Review

Predictors of functional outcomes in adults with traumatic spinal cord injury following inpatient rehabilitation: A systematic review

Faisal AlHuthaifi[1], Joseph Krzak[2,3], Timothy Hanke[2], Lawrence C. Vogel[3]

[1]Midwestern University, College of Health Sciences, Doctor of Health Sciences Program, Downers Grove, IL, USA, [2]Midwestern University, College of Health Sciences, Physical Therapy Program, Downers Grove, IL, USA, [3]Shriners Hospitals for Children®- Chicago, Chicago, IL, USA

Context: Despite functional improvements during rehabilitation, variable functional outcomes were reported when patients with Spinal Cord Injury (SCI) return to society. Higher functioning individuals at discharge can experience a decrease in independent mobility (i.e. Motor Functional Independence Measure (mFIM) Score) by one-year follow-up. However, functional gains after discharge have also been reported and associated with recovery.

Objective: To identify, categorize and rank predictors of mFIM score for patients with SCI following inpatient rehabilitation, both at the time of discharge and at one-year follow-up.

Methods: Data sources included CINAHL, PubMed, ERIC, Google Scholar, and Medline for literature published from February 2000 to February 2015. Quality and risk of bias of included studies was assessed using the Risk of Bias Assessment Instrument for Prognostic Factor Studies (QUIPS). Significant predictors of mFIM score were categorized using the domains of the International Classification of Function and Disability model ICF and ranked based on how frequently they were significant predictors of mFIM score.

Results: Twenty-seven predictors of mFIM score spanning the ICF domains were identified among seven studies. At discharge, variables in the Body Structure and Function domain were the most consistent predictors of mFIM score. At one-year follow-up, variables in the Activity and Participation domain were the most consistent predictors of mFIM score. Contextual factors were the least frequent predictors at both discharge and one-year follow-up.

Conclusion: This systematic-review assists clinicians setting realistic goals that maximize functional independence at the time of discharge and after reintegrating to society.

Keywords: FIM, mFIM, Spinal cord injury, Predictors, Rehabilitation, Motor outcomes, ICF, Follow-up

Introduction

Rehabilitation is an essential component of the overall care of individuals following spinal cord injury (SCI).[1] Rehabilitation can be defined as "an active and dynamic process by which a disabled person is helped to acquire knowledge and skills to maximize physical, psychological and social function."[2] It is a process that maximizes functional ability and minimizes disability and handicap. Effective rehabilitation is best conducted by actively involving well-integrated teams of specialists working in an interdisciplinary fashion in all stages of the process.[2] In the rehabilitation setting, efforts are mostly directed at therapeutic activities to improve functional mobility and independence.[1,3] Examples of activities commonly trained during inpatient rehabilitation include wheelchair skills, transfers, bed mobility, and self-care.[4]

The ultimate goal of the interdisciplinary team is to facilitate functional independence.[2,5] Achievement of this goal is often measured using quantitative outcome measures,[1] such as the Functional Independence Measure (FIM), a widely-used outcome measure of disability and the level of assistance required for an individual with SCI to perform activities of daily living.[6] It can be used to determine the magnitude of functional severity, the effectiveness of an intervention or the effect of

Correspondence to: Faisal K. Alhuthaifi, 400 E South Water St. #2008 Chicago, IL 60601 USA. Email: fa586@nyu.edu

DOI 10.1080/10790268.2016.1238184

time on functional outcomes for individuals in a rehabilitation setting. The FIM has been widely used for the assessment of patients with SCI.[5,7,8] It contains 18 functional tasks: thirteen motor (mFIM) and five cognitive. Each task is rated on a seven-point ordinal scale ranging from total independence (7/7) to complete dependence (1/7).[6] The FIM is commonly administered in a rehabilitation setting upon admission and at discharge. It is becoming more common in clinical and research arenas to additionally administer the FIM during subsequent follow-up visits after discharge.

Despite functional improvements in the rehabilitation setting, variable motor outcomes have been reported when patients return to society after discharge.[9] Outcome studies of individuals with SCI at one-year follow-up demonstrated that higher functioning individuals at discharge could experience a significant decrease in independent mobility.[9–11] For people with chronic SCI, increases in secondary conditions such as pressure ulcers and urinary tract infection were associated with a decline in function over time.[12] In contrast, functional gains after discharge have been associated with recovery from injury, even one year after injury.[5,12] As a result of such variability in post-discharge of motor outcome levels, researchers are beginning to describe rehabilitation as a "continuum" that includes both inpatient and post-discharge services within the first year post-injury.[13] The authors emphasized not only the importance of considering the effects of both inpatient and post discharge services when examining long-term outcomes but also identifying additional patient specific factors which can impact functional mobility across the continuum of care.[13]

Functional outcomes after discharge can be influenced by sociodemographic factors[1,14–18] and injury related characteristics[3,19–23] including age, sex, race, cause of SCI, level and severity of neurologic impairment, and the presence of traumatic brain injury.[24] As a result of this complexity, it is important to identify specific predictors of functional outcomes. By identifying these predictors, clinicians will be able to maximize functional independence not only at the time of discharge but also after individuals integrate back into society and though-out their lifespan. One tool that can be used to facilitate not only identification of predictors but also categorize them is to apply the domains of the International Classification of disability and Functioning (ICF) model.

The ICF model is a classification of health and health-related conditions that was developed by World Health Organization (WHO) and published in 2001.[25,26] The model describes functioning, disability and health, and its interaction with contextual factors (environmental and personal).[25–27] Functional mobility influences an individual's ability to participate in activities within the community.[28] Thus, functional outcome is an ideal area to study for individuals with SCI as it represents a measurement of disability across the continuum of care including both discharge from inpatient rehabilitation and at follow-up. To date, there are no systematic reviews that identify, categorize, and rank predictors of functional mobility in SCI population following rehabilitation.

The objective of the current systematic review was to identify, categorize and rank predictors of functional outcomes for patients with SCI following inpatient rehabilitation, both at the time of discharge from inpatient rehabilitation and at one-year follow-up. We anticipate that variables (predictors) in the body structure and function and the level of activity and participation are important domains influencing functional outcomes in rehabilitation settings. However, we anticipate that additional variables such as contextual factors following rehabilitation may alter functional outcomes (recovery). The results of this study will help clinicians to set realistic goals to maximize functional independence not only at the time of discharge but also after individuals integrate back into society and though-out their lifespan.

Methods

The manuscripts used in the current systematic review was identified using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines.[29]

Eligibility criteria

The review includes retrospective, prospective and longitudinal cohort studies that were written in English. Additional criteria include studies that used: 1) individuals with traumatic SCI, 2) International Standards for Neurological Classification of SCI as the primary method of neurological assessment,[30] 3) the motor FIM score as a primary outcome at discharge and/or one year follow-up assessment, 4) statistical modeling techniques to identify predictors of functional outcomes (e.g. regression) and 5) studies that took place in inpatient rehabilitation settings 6) Studies included factors independently associated with mFIM. Exclusion criteria consist of studies that focused on particular body function other than functional outcomes (e.g. respiratory management, pain, or depression), and studies that did not use statistical techniques, which explicitly identify predictors of functional outcomes (e.g. group comparisons).

Information resources

A systematic search was performed using CINAHL, PubMed, ERIC, Google Scholar, and Medline for literature published from February 1, 2000 to February 1, 2015.

Search Strategy

To build the initial article selection, a combination of search terms related to "FIM", "mFIM", "Predictors", "Mobility", "SCI", "Follow-up", "Motor FIM", "Functional", and "Spinal cord" were utilized. Furthermore, relevant papers from a previous scoping search were sought to retrieve additional keywords. Every search term has been reviewed to ensure relevance within the scope of the research question. The authors performed an expanded search to identify articles potentially missed through the electronic searches, including grey literature and unpublished studies.

All references obtained using the search strategy were imported into Endnote X7 (Thomson Reuters, Philadelphia, PA, USA). The relevant studies were screened for eligibility. Two authors (FA and JK) screened the title and the abstract. Full text of all articles considered relevant after the initial title and abstract screening were retrieved and assessed for eligibility. Any remaining non-eligible articles were excluded. Reasons for exclusion were documented.

Quality assessment of the selected articles

Following full review of the remaining manuscripts, the methods of all included studies were evaluated for risk of bias. Quality and risk of bias assessment of the studies was performed using the approach outlined by the Risk of Bias Assessment Instrument for Prognostic Factor Studies (QUIPS).[31]

Data Collection and Analysis

The following data was extracted from the included papers using evidence summary templates: author(s), year of publication, title, journal, study location, year of data collection, sample size in the hospital setting, sample size at follow-up, length of follow-up, characteristics of the study population (age, sex, level of injury at admission, and neurological classification), definition of outcomes and predictors, and results (associations between predictor variables and functional outcomes, and characteristics of predictor variables, if available).

Identified predictors of mFIM at discharge and follow-up were selected from the eligible studies based on whether or not the outcome variables were significant using regression analysis in the original studies. Additionally, the coefficient of variation (R^2) representing the strength of the full regression model was obtained at both discharge and follow-up.

Identified predictors were then categorized based on the domains of the ICF (Body Structure/ Function, Activity and participation, contextual factors). Each predictor was assign to an ICF domain independently by two reviewers (FA and JK). ICF domains were assigned based on the units of measurement used in the original studies. For example, hours spent on PT mobility training, was assigned to the activity and participation domain. In the event of disagreement between two reviewers, a third reviewer was assigned so that consensus could be reached.

After the predictors had been identified and categorized, individual variables within each ICF domain were ranked. The ranking was performed based on how frequently the variable was identified as a significant predictor of mFIM score across the included studies both at discharge and at one year follow-up.

Results

Data sources and search outcomes

The PRISMA flow chart of the total search and study selection is shown in Figure 1. Two reviewers retrieved

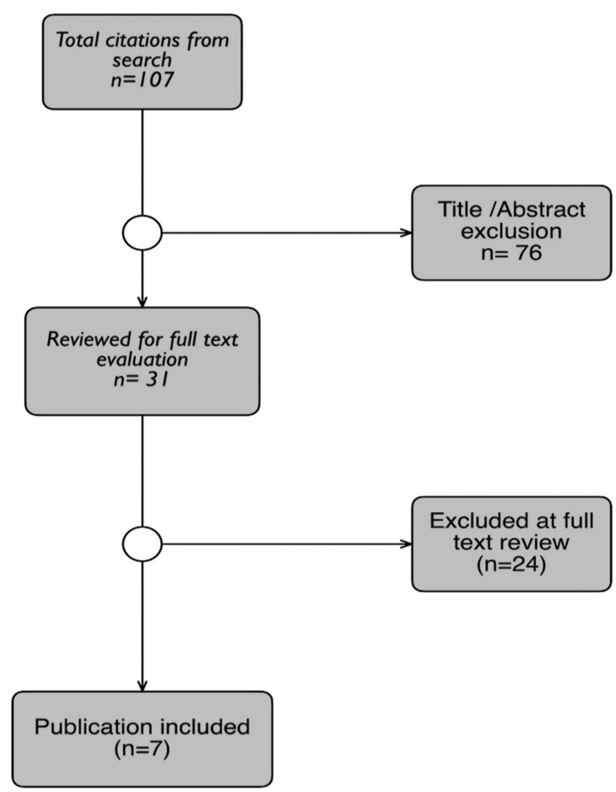

Figure 1. Preferred reporting items for systematic review and meta-analysis. (PRISMA) Search strategy diagram

a total of 107 articles from six key databases (CINAHL, PubMed, ERIC, Google Scholar, Medline and the Cochrane Library). After applying the inclusion criteria in the first stage of the review process, seventy-six studies did not meet the inclusion criteria on the basis of the study title and abstract. Of the thirty-one remaining studies, twenty-four were further excluded after the full text was comprehensively examined. Reasons for exclusion are presented in Table 1.

Of the remaining seven studies, five included both discharge and one year follow-up mFIM scores, while two studies included only mFIM at one year follow-up. Thus, the literature search generated a total of seven articles for inclusion in the current systematic review.[1,32–37]

The level of evidence for one retrospective cohort and one prospective study was Level IV. The five remaining studies qualified as Level III evidence since they were prospective studies with high follow-up percentages (≥ 85%) and integrated regression techniques in the analysis to adjust for confounding variables (Table 2).[38]

Quality Assessment

The six categories of the QUIPS were used to evaluate the included studies for potential bias. The six categories included: participation, attrition, prognostic factor measurement, confounding measurement, outcome measurement, and statistical analysis and reporting (Table 2).[31] All samples in the included studies represented the population of interest on key characteristics, limiting potential bias of the observed relationship between predictors and mFIM scores. The follow-up rate across seven studies ranged from 85.3% to 100%.[32–37] The percentage of patients who returned for follow-up was unclear for one of the studies.[1]

There was a moderate to high level of bias due to the presence of confounding variables. The included studies did not consistently state how the confounding variables were accounted for in the data analysis section. Only three out of the selected studies identified severity, age and level of injury as confounding variables.[33,35,37] Also, one study showed residual confounding effects by using large age groups that were not adequately adjusted for in the analysis.[37]

The statistical analyses included in the selected studies were appropriate in limiting invalid or false results. Furthermore, the outcomes of interest in the reported studies were adequately measured to limit any potential bias.

Table 1 Reasons for exclusion of the selected articles

Study	Reason for exlusion
Akmal *et al.*, 2003	ASIA classification was not used as the primary method of neurological assessment.
Chan *et al.*, 2013	Study did not use statistical techniques to explicitly identify predictors of motor outcomes
Cohen *et al.*, 2012	Study did not use statistical techniques to explicitly identify predictors of motor outcomes
Eastwood *et al.*, 1999	Motor FIM score is not the primary outcome at discharge and/or one follow-up assessment
Fisher *et al.*, 2005	Study did not use statistical techniques to explicitly identify predictors of motor outcomes
Fyffe *et al.*, 2014	Study did not use statistical techniques to explicitly identify predictors of motor outcomes
Horn *et al.*, 2013	Study did not use statistical techniques to explicitly identify predictors of motor outcomes
Kennedy *et al.*, 2011	Motor FIM score is not the primary outcome at discharge and/or one follow-up assessment (Independent variables included psychological factors.)
Kirshblum *et al.*, 2011	Study did not use statistical techniques to explicitly identify predictors of motor outcomes
Kozlowski *et al.*, 2013	Motor FIM score is not the primary outcome at discharge and/or one follow-up assessment
Lee *et al.*, 2014	Study did not use statistical techniques to explicitly identify predictors of motor outcomes
Lugo *et al.*, 2007	Motor FIM score is not the primary outcome at discharge and/or one follow-up assessment
McKinley *et al.*, 2004	Study did not use statistical techniques to explicitly identify predictors of motor outcomes
Muslomanoglu *et al.*, 1997	Study did not use statistical techniques to explicitly identify predictors of motor outcomes did not use statistical techniques to explicitly identify predictors of motor outcomes changes o any independent variables *
Pershouse *et al.*, 2012	Study did not use statistical techniques to explicitly identify predictors of motor outcomes did not use statistical techniques to explicitly identify predictors of motor outcomes changes to any independent variables *
Putzke *et al.*, 2003	Motor FIM score is not the primary outcome at discharge and/or one follow-up assessment
Riggins *et al.*, 2011	Motor FIM score is not the primary outcome at discharge and/or one follow-up assessment
Rodakowski *et al.*, 2014	Motor FIM score is not the primary outcome at discharge and/or one follow-up assessment
Sipski *et al.*, 2004	Study did not use statistical techniques to explicitly identify predictors of motor outcomes
Spooren *et al.*, 2011	Study did not use statistical techniques to explicitly identify predictors of motor outcomes
Weitzenkamp *et al.*, 2002	Motor FIM score is not the primary outcome at discharge and/or one follow-up assessment
Wilson *et al.*, 2012	Study did not use statistical techniques to explicitly identify predictors of motor outcomes
Yasar *et al.*, 2015	Motor FIM score is not the primary outcome at discharge and/or one follow-up assessment
Yilmaz *et al.*, 2005	Study did not use statistical techniques to explicitly identify predictors of motor outcomes changes to any independent variables

Table 2 Risk of bias assessment for the selected studies (QUIPS)

Biases	Level	Summary
Participation	Low	All samples in the included studies represented the population of interest on key characteristics.
Attrition	Moderate to high	No evidence on attempts to collect information from drop outs.
Prognostic factor measurement	Low to moderate	Proportion of the study sample is not adequate for 2 studies.
Confounding measurement	Moderate to High	Potential confounders are not appropriately accounted for, resulting in potential bias.
Outcome measurement	Low	Adequately measured to sufficiently limit potential bias.
Statistical analysis and reporting	Low	Appropriate in limiting potential presentation of invalid or false results.

On the contrary, moderate to high risk of bias due to attrition was identified among the included studies. Five out of the seven selected studies did not provide information about attempts to collect information on participants who dropped out. In addition, the selected studies did not provide insight into the potential impact of subjects lost to follow-up on study results and conclusions. Loss to follow-up is a common characteristic associated with increased risk of bias in cohort studies.[39] Acceptable guideline for follow-up rate has been reported in the literature.[39] Among the included studies the response rate on follow-up was acceptable (>85%); the rate minimizes the risk of bias due to attrition. The selected studies used clearly defined, valid and reliable measurements overall, adequate to limit potential bias.

Predictors of mFIM scores at discharge and at one-year follow-up

The adjusted R^2 values for the individual full regression models ranged from 0.59 to 0.73 at discharge and 0.25 to 0.51 at one year follow-up. We identified 27 predictors among the individual studies spanning the ICF domains (Table 3A and Table 3B). Figure 2 shows the number of identified predictors categorized using the ICF domains. When examining the variables within the seven selected studies, six of the seven studies had ten or more predictors of mFIM score.[1,32–36] One study only identified three.[37] Furthermore, of the six studies with ten or more predictors, all had variables that spanned the ICF domains of interest (e.g. Body Function and Structure, Activity and Participation, and Contextual Domain). Across 27 predictors included in the 7 studies, there were 8 predictors within the Body Structure/Function domain (30%), 9 within Activity and Participation (33%) and 10 in the Contextual domain (37%).

Predictors related to body structure and function domain

Predictive variables in the Body Structure/Function domain were significant 84% of the time at discharge and 70% at one year follow-up (Fig. 3). The neurologic level of injury was consistently identified as a predictor of mFIM across all studies. The most common mechanism used to categorize neurologic level of injury was dividing individuals into 5 groups: (1) AIS ABC (2) C1-4 AIS ABC, (3) C5-8 AIS ABC, (4) paraplegia AIS ABC, and (5) all AIS D. The results show that AIS ABC, paraplegia AIS ABC, C5-C8 AIS ABC were consistent predictors of mFIM at both discharge and follow-up.[1,32–34,36,37] Other variables including tetraplegia C1-C4 with AIS ABC, comprehensive severity index (CSI), and AIS D showed variation in predicting mFIM at discharge and at one year follow-up. Secondary complications such as pressure ulcer were found to be a predictor of mFIM only at discharge but were not at follow-up.

Predictors related to activity and participation domain

Predictors categorized to the Activity and Participation domain primarily emphasized functional status upon admission and time spent participating in rehabilitative activities. None of the included studies used standardized participation-based outcomes as predictors of motor FIM score. The predictive variables in the Activity and Participation domain were significant 82.3% of the time at discharge and 76.2% of the time at one year follow-up (Fig. 3). Patient's mFIM score upon admission and hours spent on PT mobility training including gait mobility were consistently identified as predictors of mFIM at both discharge and at one-year follow-up. Hours spent on wheelchair mobility, upright activities, and strengthening activities were predictors of mFIM only at discharge. Inpatient recreation therapy, social work, case management services were not predictors of mFIM at discharge but were consistent predictors of mFIM at a one-year follow-up. In addition, hours spent participating in OT sessions were consistently a predictor of mFIM only at one-year follow-up.

Table 3A. Prediction marker of motor outcomes at discharge

Predictor	ICF Domain	Backus, 2013	Cahow, 2011	Horn, 2013	Hsieh, 2013	Tian, 2013	Teeter, 2012	Welson, 2014*	Times Parameter used in prediction models	% of times parameter was significant
Discharge	R^2 ---->	No Data	R^2=0. 65	No Data	R^2=0.73–0.670	R^2= 0.585	R^2=0.65	NR		
ASIA ABC	Body Structure/ Function	No Data	S	No Data	X	X	S	S	3	100%
All para		No Data	S	No Data	S (for all age gr except ≥60)	X	S	X	3	100%
C5–C8, grades A–C		No Data	X	No Data	S	X	S	X	2	100%
secondary complication		No Data	X	No Data	X	S (only Para A-C)	X	X	1	100%
C1-C4 gradesA-C		No Data	X	No Data	S	X	S	X	2	50%
ASIA D		No Data	NS	No Data	S (all age except age ≥ 60)	X	S	NS	3	33. 30%
Comprehinsive severity index (CSI)		No Data	S	No Data	S (for all age gr except (16–44)	S only C5–8, A–C and grade D	NS	X	4	75. 00%
Time spent in inpatient PT Participation	Activity/ Participation	No Data	X	No Data	S (for age group ≥60)	S (only C1–4 and para A–C)	S	X	3	100%
Time spent in inpatient OT services (h)		No Data	X	No Data	S (for age group 45–60)	S (only Para A–C)	X	X	2	100%
Admission mFIM		No Data	S	No Data	S	S (except Grade D)	S	X	4	100%
Time spent in wheelchair mobility – manual (h)		No Data	X	No Data	X	X	S	X	1	100%
Time spent in gait mobility training (h)		No Data	X	No Data	X	X	S	X	1	100%
Time spent in PT mobility training (h)		No Data	X	No Data	S age gr (16–44) only	X	X	X	1	100%
Time spent in strengthening Activities (h)		No Data	X	No Data	X	X	S	X	1	100%
Time spent in Upright activities (h)		No Data	X	No Data	X	X	S	X	1	100%
Time spent in inpatient TR/SW/CM/SLP service (h)		No Data	NS	No Data	NS	NS	X	X	3	0%

Continued

Table 3A. Continued

Predictor	ICF Domain	Backus, 2013	Cahow, 2011	Horn, 2013	Hsieh, 2013	Tian, 2013	Teeter, 2012	Welson, 2014*	Times Parameter used in prediction models	% of times parameter was significant
Ventilator use at admission	Contextual	No Data	X	No Data	S (for all age gr except ≥ 60)	X	X	X	1	100%
Employment		No Data	X	No Data	X	NS	X	X	1	0%
Payer (private insurance)		No Data	S	No Data	X	X	NS	X	2	50%
Language		No Data	X	No Data	X	NS	X	X	1	0%
LOS		No Data	S	No Data	S (for age ≥ 45)	S (only C1–4)	X	X	3	100%
Days from trauma to rehab		No Data	S	No Data	S (for 16–29 yr only)	sig only C1-4	S	X	4	100%
Age		No Data	X	No Data	X	S (only AIS grade D)	S	S (<65 years)	3	100%
BMI		No Data	X	No Data	S (for age gr. 30-44)	S (only Para A-C)	S	X	3	100%
Sex		No Data	X	No Data	S (only age gr 16–39)	S (only gr Para A-C)	NS	X	3	33. 30%
Education >12yr		No Data	X	No Data	NS	S (only gr. C 5–8)	NS	X	3	33%
Ethnicity		No Data	X	No Data	X	NS	X	X	1	0%

Predictors related to contextual domain

Predictive variables were significant 64% at discharge and 57% on follow-up (Fig. 3). Age, LOS and delayed admission to rehabilitation were consistent predictors of mFIM at discharge and 75% of the time at follow-up. Sex, level of education, use of ventilator at admission, payers, and employment showed inconsistency in predicting mFIM at discharge and at one year follow-up. Patient's Body Mass Index was a predictor of mFIM at discharge; however, it failed to consistently predict mFIM at follow-up. Ethnicity was not a predictor of mFIM at either discharge or at one year follow-up. Language barrier was only predictor at one year follow-up

Discussion

The purpose of the current systematic review was to identify, categorize and rank predictors of functional outcomes for individuals with SCI following rehabilitation. Twenty-seven variables spanning each domain of the ICF model were able to predict mFIM scores at discharge and/or at one year follow-up. Different domains had more influence on mFIM score at various times during the rehabilitation process. Together, this information will help clinicians to set realistic goals to maximize functional independence not only at the time of discharge but also after individuals integrate back into society and though-out their lifespan.

Among the twenty-seven predictors of mFIM score, variables spanning the ICF domains were identified as being more consistently significant at discharge and/or follow-up: ten variables at both discharge and at one year follow-up, five only at discharge, and two only at follow-up. Additionally, two variables showed variability at discharge but were consistent at follow-up, seven variables were inconsistent predictors of mFIM score at both discharge and one year follow-up, and one variable was not significant at either discharge or at one year follow-up. Variables related to the Body Structure and Function domain were the most consistent predictors of mFIM score at discharge, and those related to the Activity and Participation domain were the most consistent predictors at one year follow-up. Aside from age, variables related to the Contextual domain were the least consistent predictors of mFIM score at both discharge and follow-up. These findings demonstrate that a particular domain of the ICF can have greater influence on functional outcomes at different stages of the rehabilitation process. For example, the amount of time spent on manual wheelchair propulsion training was a predictor of mFIM score 100% of the time at discharge but was not a predictor (0%) at one year

Table 3B. Prediction marker of motor outcomes at one-year follow-up

Predictor	ICF Domain	Backus, 2013	Cahow, 2011	Horn, 2013	Hsieh, 2013	Tian, 2013	Teeter, 2012	Welson, 2014*	Times Parameter used in prediction models	% of times parameter was significant
One-year Follow-up	R^2 ---->	R2= 0.49	R^2= 0.51	R^2=0. 516	R^2= 0.630–0.580	R^2= 0.250	R^2= 0.51	NR	One-year follow-up	
ASIA ABC	Body Structure/ Function	S	S	S	S (Only for age 16–29)	X	S	S	6	100%
All para		X	S	X	S (all age except age ≥60)	X	S	X	3	100%
C1-C4 grades A-C		X	X	X	S	X	S	X	2	100%
C5-C8 grades A-C		X	X	X	S (all age except age ≥60)	X	S	X	2	100%
Comprehensive Severity Index (CSI)		S	S	X	S (for age gr 30–44)	NS	NS	X	5	60%
AIS D		NS	NS	S	X	X	S	NS	5	40%
ventilator used at rehab admission (Airway/respiratory management)		X	X	NS	NS	S (only para)	X	X	3	33. 30%
Secondary complications		X	X	X	X	NS	X	X	1	0%
Admission mFIM	Activity/ Participation	S	S	S	S	S (only C1–8)	S	X	6	100%
Time spent in inpatient PT participation (h)		S	X	X	NS	S (only C1-8)	S	X	4	75%
Time spent in inpatient TR/SW/CM/SLP service (h)		S	S	X	S (for age gr 45–59)	S (only C5–8) *SW	X	X	4	100%
Time spent in inpatient OT service (h)		X	X	X	S (for age group 30–44)	NS	X	X	2	50. 00%
Time spent in PT mobility training (h)		X	X	X	S (Only for age 16–29)	X	X	X	1	100. 00%
Time spent in gait training (h)		X	X	X	X	X	S	X	1	100%
Time spent in upright activities		X	X	X	X	X	NS	X	1	0%
Time spent in Strengthening activities (h)		X	X	X	X	X	NS	X	1	0%
Wheelchair mobility – manual (h)		X	X	X	X	X	NS	X	1	0%
LOS	Contextual	X	NS	S	S (for age gr 30–60)	S (only para+ Grade D)	X	X	4	75%
Days from trauma to rehab		X	S	X	S (for age gr. 16–44)	NS (for all levels)	S	X	4	75%

Continued

Table 3B. Continued

Predictor	ICF Domain	Backus, 2013	Cahow, 2011	Horn, 2013	Hsieh, 2013	Tian, 2013	Teeter, 2012	Welson, 2014*	Times Parameter used in prediction models	% of times parameter was significant
Employment		X	X	X	X	S	X	X	1	100%
Payer (private insurance)		NS	NS	S	X	X	S	X	4	50%
Language		X	X	X	X	S	X	X	1	100%
Ventilator used at rehab admission (Airway/respiratory management)		X	X	NS	NS	S (only para)	X	X	3	33. 30%
Age		S	X	S	X	S (onlyPara gr A-C)	S	S (<65 years)	5	100%
Sex		X	X	X	X	S (onlyPara gr A–C)	NS	X	2	50%
Education		S	X	X	NS	NS	S	X	4	50%
BMI		X	X	NS	NS	S (only C1–4)	NS	X	4	25%
Ethnicity		NS	X	NS	X	NS	X	X	3	0. 00%

follow-up. Conversely, time spent participating in Recreational Therapy, Social Work, and Case Management was a predictor of mFIM score only at one year follow-up. The common language of the ICF as a model of health and disability was applied to classify the ranked variables across domains. Identifying individual variables within each domain allows for the evaluation of the relationships among variables within each domain, as well as, the relationship between variables in different domains.[28,40,41]

The value of the coefficient of determination (R^2) is meaningful for conceptualizing the degree of association between full regression models and the mFIM scores.[42] As shown in the results, the decrease in R^2 from discharge to follow-up indicates that the predictive capabilities of these models were variable and reduced over time. This variability suggests that not only are there additional variables affecting functional outcomes following discharge from rehabilitation, but more frequent clinical evaluations following discharge are indicated to identify the need for further intervention.

Body structure/function domain

Predictors in the Body Structure and Function domain showed that injury category levels C5–C8, paraplegia ABC, and combined paraplegia and tetraplegia injury levels AIS ABC were the most consistent predictors of mFIM at discharge and follow-up. It has been demonstrated in previous studies that mFIM is strongly associated with the neurological level of the individual's SCI. However, the level of injury alone cannot fully capture the spectrum of functional capability following rehabilitation. For patients in the AIS A, B, and C levels, the likelihood of future ambulation is very limited. Individuals in the AIS D level appeared to be independent of the neurological level of injury due to the presence of motor function below the level of injury. Individuals with AIS D come to rehab with a basic goal to further improve functional independence that may be translated to future ambulation. Overall, Studies showed that the number of ambulatory patients with AIS D is four times as many compared in AIS A, B, and C levels.[43] However, studies also showed that individuals in the AIS D level might be affected by impairments including spasticity, muscle weakness, and neuropathic pain.[1] These factors may add to the inconsistency of the results and also limit independent mobility at discharge and at one year follow-up. Similar findings were identified in the current systematic review where the overall predictive value of an AIS D injury was inconsistent following rehabilitation.

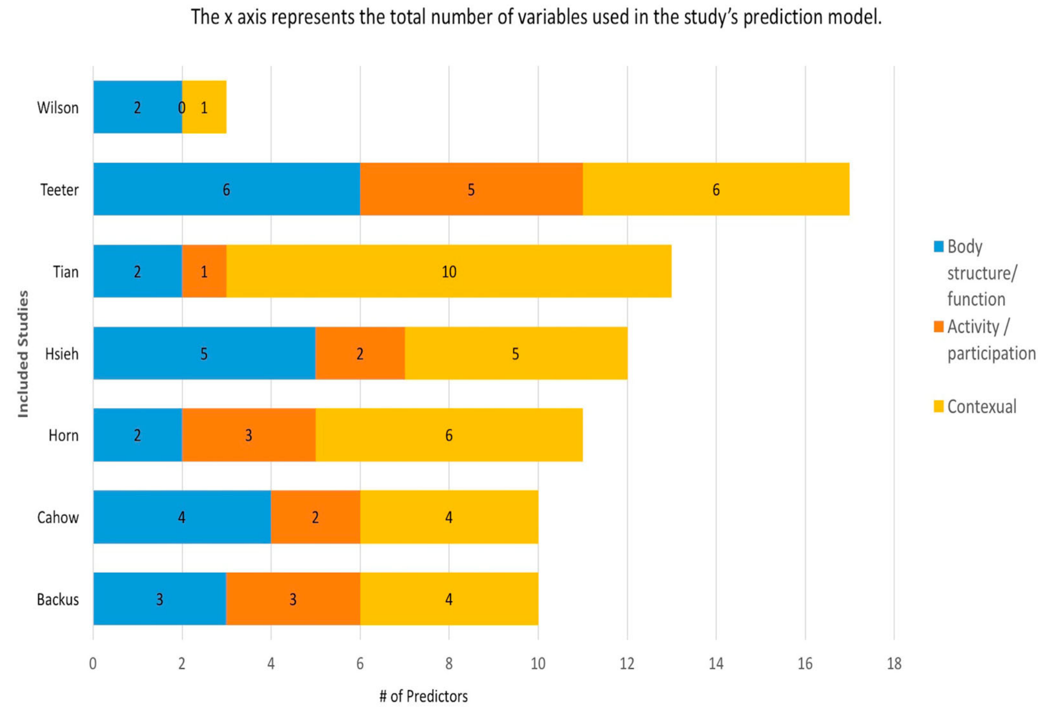

Figure 2. Number of predictors in each selected study. (Colour online)

Activity/participation domain

Variables in the Activity and Participation domain including Admission FIM score, PT participation score, and hours spent on PT mobility training (including ambulation training) were the most consistent predictors of mFIM. The result indicates that within the interactive process of rehabilitation, a patient's participation can significantly affect functional outcomes. These findings are consistent with a previous study which showed that patients sharing the same level of injury who participated more during rehabilitation sessions reported higher functional outcomes.[1,44] The study further concluded that patient participation is a significant element of successful SCI rehabilitation and must be enabled, encouraged and tailored to every individual with SCI in the rehabilitation settings. In Teeter *et al.,* higher levels of intrinsic and extrinsic motivation were identified as possible patient characteristics associated with high functional improvement following rehabilitation.[1] Individuals who are more responsive to rehabilitation are likely to have supportive personal features that enhance activity and participation levels, as well as, mFIM scores.[1,44]

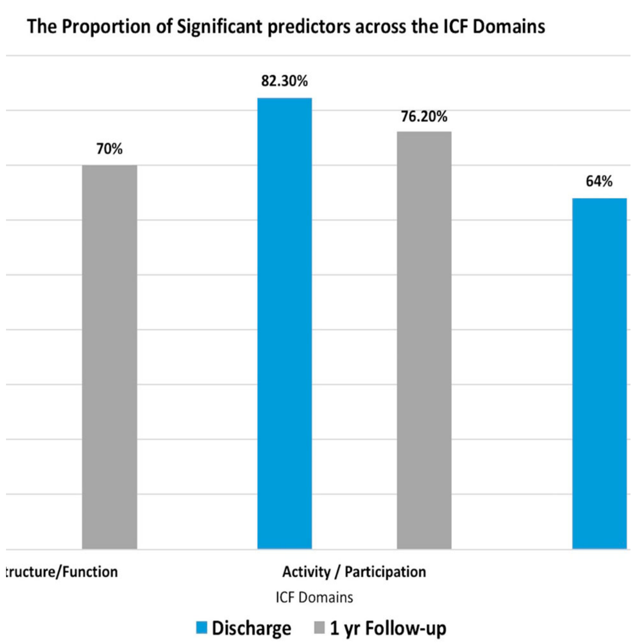

Figure 3. Rate of significant predictors in the ICF domain at discharge and at one year follow-up. (Colour online)

Although other inpatient services such as Recreation Therapy, Social Work, and Case Management were not significant predictors of mFIM scores at discharge, they were consistent predictors at one year follow-up. This suggests that the skills and knowledge obtained from these professionals are more impactful on independent functional mobility when they can be applied in a community setting.

Contextual Domain

Overall, variables in the Contextual domain were less likely to predict mFIM scores at discharge and at follow-up. However, it is important to consider the direct effect of contextual factors on the identified predictors, themselves, of functional outcome. For example, the time spent in participating in the various rehab intervention activities can be actually conditioned by contextual factors such as patient/therapist goals, motivation, scheduling. However, in other studies, contextual factors were found to be more strongly associated with measures of life satisfaction than measures of the Activity and Participation domain (as measured by mFIM, Craig Hospital Inventory of Environmental Factors, and Craig Handicap Assessment and Reporting Technique).[45–47]

In the current systematic review, variables in the contextual domain showed that age at injury, LOS, and delayed admission to rehabilitation were the most consistent predictor of mFIM. The findings are consistent with other studies on the positive influence of rehabilitation LOS on functional achievements as determined by improvement in mFIM.[48–51] These results suggest that admission to rehabilitation following SCI should be expedited and discharged should be considered based on the attainment of goals. At the time of discharge consideration of physical, psychological and environmental constraints within the community must be considered to minimize the effect of the contextual barriers on functional gains achieved during rehabilitation. Nevertheless, predictors such as LOS can be influenced by external factors like governmental policies, health system administration and financial considerations that in return may affect mFIM during and following rehabilitation.

Older age at injury can negatively affect functional outcomes from discharge to one year follow-up. Although results from other studies found that neurological recovery to be independent of age, the findings further demonstrated that neurological improvement in elderly population fails to be translated into equivalent functional mobility gains.[52] Lack of functional mobility gains was mainly associated with age-associated conditions such as reduced cardiovascular capacity, endurance, and various chronic health conditions (cardiovascular disease, osteopathic disorder).[53,54] This suggests that facilitating tailored interventions for a particular age population will help to accommodate their specific needs and serve the overall goal of rehabilitation.

Race and ethnicity were not identified as predictors of mFIM score. This suggests that changes in mFIM may not possibly emerge from racial and ethnic differences. However, it is expected that ethnic group's results from these studies may vary from one environment to another, given the differences in culturally associated factors, accessibility to cost-effective resources and supporting means during and following rehabilitation.

Clinical relevance

The findings in this study allows clinicians to set more realistic goals to maximize functional independence not only at the time of discharge but also after individuals integrate back into the community and though-out their lifetime. Also, the findings in the current systematic review can help prioritize services received as a patient prepares for discharge and guide discharge planning to ensure that post-discharge services are available once a patient reintegrates back into the community.

Study limitations and future direction

There are a number of limitations were encountered in the current systematic review that warrant discussion. First, the mapping of predictors into the ICF domains was not entirely straightforward. By way of explanation, there is a risk of decreased reliability in the process of identifying which domain the predictor relate to.[25] In an effort to minimize this risk, multiple expert opinions were carried to confirm the accuracy of placement of the predictors into its correct domain. Second, although many studies showed that the Spinal Cord Independence Measure (SCIM) is the gold standard in serving as a common tool for assessment of individuals with SCI, its application in clinical practice has not yet been fully embraced. In addition, the SCIM has undergone two major revisions in 2001 and 2007. The current version is the SCIM-III. Consequently, there is insufficient data in the literature to fully utilize the SCIM-III as an outcome measure for the purpose of this systematic review. However, future studies should utilize the SCIM-III assessment tool to improve reliability and sensitivity measures of functional outcomes during and after rehabilitation.

Although contextual (personal and environmental) factors are essential to the framework of the ICF, they have yet to be fully classified. This is a current limitation of the ICF, as personal and environmental factors are critical to the process and outcome of the rehabilitation for individuals with SCI. The ICF has also been criticized for its inability to clearly portray change of health-related factors over time.[2]

The included studies did not explicitly include formal outcomes measures of participation. The included studies measured the activity and participation through time spent in participating in rehabilitative activities. Based on the current literature, it is still questionable as to whether the number of hours is a valid parameter for measuring activity and participation, as this perspective overlooks the association of subjective character of experience with factors related to the contextual domain. Given the importance of participation to people with SCI, it is crucial that clinicians and researchers have access to outcome measures that accurately measure participation in ways that are both theoretically and psychometrically valid.[55]

Although the potential risk for confounding was considered in the assessment of the quality of the selected studies, we were not able to control for confounding/ extraneous independent variables in our analyses. Furthermore, the QUIPS assessment revealed moderate to high level of bias in the selected studies due to confounding. It is important to consider whether the most significant confounders are listed, measured accurately, and controlled for. That in return will lead to better reliability of the results.

Conclusion

The current systematic review presented a standardized process to identify, categorize and rank predictors of functional outcomes (mFIM) following SCI based on the common language framework of the ICF. Identifying, categorizing, and ranking predictors of functional outcomes following SCI is a complex process, given the effect of contextual factors on injury-related characteristics and the level of activity and participation of individuals with SCI. We concluded that predictors related to body structure and function were found to be the most consistent predictor at discharge and predictors related to activity and participation to be the most consistent at one year follow-up. Predictors related to the contextual domain were the least consistent predictors of mFIM at both discharge and follow-up.

This study suggests that predictors of functional outcomes are becoming more important throughout recovery. It is imperative to raise this finding because the ultimate goal of rehabilitation should be preparing individuals with traumatic SCI to independently integrate back into the community.

In the future, we suggest investigating the predictive capacity of further various variables related to functional outcomes and consider a balanced distribution of predictors across the domains in the ICF using a valid and reliable tool of functional outcome measure.

Disclaimer statements

Contributors None.

Funding None.

Conflict of Interest: No author has a conflict of interest with the material presented.

Ethics approval None.

Disclosures None.

References

1 Teeter L, Gassaway J, Taylor S, LaBarbera J, McDowell S, Backus D, *et al.* Relationship of physical therapy inpatient rehabilitation interventions and patient characteristics to outcomes following spinal cord injury: the SCIRehab project. J Spinal Cord Med 2012;35(6):503–26.
2 Dean SG, Siegert RJ, Taylor WJ. Interprofessional rehabilitation : a person-centred approach. Chichester, West Sussex ; Ames, Iowa: Wiley-Blackwell; 2012. xviii, 195 pp.
3 Post MW, Dallmeijer AJ, Angenot EL, van Asbeck FW, van der Woude LH. Duration and functional outcome of spinal cord injury rehabilitation in the Netherlands. J Rehabil Res Dev 2005; 42(3 Suppl 1):75–85.
4 Al-Jadid MS, Al-Asmari AK, Al-Moutaery KR. Quality of life in males with spinal cord injury in Saudi Arabia. Saudi Med J 2004; 25(12):1979–85.
5 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(11):1471–6.
6 Ota T, Akaboshi K, Nagata M, Sonoda S, Domen K, Seki M, *et al.* Functional assessment of patients with spinal cord injury: measured by the motor score and the Functional Independence Measure. Spinal Cord 1996;34(9):531–5.
7 Qu H, Shewchuk RM, Chen YY, Richards JS. Evaluating the quality of acute rehabilitation care for patients with spinal cord injury: an extended Donabedian model. Qual Manag Health Care 2010;19(1):47–61.
8 Abdul-Sattar AB. Predictors of functional outcome in patients with traumatic spinal cord injury after inpatient rehabilitation: In Saudi Arabia. NeuroRehabilitation 2014;35(2):341–7.
9 Chan SC, Chan AP. One-year follow-up of Chinese people with spinal cord injury: a preliminary study. J Spinal Cord Med 2013; 36(1):12–23.
10 Charlifue S, Gerhart K. Community integration in spinal cord injury of long duration. NeuroRehabilitation 2004;19(2):91–101.
11 Forchheimer M, Tate DG. Enhancing community re-integration following spinal cord injury. NeuroRehabilitation 2004;19(2): 103–13.
12 Pershouse KJ, Barker RN, Kendall MB, Buettner PG, Kuipers P, Schuurs SB, *et al.* Investigating changes in quality of life and function along the lifespan for people with spinal cord injury. Arch Phys Med Rehabil 2012;93(3):413–9.
13 Whiteneck GG, Gassaway J, Dijkers MP, Lammertse DP, Hammond F, Heinemann AW, *et al.* Inpatient and postdischarge rehabilitation services provided in the first year after spinal cord injury: findings from the SCIRehab Study. Arch Phys Med Rehabil 2011;92(3):361–8.
14 Jang Y, Wang YH, Wang JD. Return to work after spinal cord injury in Taiwan: the contribution of functional independence. Arch Phys Med Rehabil 2005;86(4):681–6.
15 Tooth L, McKenna K, Geraghty T. Rehabilitation outcomes in traumatic spinal cord injury in Australia: functional status, length of stay and discharge setting. Spinal Cord 2003;41(4):220–30.
16 Wilson JR, Grossman RG, Frankowski RF, Kiss A, Davis AM, Kulkarni AV, *et al.* A clinical prediction model for long-term functional outcome after traumatic spinal cord injury based on acute clinical and imaging factors. J Neurotrauma 2012;29(13):2263–71.
17 Ferdiana A, Post MW, de Groot S, Bultmann U, van der Klink JJ. Predictors of return to work 5 years after discharge for wheelchair-dependent individuals with spinal cord injury. J Rehabil Med 2014; 46(10):984–90.
18 Sipski ML, Jackson AB, Gomez-Marin O, Estores I, Stein A. Effects of gender on neurologic and functional recovery after spinal cord injury. Arch Phys Med Rehabil 2004;85(11):1826–36.

19 Wilson JR, Cadotte DW, Fehlings MG. Clinical predictors of neurological outcome, functional status, and survival after traumatic spinal cord injury: a systematic review. J Neurosurg Spine 2012;17(1 Suppl):11–26.
20 Eastwood EA, Hagglund KJ, Ragnarsson KT, Gordon WA, Marino RJ. Medical rehabilitation length of stay and outcomes for persons with traumatic spinal cord injury—1990–1997. Arch Phys Med Rehabil 1999;80(11):1457–63.
21 Fisher CG, Noonan VK, Smith DE, Wing PC, Dvorak MF, Kwon BK. Motor recovery, functional status, and health-related quality of life in patients with complete spinal cord injuries. Spine (Phila Pa 1976) 2005;30(19):2200–7.
22 Celani MG, Spizzichino L, Ricci S, Zampolini M, Franceschini M, Retrospective Study Group on SCI. Spinal cord injury in Italy: A multicenter retrospective study. Arch Phys Med Rehabil 2001;82 (5):589–96.
23 Lysack C, Komanecky M, Kabel A, Cross K, Neufeld S. Environmental factors and their role in community integration after spinal cord injury. Can J Occup Ther 2007;74 Spec No. :243–54.
24 Whiteneck G, Gassaway J, Dijkers M, Jha A. New approach to study the contents and outcomes of spinal cord injury rehabilitation: the SCIRehab Project. J Spinal Cord Med 2009;32(3):251–9.
25 Xiong T, Hartley S. Challenges in linking health-status outcome measures and clinical assessment tools to the ICF. Adv Physiother. 2008;10(3):152–6.
26 Jette AM. Toward a common language for function, disability, and health. Phys Ther 2006;86(5):726–34.
27 Biering-Sørensen F, Scheuringer M, Baumberger M, Charlifue SW, Post MW, Montero F, *et al.* Developing core sets for persons with spinal cord injuries based on the International Classification of Functioning, Disability and Health as a way to specify functioning. Spinal Cord 2006;44(9):541–6.
28 Vall J, Costa CM, Pereira LF, Friesen TT. Application of International Classification of Functioning, Disability and Health (ICF) in individuals with spinal cord injury. Arq Neuropsiquiatr 2011;69(3):513–8.
29 PRISMA. The PRISMA Statement.1 Available from: http://www.prisma-statement.org/statement.htm. Accessed 26 August 2016.
30 Kirshblum SC, Burns SP, Biering-Sorensen F, Donovan W, Graves DE, Jha A, *et al.* International standards for neurological classification of spinal cord injury, revised 2011. J Spinal Cord Med 2011 Nov;34(6):535–46.
31 Hayden JA, van der Windt DA, Cartwright JL, Cote P, Bombardier C. Assessing bias in studies of prognostic factors. Ann Intern Med 2013;158(4):280–6.
32 Backus D, Gassaway J, Smout RJ, Hsieh CH, Heinemann AW, DeJong G, *et al.* Relation between inpatient and postdischarge services and outcomes 1 year postinjury in people with traumatic spinal cord injury. Arch Phys Med Rehabil 2013;94(4 Suppl):S165–74.
33 Hsieh CH, DeJong G, Groah S, Ballard PH, Horn SD, Tian W. Comparing rehabilitation services and outcomes between older and younger people with spinal cord injury. Arch Phys Med Rehabil 2013;94(4 Suppl):S175–86.
34 Horn SD, Smout RJ, DeJong G, Dijkers MP, Hsieh CH, Lammertse D, *et al.* Association of various comorbidity measures with spinal cord injury rehabilitation outcomes. Arch Phys Med Rehabil 2013;94(4 Suppl):S75–86.
35 Tian W, Hsieh CH, DeJong G, Backus D, Groah S, Ballard PH. Role of body weight in therapy participation and rehabilitation outcomes among individuals with traumatic spinal cord injury. Arch Phys Med Rehabil 2013;94(4 Suppl):S125–36.
36 Cahow C, Gassaway J, Rider C, Joyce JP, Bogenschutz A, Edens K, *et al.* Relationship of therapeutic recreation inpatient rehabilitation interventions and patient characteristics to outcomes following spinal cord injury: the SCIRehab project. J Spinal Cord Med 2012;35(6):547–64.
37 Wilson JR, Davis AM, Kulkarni AV, Kiss A, Frankowski RF, Grossman RG, *et al.* Defining age-related differences in outcome after traumatic spinal cord injury: analysis of a combined, multicenter dataset. Spine J 2014;14(7):1192–8.
38 Nallamothu BK, Hayward RA, Bates ER. Key Issues in Outcomes Research. Circulation 2008;118:1294–303.
39 Kristman V, Manno M, Cote P. Loss to follow-up in cohort studies: how much is too much? Eur J Epidemiol 2004;19(8):751–60.
40 Simon HA. The architecture of complexity: Springer; 1991.
41 Association AS-L-H. International Classification of Functioning, Disability, and Health (ICF) Available from: http://www.asha.org/slp/icf/. Accessed 26 August 2016.
42 Portney LG, Watkins MP. Foundations of clinical research: applications to practice: Prentice Hall Upper Saddle River, NJ; 2000.
43 Burns SP, Golding DG, Rolle WA, Jr., Graziani V, Ditunno JF, Jr. Recovery of ambulation in motor-incomplete tetraplegia. Arch Phys Med Rehabil 1997;78(11):1169–72.
44 Lindberg J, Kreuter M, Taft C, Person LO. Patient participation in care and rehabilitation from the perspective of patients with spinal cord injury. Spinal Cord 2013;51(11):834–7.
45 Whiteneck G, Meade MA, Dijkers M, Tate DG, Bushnik T, Forchheimer MB. Environmental factors and their role in participation and life satisfaction after spinal cord injury. Arch Phys Med Rehabil 2004;85(11):1793–803.
46 Dijkers MP, Yavuzer G, Ergin S, Weitzenkamp D, Whiteneck GG. A tale of two countries: environmental impacts on social participation after spinal cord injury. Spinal Cord 2002;40(7): 351–62.
47 House LA, Russell HF, Kelly EH, Gerson A, Vogel LC. Rehabilitation and future participation of youth following spinal cord injury: caregiver perspectives. Spinal Cord 2009;47(12):882–6.
48 van der Putten JJ, Stevenson VL, Playford ED, Thompson AJ. Factors affecting functional outcome in patients with nontraumatic spinal cord lesions after inpatient rehabilitation. Neurorehabil Neural Repair 2001;15(2):99–104.
49 McKinley WO, Seel RT, Gadi RK, Tewksbury MA. Nontraumatic vs. traumatic spinal cord injury: a rehabilitation outcome comparison. Am J Phys Med Rehabil 2001;80(9):693–9; quiz 700, 716.
50 Ronen J, Itzkovich M, Bluvshtein V, Thaleisnik M, Goldin D, Gelernter I, *et al.* Length of stay in hospital following spinal cord lesions in Israel. Spinal Cord 2004;42(6):353–8.
51 Sumida M, Fujimoto M, Tokuhiro A, Tominaga T, Magara A, Uchida R. Early rehabilitation effect for traumatic spinal cord injury. Arch Phys Med Rehabil 2001;82(3):391–5.
52 Furlan JC, Hitzig SL, Craven BC. The influence of age on functional recovery of adults with spinal cord injury or disease after inpatient rehabilitative care: a pilot study. Aging Clin Exp Res 2013;25(4):463–71.
53 Furlan JC, Fehlings MG. The impact of age on mortality, impairment, and disability among adults with acute traumatic spinal cord injury. J Neurotrauma 2009;26(10):1707–17.
54 Putzke JD, Barrett JJ, Richards JS, DeVivo MJ. Age and spinal cord injury: an emphasis on outcomes among the elderly. J Spinal Cord Med 2003;26(1):37–44.
55 van Eijk-Hustings Y, Kroese M, Tan F, Boonen A, Bessems-Beks M, Landewe R. Challenges in demonstrating the effectiveness of multidisciplinary treatment on quality of life, participation and health care utilisation in patients with fibromyalgia: a randomised controlled trial. Clin Rheumatol 2013;32(2):199–209.