 (0.9)	4 (0.6)
			Minimal assistance with helper	4	3	12 (1.2)	10 (1.5)
			Supervision or setup with helper	5	4	35 (3.6)	28 (4.2)
			Modified independence with no helper	6	5	131 (13.3)	88 (13.3)
			Complete independence with no helper	7	6	781 (79.3)	520 (78.4)
	FIM O(1)	Specification: Expression	Vocal	1	0	306 (31.1)	199 (30.1)
			Nonvocal	2	1	13 (1.3)	11 (1.7)
			Both	3	2	664 (67.5)	451 (68.2)
Social Cognition	FIM P	Social interaction	Total assistance with helper	1	0	4 (0.4)	4 (0.6)
			Maximal assistance with helper	2	1	14 (1.4)	10 (1.5)
			Moderate assistance with helper	3	2	16 (1.6)	13 (2.0)
			Minimal assistance with helper	4	3	33 (3.4)	23 (3.5)
			Supervision or setup with helper	5	4	42 (4.3)	31 (4.7)
			Modified independence with no helper	6	5	195 (19.8)	126 (19.0)
			Complete independence with no helper	7	6	681 (69.1)	456 (68.8)
	FIM Q	Problem solving	Total assistance with helper	1	0	24 (2.4)	20 (3.0)
			Maximal assistance with helper	2	1	29 (2.9)	16 (2.4)
			Moderate assistance with helper	3	2	27 (2.7)	16 (2.4)
			Minimal assistance with helper	4	3	63 (6.4)	46 (6.9)
			Supervision or setup with helper	5	4	148 (15.0)	92 (13.9)
			Modified independence with no helper	6	5	212 (21.5)	141 (21.3)
			Complete independence with no helper	7	6	482 (48.9)	332 (50.1)
	FIM R	Memory	Total assistance with helper	1	0	7 (0.8)	7 (1.2)
			Maximal assistance with helper	2	1	11 (1.2)	7 (1.2)
			Moderate assistance with helper	3	2	15 (1.7)	13 (2.2)
			Minimal assistance with helper	4	3	19 (2.1)	15 (2.6)
			Supervision or setup with helper	5	4	70 (7.9)	43 (7.4)
			Modified independence with no helper	6	5	151 (17.0)	97 (16.6)
			Complete independence with no helper	7	6	617 (69.3)	401 (68.8)

Appendix 2a: Descriptive statistics, frequencies and percentages of responses to Spinal Cord Independence Measure (SCIM) self-care items with original and transformed coding of response options for the entire and the analysis sample.

Question		Response Options	Original Coding	Coding for the Rasch analysis	Complete sample *n* (%)	Analysis sample *n* (%)
SCIM 1	Feeding	Needs parenteral, gastronomy, or fully assisted oral feeding	0	0	96 (9.7)	62 (9.4)
	cutting, opening containers, pouring, bringing food to mouth, holding cup with fluid	Needs partial assistance for eating and/or drinking, or for wearing adaptive devices.	1	1	79 (8.0)	47 (7.1)
		Eats independently; needs adaptive devices or assistance only for cutting food and/or pouring and/or opening containers.	2	2	225 (22.8)	156 (23.5)
		Eats and drinks independently; does not require assistance or adaptive devices.	3	3	585 (59.4)	398 (60.0)
SCIM 2	Bathing - upper body	Requires total assistance	0	0	153 (15.5)	98 (14.8)
	soaping washing, drying body and head, manipulating water tap	Requires partial assistance	1	1	244 (24.8)	172 (25.9)
		Washes independently with adaptive devices or in a specific setting (e.g. bars, chair)	2	2	304 (30.9)	195 (29.4)
		Washes independently; does not require adaptive devices or in a specific setting (not customary for healthy people) (adss)	3	3	284 (28.8)	198 (29.9)
SCIM 3	Bathing - lower body	Requires total assistance	0	0	513 (52.1)	336 (50.7)
	soaping washing, drying body and head, manipulating water tap	Requires partial assistance	1	1	162 (16.4)	103 (15.5)
		Washes independently with adaptive devices or in a specific setting (e.g. bars, chair)	2	2	183 (18.6)	129 (19.5)
		Washes independently; does not require adaptive devices or in a specific setting(not customary for healthy people) (adss)	3	3	127 (12.9)	95 (14.3)
SCIM 4	Dressing - upper body	Requires total assistance	0	0	218 (22.1)	145 (21.9)
	clothes, shoes, permanent orthoses: dressing, wearing, undressing	Requires partial assistance with clothes without buttons, zippers or laces (cwobzl)	1	1	191 (19.4)	126 (19.0)
		Independent with cwobzl; requires adaptive devices and/or specific settings (adss)	2	2	105 (10.7)	64 (9.7)
		Independent with cwobzl; does not require adss; needs assistance or adss only for bzl	3	3	125 (12.7)	81 (12.2)
		Dresses (any cloth) independently; does not require adaptive devices or specific setting	4	4	346 (35.1)	247 (37.3)
SCIM 5	Dressing - lower body	Requires total assistance	0	0	551 (55.9)	364 (54.9)
	clothes, shoes, permanent orthoses: dressing, wearing, undressing	Requires partial assistance with clothes without buttons, zippers or laces (cwobzl)	1	1	98 (9.9)	62 (9.4)
		Independent with cwobzl; requires adaptive devices and/or specific settings (adss)	2	2	86 (8.7)	58 (8.7)
		Independent with cwobzl; does not require adss; needs assistance or adss only for bzl	3	3	107 (10.9)	71 (10.7)
		Dresses (any cloth) independently; does not require adaptive devices or specific setting	4	4	143 (14.5)	108 (16.3)
SCIM 6	Grooming	Requires total assistance	0	0	130 (13.2)	73 (11.0)
	washing hands and face, brushing teeth, combing hair, shaving, applying makeup	Requires partial assistance	1	1	118 (12.0)	87 (13.1)
		Grooms independently with adaptive devices	2	2	87 (8.8)	60 (9.0)
		Washes independently without adaptive devices	3	3	650 (66.0)	443 (66.8)
SCIM 7	Respiration	Requires tracheal tube (TT) and permanent or intermittent assisted ventilation (IAV).	0	0	11 (1.1)	10 (1.5)
		Breathes independently with TT; requires oxygen, much assistance in coughing or TT management.	2	1	10 (1.0)	5 (0.8)
		Breathes independently with TT; requires little assistance in coughing or TT management.	4	2	4 (0.4)	3 (0.5)
		Breathes independently without TT; requires oxygen, much assistance in coughing, a mask (e.g. peep) or IAV (bipap).	6	3	93 (9.4)	56 (8.4)
		Breathes independently without TT; requires little assistance or stimulation for coughing.	8	4	54 (5.5)	33 (5.0)
		Breathes independently without assistance or device.	10	5	813 (82.5)	556 (83.9)
SCIM 8	Sphincter Management	Indwelling catheter.	0	0	471 (47.8)	313 (47.2)
	Bladder	Residual urine volume (RUV) > 100cc; no regular catheterization or assisted intermittent catheterization.	3	1	95 (9.6)	59 (8.9)
		Residual urine volume (RUV) < 100cc or intermittent self-catheterization; needs assistance for applying drainage instrument.	6	2	68 (6.9)	46 (6.9)
		Intermittent self-catheterization; uses external drainage instrument; does not need assistance for applying.	9	3	38 (3.9)	27 (4.1)
		Intermittent self-catheterization; continent between catheterizations; does not use external drainage instrument.	11	4	144 (14.6)	86 (13.0)
		RUV <100cc; needs only external urine drainage; no assistance is required for drainage	13	5	21 (2.1)	15 (2.3)
		RUV <100cc; continent; does not use external drainage instrument.	15	6	148 (15.0)	117 (17.6)
SCIM 9	Sphincter Management	Irregular timing or very low frequency (less than once in 3 days) of bowel movements	0	0	205 (20.8)	139 (21.0)
	Bowel	Regular timing, but requires assistance (e.g., for applying suppository); rare accidents (less than twice a month).	5	1	474 (48.1)	298 (44.9)
		Regular bowel movements, without assistance; rare accidents (less than twice a month)	8	2	106 (10.8)	69 (10.4)
		Regular bowel movements, without assistance, no accidents.	10	3	200 (20.3)	157 (23.7)
SCIM 10	Use of Toilet	Requires total assistance.	0	0	529 (53.7)	342 (51.6)
	perineal hygiene, adjustment of clothes before/after, use of napkins or diapers	Requires partial assistance; does not clean self	1	1	90 (9.1)	63 (9.5)
		Requires partial assistance; cleans self independently	2	2	58 (5.9)	35 (5.3)
		Uses toilet independently in all tasks but needs adaptive devices or special setting (e.g. bars)	4	3	156 (15.8)	109 (16.4)
		Uses toilet independently; does not require adaptive devices or special setting.	5	4	152 (15.4)	114 (17.2)

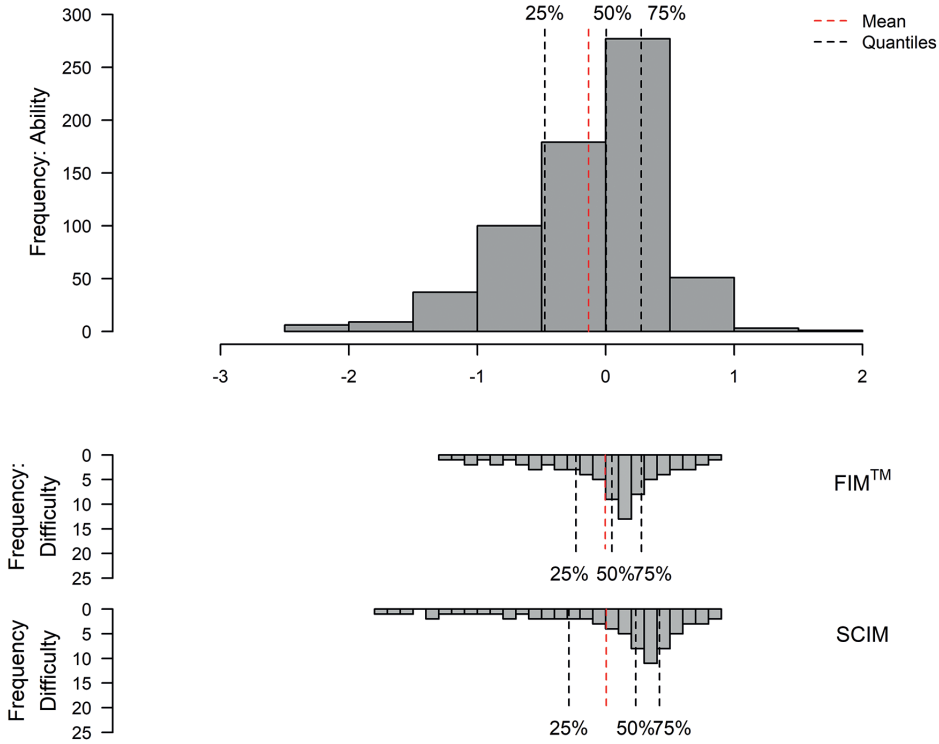
Appendix 2b: Descriptive statistics, frequencies and percentages of responses to Spinal Cord Independence Measure (SCIM) bowel and bladder management items (including respiration) with original and transformed coding of response options for the entire and the analysis sample

Domain	Question		Response Options	Original Coding	Coding for the Rasch analysis	Complete sample *n* (%)	Analysis sample *n* (%)
Mobility	SCIM 11	Mobility (room and toilet)	Needs assistance in all activities: turning upper body in bed, turning lower body in bed, sitting up in bed, doing push-ups in wheelchair, with or without adaptive devices, nut not with electronic aids.	0	0	326 (33.1)	216 (32.6)
			Performs one of the activities without assistance.	2	1	189 (19.2)	124 (18.7)
			Performs two or three of the activities without assistance.	4	2	169 (17.2)	104 (15.7)
			Performs all the bed mobility and pressure release activities independently.	6	3	301 (30.6)	219 (33.0)
	SCIM 12	Transfers: bed – wheelchair	Requires total assistance	0	0	382 (38.8)	260 (39.2)
		locking wheelchair, lifting footrests, removing and adjusting arm rests, transferring, lifting feet	Needs partial assistance and/or supervision, and/or adaptive devices (e.g. sliding board)	1	1	323 (32.8)	210 (31.7)
			Independent (or does not require wheelchair)	2	2	280 (28.4)	193 (29.1)
	SCIM 13	Transfers: wheelchair- toilet-tub	Requires total assistance	0	0	495 (50.3)	331 (49.9)
		if uses toilet wheelchair: transfers to and from; if uses regular wheelchair: locking wheelchair, lifting footrests, removing and adjusting armrests, transferring, lifting feet	Needs partial assistance and/or supervision, and/or adaptive devices (e.g. sliding board)	1	1	392 (39.8)	259 (39.1)
			Independent (or does not require wheelchair)	2	2	98 (9.9)	73 (11.0)
	SCIM 14	Mobility Indoors	Requires total assistance	0	0	211 (21.4)	150 (22.6)
			Needs electric wheelchair or partial assistance to operate manual wheelchair	1	1	205 (20.8)	127 (19.2)
			Moves independently in manual wheelchair	2	2	398 (40.4)	256 (38.6)
			Requires supervision while walking (with or without devices)	3	3	32 (3.2)	20 (3.0)
			Walks with a walking frame or crutches (swing)	4	4	39 (4.0)	29 (4.4)
			Walks with a crutches or two canes (reciprocal walking)	5	5	31 (3.1)	20 (3.0)
			Walks with one cane	6	6	6 (0.6)	6 (0.9)
			Needs leg orthosis only	7	7	7 (0.7)	6 (0.9)
			Walks without walking aids	8	8	56 (5.7)	49 (7.4)
	SCIM 15	Mobility for Moderate Distances	Requires total assistance	0	0	223 (22.6)	160 (24.1)
		(10-100 meters)	Needs electric wheelchair or partial assistance to operate manual wheelchair	1	1	224 (22.7)	143 (21.6)
			Moves independently in manual wheelchair	2	2	374 (38.0)	234 (35.3)
			Requires supervision while walking (with or without devices)	3	3	35 (3.6)	23 (3.5)
			Walks with a walking frame or crutches (swing)	4	4	33 (3.4)	25 (3.8)
			Walks with a crutches or two canes (reciprocal walking)	5	5	40 (4.1)	27 (4.1)
			Walks with one cane	6	6	7 (0.7)	7 (1.1)
			Needs leg orthosis only	7	7	4 (0.4)	3 (0.5)
			Walks without walking aids	8	8	45 (4.6)	41 (6.2)
	SCIM 16	Mobility Outdoors	Requires total assistance	0	0	296 (30.1)	211 (31.8)
		(more than 100 meters)	Needs electric wheelchair or partial assistance to operate manual wheelchair	1	1	394 (40.0)	245 (37.0)
			Moves independently in manual wheelchair	2	2	183 (18.6)	117 (17.6)
			Requires supervision while walking (with or without devices)	3	3	17 (1.7)	12 (1.8)
			Walks with a walking frame or crutches (swing)	4	4	27 (2.7)	21 (3.2)
			Walks with a crutches or two canes (reciprocal walking)	5	5	26 (2.6)	20 (3.0)
			Walks with one cane	6	6	4 (0.4)	4 (0.6)
			Needs leg orthosis only	7	7	4 (0.4)	3 (0.5)
			Walks without walking aids	8	8	34 (3.5)	30 (4.5)
	SCIM 17	Stair Management	Unable to ascend or descend stairs	0	0	805 (81.7)	531 (80.1)
			Ascends and descends at least 3 steps with support or supervision of another person	1	1	56 (5.7)	38 (5.7)
			Ascends and descends at least 3 steps with support of handrail and/or crutch or cane	2	2	87 (8.8)	63 (9.5)
			Ascends and descends at least 3 steps without any support or supervision	3	3	37 (3.8)	31 (4.7)
	SCIM 18	Transfers: Wheelchair-car	Requires total assistance	0	0	568 (57.7)	386 (58.2)
		approaching car, locking wheelchair, removing arm- and footrests, transferring to and from car, bringing wheelchair into and out of car	Needs partial assistance and/or supervision and/or adaptive devices	1	1	306 (31.1)	194 (29.3)
			Transfers independent; does not require adaptive devices (or does not require wheelchair)	2	2	111 (11.3)	83 (12.5)
	SCIM 19	Transfers: ground – wheelchair	Requires assistance	0	0	851 (86.4)	563 (84.9)
			Transfers independent with or without adaptive devices (or does not require wheelchair)	1	1	134 (13.6)	100 (15.1)

Appendix 2c: Descriptive statistics, frequencies and percentages of responses to Spinal Cord Independence Measure (SCIM) mobility items with original and transformed coding of response options for the entire and the analysis sample

Domain	Question		Response Options	Original Coding	Coding for the Rasch analysis	Complete sample *n* (%)	Analysis sample *n* (%)
Mobility	SCIM 11	Mobility (room and toilet)	Needs assistance in all activities: turning upper body in bed, turning lower body in bed, sitting up in bed, doing push-ups in wheelchair, with or without adaptive devices, not with electronic aids.	0	0	326 (33.1)	216 (32.6)
			Performs one of the activities without assistance.	2	1	189 (19.2)	124 (18.7)
			Performs two or three of the activities without assistance.	4	2	169 (17.2)	104 (15.7)
			Performs all the bed mobility and pressure release activities independently.	6	3	301 (30.6)	219 (33.0)
	SCIM 12	Transfers: bed – wheelchair locking wheelchair, lifting footrests, removing and adjusting arm rests, transferring, lifting feet	Requires total assistance	0	0	382 (38.8)	260 (39.2)
			Needs partial assistance and/or supervision, and/or adaptive devices (e.g. sliding board)	1	1	323 (32.8)	210 (31.7)
			Independent (or does not require wheelchair)	2	2	280 (28.4)	193 (29.1)
	SCIM 13	Transfers: wheelchair- toilet-tub if uses toilet wheelchair: transfers to and from; if uses regular wheelchair: locking wheelchair, lifting footrests, removing and adjusting armrests, transferring, lifting feet	Requires total assistance	0	0	495 (50.3)	331 (49.9)
			Needs partial assistance and/or supervision, and/or adaptive devices (e.g. sliding board)	1	1	392 (39.8)	259 (39.1)
			Independent (or does not require wheelchair)	2	2	98 (9.9)	73 (11.0)
	SCIM 14	Mobility Indoors	Requires total assistance	0	0	211 (21.4)	150 (22.6)
			Needs electric wheelchair or partial assistance to operate manual wheelchair	1	1	205 (20.8)	127 (19.2)
			Moves independently in manual wheelchair	2	2	398 (40.4)	256 (38.6)
			Requires supervision while walking (with or without devices)	3	3	32 (3.2)	20 (3.0)
			Walks with a walking frame or crutches (swing)	4	4	39 (4.0)	29 (4.4)
			Walks with a crutches or two canes (reciprocal walking)	5	5	31 (3.1)	20 (3.0)
			Walks with one cane	6	6	6 (0.6)	6 (0.9)
			Needs leg orthosis only	7	7	7 (0.7)	6 (0.9)
			Walks without walking aids	8	8	56 (5.7)	49 (7.4)
	SCIM 15	Mobility for Moderate Distances (10-100 mtrs)	Requires total assistance	0	0	223 (22.6)	160 (24.1)
			Needs electric wheelchair or partial assistance to operate manual wheelchair	1	1	224 (22.7)	143 (21.6)
			Moves independently in manual wheelchair	2	2	374 (38.0)	234 (35.3)
			Requires supervision while walking (with or without devices)	3	3	35 (3.6)	23 (3.5)
			Walks with a walking frame or crutches (swing)	4	4	33 (3.4)	25 (3.8)
			Walks with a crutches or two canes (reciprocal walking)	5	5	40 (4.1)	27 (4.1)
			Walks with one cane	6	6	7 (0.7)	7 (1.1)
			Needs leg orthosis only	7	7	4 (0.4)	3 (0.5)
			Walks without walking aids	8	8	45 (4.6)	41 (6.2)
	SCIM 16	Mobility Outdoors (more than 100 meters)	Requires total assistance	0	0	296 (30.1)	211 (31.8)
			Needs electric wheelchair or partial assistance to operate manual wheelchair	1	1	394 (40.0)	245 (37.0)
			Moves independently in manual wheelchair	2	2	183 (18.6)	117 (17.6)
			Requires supervision while walking (with or without devices)	3	3	17 (1.7)	12 (1.8)
			Walks with a walking frame or crutches (swing)	4	4	27 (2.7)	21 (3.2)
			Walks with a crutches or two canes (reciprocal walking)	5	5	26 (2.6)	20 (3.0)
			Walks with one cane	6	6	4 (0.4)	4 (0.6)
			Needs leg orthosis only	7	7	4 (0.4)	3 (0.5)
			Walks without walking aids	8	8	34 (3.5)	30 (4.5)
	SCIM 17	Stair Management	Unable to ascend or descend stairs	0	0	805 (81.7)	531 (80.1)
			Ascends and descends at least 3 steps with support or supervision of another person	1	1	56 (5.7)	38 (5.7)
			Ascends and descends at least 3 steps with support of handrail and/or crutch or cane	2	2	87 (8.8)	63 (9.5)
			Ascends and descends at least 3 steps without any support or supervision	3	3	37 (3.8)	31 (4.7)
	SCIM 18	Transfers: Wheelchair-car approaching car, locking wheelchair, removing arm- and footrests, transferring to and from car, bringing wheelchair into and out of car	Requires total assistance	0	0	568 (57.7)	386 (58.2)
			Needs partial assistance and/or supervision and/or adaptive devices	1	1	306 (31.1)	194 (29.3)
			Transfers independent; does not require adaptive devices (or does not require wheelchair)	2	2	111 (11.3)	83 (12.5)
	SCIM 19	Transfers: ground – wheelchair	Requires assistance	0	0	851 (86.4)	563 (84.9)
			Transfers independent with or without adaptive devices (or does not require wheelchair)	1	1	134 (13.6)	100 (15.1)

Appendix 3: Person-Item map for the co-calibration of FIM™ motor & SCIM



Appendix 4: Spinal Cord Independence Measure (SCIM) total scores and corresponding Rasch transformed Functional Independence Measure (FIM™) motor scores

SCIM score (0 to 37)	Rasch based FIM™ motor score	SCIM score (38-75)	Rasch based FIM™ motor score
0	0	38	54
1	0	39	55
2	0	40	56
3	1	41	57
4	1	42	58
5	2	43	59
6	2	44	60
7	3	45	60
8	4	46	61
9	5	47	62
10	6	48	62
11	7	49	63
12	9	50	63
13	10	51	64
14	11	52	64
15	13	53	65
16	14	54	65
17	15	55	66
18	17	56	66
19	18	57	67
20	19	58	67
21	21	59	68
22	23	60	68
23	24	61	69
24	26	62	69
25	28	63	70
26	30	64	70
27	32	65	71
28	35	66	71
29	37	67	72
30	39	68	73
31	42	69	73
32	44	70	74
33	46	71	75
34	48	72	75
35	50	73	76
36	51	74	77
37	53	75	78