Walking-related outcomes for individuals with traumatic and non-traumatic spinal cord injury inform physical therapy practice

**Andresa R. Marinho^{1,2}, Heather M. Flett^{1,2}, Catharine Craven^{1,2},
C. Andrea Ottensmeyer¹, Daria Parsons^{1,2}, Molly C. Verrier^{1,2}**

¹University of Toronto, Toronto, ON, Canada, ²Toronto Rehabilitation Institute – UHN, Toronto, ON, Canada

Objectives: To describe and compare patient demographics, inpatient lengths of stay (LOS), and walking-related functional outcomes of individuals with spinal cord injuries (SCIs) of traumatic (TSCI) and non-traumatic (NTSCI) etiologies. To contrast these features between individuals who walked from those who did not walk at discharge from inpatient rehabilitation.

Design: Prospective observational study; comparisons between TSCI and NTSCI, walkers and non-walkers. Information collected as a pilot project within a provincial SCI informatics strategy.

Setting: Rehabilitation hospital specialized for SCIs.

Participants: Adults with NTSCI ($n = 31$) or TSCI ($n = 59$) admitted to inpatient rehabilitation, 2007–2009.

Outcome measures: Lower-extremity motor scores (LEMS), spinal cord independence measure version III (SCIM-III) total and mobility subscores, functional independence measure (FIM), Length of Stay (LOS) at inpatient facilities.

Results: Groups (NTSCI vs. TSCI) did not differ in the proportion of individuals that achieved “walker” status (SCIM-III mobility indoors (MI) score ≥ 3 at rehab discharge) ($P = 0.41$, 48.9% overall). Inpatient LOS at both acute care and rehabilitation facilities did not differ between groups; however, TSCI non-walkers had longer inpatient rehabilitation LOS than TSCI walkers. Among walkers, improvement was shown on all three mobility subscores of the SCIM-III between admission and discharge from rehabilitation; highest significance was shown on the SCIM-III MI. Walking status at discharge (SCIM-III MI) was most strongly correlated with LEMS at rehab admission ($r = 0.71$, $P < 0.001$).

Conclusion: Walking outcomes are comparable among individuals with NTSCI vs. TSCI admitted for specialized SCI rehabilitation. Routine use of SCIM-III mobility items for assessment of walking outcome is recommended for inpatient rehabilitation.

Keywords: Myelopathy, Spinal cord injuries, Traumatic, Non-traumatic, Outcome measures, Rehabilitation, Walking, Mobility, Locomotor training, Paraplegia, Tetraplegia

Introduction

Recovery of ambulation is the primary goal of many individuals with spinal cord injury (SCI)¹ and the aim of several new pharmacological and rehabilitative approaches.^{2,3} However, there are multiple physical and environmental determinants of the recovery of walking ability following SCI.^{4,5} Currently, evidence is insufficient to show the superiority of one type of locomotor training method over another,⁶ although the intensity and timing of treatment are important

determinants of success.⁷ In spinal cord rehabilitation, as elsewhere, the choice of outcome measures used to quantify walking ability will influence the ability of clinicians to make appropriate decisions regarding care (e.g. prognosis, choice of intervention(s), discharge timing, and adaptive equipment needs) and our ability to evaluate the success of rehabilitation interventions. Hence, the choice of outcome measure is critical.

Recent reviews of outcome measures used to assess gait and walking ability in individuals with SCI have highlighted the strengths and limitations of several commonly used measures^{8–10} Timed measures such as the 10 meter walk test (10mWT), 6 minute walk test (6MWT),

Correspondence to: Molly C. Verrier, Centre for Function and Well-Being, University of Toronto, 160-500 University Avenue, Toronto, ON, Canada M5G 1V7. Email: m.verrier@utoronto.ca

and the Timed-Up and Go Test (TUG) show excellent reliability, construct validity, and responsiveness to change.^{9–11} However, these tests do not include individuals that are dependent or partially dependent on a wheelchair for locomotion, a common situation at admission to inpatient rehabilitation. Categorical measures developed specifically for individuals with SCI, the Walking Index for Spinal Cord Injury (WISCI-II)¹² and the three walking items of the SCIM-III: mobility indoors (MI) (indoors and outdoors, on even surfaces), mobility for moderate distances (10/100 m), and mobility outdoors (>100 m)¹³ encompass multiple levels of assistance often required for ambulation training, including the use of gait aids, orthoses, and/or a wheelchair. The WISCI-II and SCIM-III mobility subscales have robust reliability and construct validity.⁹ SCIM-III has also been shown to have well-ordered categories for MI and moderate distances.¹⁴ Both the WISCI and the SCIM have greater reliability and internal consistency than the locomotor items of the functional independence measure (FIM_L),⁹ which have been used far more commonly in this population, despite not being designed for this population.

Use of outcome measures that encompass a broad range of mobility levels across the spectrum of SCIs is important, given increasing attention to the processes and pathophysiology of rehabilitation of individuals with SCIs of non-traumatic etiology (NTSCI). Until recently, the majority of research attention has been focused on SCIs with traumatic causes (TSCI), particularly in regions where TSCI predominates.^{15,16} However, individuals with NTSCI represent a large proportion of the SCI population; they tend to be older, less likely to be male, and more likely to have an incomplete SCI when compared with individuals with TSCI.^{17–19}

The number of studies that compare the demographics, healthcare trajectories, and complications of individuals with TSCI vs. individuals with NTSCI is growing; however, there is still a scarcity of data regarding the functional outcomes of individuals with NTSCI. The few published studies on walking ability in NTSCI suggest similar walking outcomes are achievable by individuals with NTSCI or TSCI.^{19–21} Since the SCIM-III was designed specifically for individuals with SCI, shows excellent psychometric properties, and has walking items ordered with regard to level of assistance and adaptive equipment required, we used the SCIM-III to describe walking outcomes of individuals with either NTSCI or TSCI.

Therefore, the primary objectives of the current study were: (1) to describe and compare patient

characteristics, inpatient stay, and walking-related functional outcomes of individuals with TSCI and NTSCI and (2) to contrast these features between individuals who were able to walk or not at the time of discharge from inpatient rehabilitation. Walking was defined as a SCIM-III MI subscore ≥ 3 . A secondary objective was to identify potential predictors of walking ability at discharge from inpatient rehabilitation.

Methods

This study was part of pilot project of a provincial SCI informatics strategy, which was developed to facilitate understanding of SCI health services and patient status across the continuum of care.²² Data were collected at an inpatient rehabilitation facility, which specializes in care for adults with SCIs. Ethics approval was obtained from the Toronto Rehabilitation Institute Research Ethics Board. All applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed.

Eligible participants included consenting English-speaking adults (≥ 16 years) with SCI of traumatic or non-traumatic etiology admitted for their first episode of rehabilitation between April 1 2007 and August 30 2009. These etiologies of spinal cord pathology are defined elsewhere.^{22,23} All participants with NTSCI etiology had spinal surgery and were admitted to inpatient rehabilitation from an acute care facility. Eligible participants with SCI of traumatic etiology were recruited from April 2007 through December 2009 provided they had consented to study participation at one of the affiliated tertiary-level spine acute care facilities (four sites in two cities) prior to rehab admission. Eligible participants with SCI of non-traumatic etiology were recruited at rehab admission between February 2008 and December 2008. The differences in the timeline for traumatic vs. non-traumatic participant accrual were due to the differences in the timing of the Research Ethics Board approval.

Participants provided written informed consent for prospective data collection via interview, chart abstraction, and/or direct observation regarding their demographic characteristics, neurological impairment, and rehabilitation outcomes including walking measures.

Demographic and length of stay (LOS) data collected included gender, age (years), total inpatient LOS (time from injury (if TSCI) or surgery (if NTSCI) to discharge from inpatient rehabilitation), acute care inpatient LOS (time from injury/surgery to inpatient rehabilitation admission), and inpatient rehabilitation LOS. At inpatient rehabilitation admission, neurological level of injury, American Spinal Injury Association (ASIA)

Impairment Scale (AIS), total motor score, Upper Extremity Motor Score (UEMS) and Lower Extremity Motor Score (LEMS) were collected based on the International Standards for Neurological Classification of SCI.²⁴ For participants with NTSCI, the procedure was identical, with the exception of assignment of neurological level of injury, which was labeled by the investigator based on the following criterion. The neurological level of injury was defined as the most caudal segment with normal motor and sensory function, provided the sensory level was not more than three dermatomes above the motor level. In the event of a discordance of more than three levels between the motor and sensory level, the motor level was recorded. The sensory level was physician assigned as “the most caudal segment with normal light touch and pin-prick sensation.”

The participant's functional level was described using the FIM total score as well as the SCIM-III total score and three mobility subscales of the SCIM-III, “mobility indoors,” “mobility for moderate distances,” and “mobility outdoors” at inpatient rehabilitation admission and discharge. The FIM_L was not specifically examined, as the clinicians must choose at admission whether to score this item regarding wheelchair use or ambulation, based on their prediction of what the individual's primary mode of locomotion will be at discharge. Uncertainty regarding consistent application of the threshold for collecting FIM_L resulted in exclusion of the data.

Walking ability was evaluated further using the *Walking Battery*, a suite of measures routinely used by clinician researchers at the study facility for inpatient rehabilitation assessment.²⁵ This battery included the 10mWT, 6MWT, TUG,⁹ and the WISCI-II.¹² Results from the *Walking Battery* are not presented here as many of these measures exclude participants that could not walk, and preliminary analyses showed no significant differences between those tested in the TSCI and NTSCI groups.

Participants were classified as “walkers” or “non-walkers” irrespective of injury etiology based on their SCIM-III mobility indoors scores. Participants were classified as walkers if they had a SCIM-III MI score ≥ 3 (could walk 10 m indoors and outdoors on even surface, with or without a device, and required supervision or less assistance)¹⁴ at discharge from inpatient rehabilitation, and as non-walkers if their MI score at discharge was ≤ 2 . MI was chosen for this definition as it may provide relevant insight into the individual's mobility and independence in their home,²⁶ functionally important features of a person's health status and well-being.

Statistical analysis

Analyses were conducted using the statistical package SAS 9.2 (SAS Institute Inc., Cary, NC, USA). Univariate distribution analyses were conducted for all variables. Ordinal data were expressed as medians, interquartile ranges, and percentages. Chi-square (χ^2) tests of independence were used to test for differences between groups in gender (TSCI vs. NTSCI, walkers vs. non-walkers within TSCI or NTSCI). Odds ratios and their asymptotic 95% confidence intervals were calculated to compare etiology or walking status between individuals with paraplegia/tetraplegia or complete/incomplete SCIs. Normally distributed data were compared between groups using paired (e.g. admission vs. discharge) or unpaired (e.g. TSCI vs. NTSCI) Student's *t*-tests. Non-normal or ordinal data were tested comparing scores at admission and discharge from inpatient rehabilitation using the Wilcoxon signed rank test; the Mann-Whitney *U* test was used for unpaired comparisons. Spearman rank correlations were calculated between potential predictors of walking ability and the three walking-related items of SCIM-III.

Significance tests were conducted with an overall α -level of 0.05. Multiple comparisons were made in the analysis (92 tests), in three families of hypotheses: whether there were differences in outcome between participants with NTSCI vs. TSCI, differences between walkers and non-walkers with NTSCI, and differences between walkers and non-walkers with TSCI. To avoid false-positive findings with multiple comparisons, we used a modified Bonferroni correction; hence, individual tests were considered significant if the *P* value was smaller than $0.05/(92/3) = 0.0016$.

Results

Demographics and injury types

Data were collected for 95 consenting participants with SCI admitted for inpatient rehabilitation between 2007 and 2009. Five participants with TSCI were excluded from the study due to missing SCIM-III MI at discharge, precluding classification as a walker or non-walker by the study definition (Fig. 1). Of the 90 participants included in the analysis, 31 (34.4%) had incurred a NTSCI and 59 (65.6%) a TSCI. Males were the predominant gender in both groups (64.5% in NTSCI and 78.0% in TSCI, Table 1), with no significant difference between groups in gender split (χ^2 test, *P* = 0.17). The participants with NTSCI were significantly older than the TSCI participants (median (interquartile range): 60 (48–66) vs. 43 (28–58) years; Mann-Whitney *U* test: *P* < 0.001). Participants with NTSCI were more likely than those with TSCI to have an incomplete than

Figure 1 Participants with TSCI and NTSCI who walked and did not walk at discharge from inpatient rehabilitation. There was no statistical difference in the proportion of walkers to non-walkers between TSCI and NTSCI (χ^2 test, $P = 0.41$).

complete SCI (odds ratio = 4.1; 95% confidence interval = 1.1, 15.1).

In total, 44 participants (48.9%) walked at discharge from rehabilitation (i.e. had a SCIM-III MI score ≥ 3) (Fig. 1). No difference was found in the proportion of walkers to non-walkers between NTSCI and TSCI groups (χ^2 test of independence, $P = 0.41$). No statistically significant differences were found between walkers and non-walkers in gender or age in either the NTSCI or TSCI groups (Table 1). There was a higher

proportion of individuals with paraplegia among non-walkers with NTSCI than walkers with NTSCI (odds ratio = 10.7; 95% confidence interval = 1.1–101.3); no significant difference was found in participants with TSCI (odds ratio = 1.8; 95% confidence interval = 0.6–5.0). None of the participants with complete SCIs could be defined as walkers using our definition. Among non-walkers, 77% of participants with NTSCI and 42% of participants with TSCI had incomplete SCIs. Due to the small sample sizes for some levels of

Table 1 Demographics and injury characteristics of individuals with NTSCI and TSCI who walked or did not walk at discharge from inpatient rehabilitation

	NTSCI	TSCI	NTSCI		TSCI	
			Non-walkers	Walkers	Non-walkers	Walkers
<i>Gender</i>	<i>n</i> = 31	<i>n</i> = 59	<i>n</i> = 14	<i>n</i> = 17	<i>n</i> = 32	<i>n</i> = 27
Male: <i>n</i> (%)	20 (64.5)	46 (78.0)	8 (57.1)	12 (70.6)	24 (75.0)	22 (81.5)
Female: <i>n</i> (%)	11 (35.5)	13 (22.0)	6 (42.9)	5 (29.4)	8 (25.0)	5 (18.5)
<i>Age (years)</i>	<i>n</i> = 31	<i>n</i> = 59	<i>n</i> = 14	<i>n</i> = 17	<i>n</i> = 32	<i>n</i> = 27
Median (IQR)	60* (48–66)	43* (28–58)	60.5 (57–66)	58 (47–65)	41.5 (28.5–58.5)	47 (26–58)
<i>Neurological status</i>	<i>n</i> = 30	<i>n</i> = 58	<i>n</i> = 14	<i>n</i> = 17	<i>n</i> = 31	<i>n</i> = 27
Paraplegia: <i>n</i> (%)	21 (70.0)	28 (48.3)	12** (92.3)	9** (52.9)	17 (54.8)	11 (40.7)
Tetraplegia: <i>n</i> (%)	9 (30.0)	30 (51.7)	1** (7.7)	8** (47.1)	14 (45.2)	16 (59.3)
Incomplete: <i>n</i> (%)	27** (90.0)	40** (69.0)	10 (76.9)	17 (100.0)	13 (41.9)	27 (100.0)
Complete: <i>n</i> (%)	3** (10.0)	18** (31.0)	3 (23.1)	0 (0.0)	18 (58.1)	0 (0.0)
<i>Initial level of injury</i>	<i>n</i> = 30	<i>n</i> = 59	<i>n</i> = 13	<i>n</i> = 17	<i>n</i> = 32	<i>n</i> = 27
Cervical: <i>n</i> (%)	7 (23.3)	31 (52.5)	1 (7.7)	6 (35.3)	15 (46.9)	16 (59.3)
Thoracic: <i>n</i> (%)	20 (66.7)	24 (40.7)	11 (84.6)	9 (52.9)	16 (50.0)	8 (29.6)
Lumbar: <i>n</i> (%)	3 (10.0)	3 (5.1)	1 (7.7)	2 (11.8)	1 (3.1)	2 (7.4)
Sacral: <i>n</i> (%)	0 (0.0)	1 (1.7)	0 (0.0)	0 (0.0)	0 (0.0)	1 (3.7)
<i>Initial AIS</i>	<i>n</i> = 30	<i>n</i> = 59	<i>n</i> = 13	<i>n</i> = 17	<i>n</i> = 32	<i>n</i> = 27
A: <i>n</i> (%)	3 (10.0)	18 (30.5)	3 (23.1)	0 (0.0)	18 (56.3)	0 (0.0)
B: <i>n</i> (%)	2 (6.7)	3 (5.1)	1 (7.7)	1 (5.9)	2 (6.3)	1 (3.7)
C: <i>n</i> (%)	5 (16.7)	16 (27.1)	3 (23.1)	2 (11.8)	9 (28.1)	7 (25.9)
D: <i>n</i> (%)	20 (66.7)	22 (37.3)	6 (46.1)	14 (82.3)	3 (9.4)	19 (70.4)

NTSCI, non-traumatic spinal cord injury; TSCI, traumatic spinal cord injury; IQR, interquartile range; AIS, ASIA Impairment Scale.

*Mann–Whitney U test: $P < 0.001$.

**95% confidence interval of odds ratio does not include 1.

injury and AIS grades, it was inappropriate to test for differences between etiologies or walking status for these classifications (Table 1).

Inpatient LOS

No statistical differences were observed in inpatient LOS between participants with TSCI and those with NTSCI (Table 2). Within the TSCI group, total inpatient LOS was significantly longer among non-walkers (median = 142.5 days) than walkers (median = 98 days; Mann–Whitney *U* test: $P < 0.001$). Median inpatient rehabilitation LOS was also significantly longer in non-walkers (median = 114.5 days) compared to walkers (median = 81 days; Mann–Whitney *U* test: $P < 0.001$) among TSCI participants. The difference in median total inpatient LOS between non-walkers and walkers with TSCI was 44.5 days; the difference in median inpatient rehabilitation LOS was 33.5 days. Within the NTSCI group, no statistical differences were observed in LOS between walkers and non-walkers, although non-significant trends towards longer total inpatient LOS and inpatient rehabilitation LOS appeared among non-walkers.

Functional status and motor score changes during inpatient rehabilitation

A statistically significant increase from inpatient rehabilitation admission to discharge was found in SCIM-III total scores and FIM total scores for all groups (NTSCI and TSCI, walkers and non-walkers; Table 3). Participants with NTSCI tended to have higher total FIM scores (median (interquartile range): 78(70–89)) at admission to inpatient rehabilitation than participants with TSCI (66(54–77), $P < 0.001$). Total SCIM-III at admission was not statistically different between groups at the stringent levels used in this study (Mann–Whitney *U* test: $P = 0.003$), although a trend towards higher values among the NTSCI group might be noted (NTSCI: 65.5(55–74), TSCI: 51(25–66)). Total SCIM-III at discharge was similar between participants with NTSCI (76(66–87)) and those with TSCI (71.5(58–90.5), Mann–Whitney *U* test: $P = 0.27$), while total FIM score was higher at discharge for participants with NTSCI (117(108–121)) than for participants with TSCI (98(88–117), Mann–Whitney *U* test: $P < 0.001$).

Looking at AIS motor scores, participants with NTSCI had significantly higher total motor scores at admission (total motor score: 78(67–84)) than participants with TSCI at admission (50(45.5–73.5), Mann–Whitney *U* test: $P < 0.001$), although the UEMS and LEMS scores separately were not

Table 2 LOS (days) across the continuum of care for individuals with NTSCI and TSCI admitted for tertiary-level inpatient rehabilitation

	NTSCI	TSCI	NTSCI × TSCI <i>P</i> value*	NTSCI			TSCI		
				Non-walkers	Walkers	<i>W</i> × <i>NW</i> <i>P</i> value*	Non-walkers	Walkers	<i>W</i> × <i>NW</i> <i>P</i> value*
Total inpatient stay (tLOS)									
Median (IQR)	122 (101–153)	126 (95–159)	0.87	143.5 (113–163)	107 (83–148)	0.10	142.5 (124.5–176.5)	98 (75–122)	<0.001
<i>n</i>	29	59		14	15		32	27	
Acute care inpatient stay (acLOS)									
Median (IQR)	20 (14–30)	18 (13–31)	0.61	21 (14–33)	20 (14–29)	0.59	18 (13.5–37.5)	19 (13–24)	0.63
<i>n</i>	29	59		14	15		32	27	
Rehabilitation inpatient stay (rLOS)									
Median (IQR)	93 (59–115)	99 (75–127)	0.47	108.5 (91–127)	93 (57–99)	0.08	114.5 (95–138)	81 (42–106)	<0.001
<i>n</i>	31	59		14	17		32	27	

NTSCI, non-traumatic spinal cord injury; TSCI, traumatic spinal cord injury; *W*, walker at discharge from inpatient rehabilitation; *NW*, non-walker at discharge from inpatient rehabilitation; IQR, interquartile range.

*Comparisons made using Mann–Whitney *U* tests.

Table 3 Functional status and AIS motor scores of walkers and non-walkers with NTSCI and TSCI at admission and discharge from inpatient rehabilitation

	NTSCI (n = 31)						TSCI (n = 59)					
	Non-walkers (n = 14)			Walkers (n = 17)			Non-walkers (n = 32)			Walkers (n = 27)		
	Admission*	Discharge*	WSR P value	Admission*	Discharge*	WSR P value	Admission*	Discharge*	WSR P value	Admission*	Discharge*	WSR P value
<i>Independence measures</i>												
SCIM-III Total (0–100)	58 (54–65)	65.5 (61–71)	47.5	74 (64–86)	87 (81–94)	45.5	34 (23–57)	60.5 (27–71)	153.5	65.5 (42–90.5)	91 (84–100)	100.5
n	14	14	0.001	16	17	<0.001	30	30	<0.001	24	26	<0.001
FIM total (0–126)	70.5 (68–77)	108 (104–111)	52.5	86 (78–96)	120 (119–123)	76.5	60 (48–68)	95 (70–115)	203	69 (59–96)	98 (95–120)	171.5
n	14	14	<0.001	17	17	<0.001	30	29	<0.001	27	26	<0.001
<i>AIS motor scores (MS)</i>												
Total MS (0–100)	67 (50–74)	84.5 (74.5–90)	27.5	82 (77–87)	93 (87–95)	60.0	50 (25–50)	50 (46–63)	95	75.5 (54–90)	92 (84–98)	138
n	13	12	0.002	17	17	0.003	30	29	<0.001	26	25	<0.001
UEMS (0–50)	50 (50–50)	50 (50–50)	1.5	50 (46–50)	50 (48–50)	2.0	50 (16–50)	50 (39–50)	45.5	43.5 (23–50)	48 (41–50)	60
n	13	12	0.50	17	17	0.80	31	29	<0.001	27	25	<0.001
LEMS (0–50)	18 (0–24)	35 (24.5–43)	27.5	37 (31–42)	45 (41–48)	76.5	0 (0–14)	0 (0–20)	39	40 (24–46)	48 (40–50)	115.5
n	13	12	0.002	17	17	<0.001	31	31	<0.001	26	25	<0.001

AIS, ASIA Impairment Scale; Lower Extremity Motor Score; NTSCI, non-traumatic spinal cord injury; TSCI, traumatic spinal cord injury; SCIM-III, Spinal Cord Independence Measure; UEMS, Upper Extremity Motor Score; WSR, Wilcoxon signed rank test score.

*Data are presented as median (interquartile range).

significantly different between NTSCI and TSCI at admission. At discharge, total motor score, UEMS, and LEMS were not statistically different between NTSCI and TSCI groups, although in general, scores for individuals with TSCI trended lower than NTSCI on all three variables.

Participants with TSCI (both walkers and non-walkers) showed statistically improved total motor scores, UEMS, and LEMS on discharge from inpatient rehabilitation (Table 3). In contrast, among participants with NTSCI, the strongest evidence for change in motor scores was shown in the LEMS among walkers. No significant change was shown among the NTSCI group in the UEMS, which might be expected given their very high UEMS values at admission. Trends towards improvement in total motor score and UEMS among non-walkers with NTSCI were not statistically significant at our stringent α -levels.

Walking outcomes

Participants with NTSCI showed scores at admission and discharge in SCIM-III MI, moderate distance, and mobility outdoors, which were not statistically distinguishable from those of participants with TSCI (Mann–Whitney *U* tests, non-significant for all six comparisons, data not presented). Non-walkers (participants with SCIM-III MI scores <3 at discharge) with either NTSCI or TSCI showed no statistical improvement from admission to discharge in these three scales. However, walkers in both etiology groups showed clear improvement on the SCIM-III MI (Table 4). At our stringent α -levels, only walkers with TSCI showed significant improvement from admission to discharge on the SCIM-III moderate distances, although trends toward improvement appeared among NTSCI walkers using SCIM-III moderate distances, and in both etiology groups using the SCIM-III mobility outdoors (Table 4).

Walking predictors

With all participants' data pooled, the potential predictor of walking ability that correlated most strongly with SCIM-III MI at discharge was LEMS at admission to inpatient rehabilitation (Table 5). Initial LEMS also showed a strong positive association with SCIM-III moderate distances and mobility outdoors. Significant negative associations were found between total inpatient LOS and inpatient rehabilitation LOS and SCIM-III MI, moderate distances, and mobility outdoors. Weaker negative associations were also found between acute care inpatient LOS and SCIM-III moderate distances and mobility outdoors. There were no significant

Table 4 SCIM-III mobility item scores at admission and discharge of individuals designated as “walkers” at discharge from inpatient rehabilitation

	NTSCI			TSCI		
	Admission	Discharge	WSR P value	Admission	Discharge	WSR P value
SCIM-III MI*	4 (2–4)	4 (4–6)	33.0	2 (1–6)	6 (5–8)	115.5
<i>n</i>	17	17	0.001	27	27	<0.001
SCIM-III MOD*	4 (2–4)	4 (4–6)	27.5	2 (1–6)	6 (4–8)	91
<i>n</i>	17	17	0.002	27	26	<0.001
SCIM-III OUT*	3 (1.5–4)	4 (4–6)	27.5	1.5 (1–6)	6 (2–8)	44
<i>n</i>	16	17	0.002	24	26	0.003

NTSCI, non-traumatic spinal cord injury; TSCI, traumatic spinal cord injury; SCIM-III MI, SCIM mobility indoors; SCIM-III MOD, SCIM moderate distance; SCIM-III OUT, SCIM mobility outdoors; WSR, Wilcoxon signed rank test score.

*Data are presented as median (interquartile range).

associations between age or initial UEMS and walking outcomes on the SCIM-III. Correlations were also calculated separately for participants with NTSCI and those with TSCI; similar associations were observed.

Discussion

In this prospective observational study, individuals with SCIs treated at a specialized inpatient rehabilitation center were compared regarding injury etiology and walking outcome. Individuals with TSCI formed the majority of patients in the sample; however, individuals with NTSCI formed a substantial proportion, in keeping with recent epidemiological trends of an increasing incidence of those with NTSCI admitted for inpatient rehabilitation. Indeed, recent studies have shown that across the province of Ontario, Canada,¹⁸

and in some other regions,^{17,19,27} individuals with NTSCI form the majority of SCI cases in inpatient rehabilitation. While individuals with NTSCI or TSCI differed in a number of important characteristics at admission (explored further below), the proportion of individuals that could be considered “walkers” at discharge, framed using the SCIM-III mobility indoors, was not significantly different between the NTSCI and TSCI groups. This supports similar findings from an Italian spinal cord unit,^{19,21} and highlights the importance of inpatient rehabilitation for individuals with NTSCI.

As the sample size was relatively small, the demographics of our sample may not be completely representative of the broader population of individuals with SCI in this region and should be interpreted with caution.

Table 5 Correlations between potential predictors of walking ability and SCIM-III mobility item scores at discharge from inpatient rehabilitation

Potential predictors		SCIM at Discharge		
		SCIM-III MI	SCIM-III MOD	SCIM-III OUT
Age (years)	<i>r</i>	−0.004	0.017	−0.041
	<i>P</i> value	0.97	0.89	0.71
	<i>n</i>	90	87	88
Total inpatient stay (tLOS)	<i>r</i>	−0.641	−0.641	−0.667
	<i>P</i> value	<0.001	<0.001	<0.001
	<i>n</i>	88	85	86
Acute care inpatient stay (acLOS)	<i>r</i>	−0.202	−0.281	−0.308
	<i>P</i> value	0.06	0.009	0.004
	<i>n</i>	88	85	86
Rehabilitation inpatient stay (rLOS)	<i>r</i>	−0.580	−0.567	−0.565
	<i>P</i> value	<0.001	<0.001	<0.001
	<i>n</i>	90	87	88
Initial UEMS	<i>r</i>	0.094	0.150	0.202
	<i>P</i> value	0.39	0.17	0.06
	<i>n</i>	87	84	85
Initial LEMS	<i>r</i>	0.710	0.700	0.662
	<i>P</i> value	<0.001	<0.001	<0.001
	<i>n</i>	88	85	86

SCIM-III MI, SCIM-III mobility indoors; SCIM-III MOD, SCIM-III moderate distance; SCIM-III OUT, SCIM-III mobility outdoors; UEMS, AIS upper extremity motor score; LEMS, AIS lower extremity motor score; *r*, Spearman rank correlation.

However, our findings agree with previous comparative studies showing that individuals with NTSCI tend to be older than individuals with TSCI.^{15,17–19,21,27,28} Both etiology groups included a higher prevalence of males, as reported previously,^{15,17–19,21,27,28} however, in contrast to many other studies,^{16–20,27} no statistical difference in male:female ratio was found between the NTSCI and TSCI groups. As might be expected from the nature of the etiologies, and seen elsewhere,^{16,17,19,21,28} we found a larger proportion of persons with NTSCI to have incomplete SCIs, compared to those with TSCI. We observed a potential trend toward a larger proportion of individuals in the NTSCI group with paraplegia than in the TSCI group, although this was not a statistically significant difference. This potential difference has been found previously in population-based samples^{15,17,27} and at single institutions.¹⁶ Since common causes of NTSCI are tumors, degenerative processes, and iatrogenic processes in the thoracic and lumbosacral regions,¹⁶ paraplegia might be expected to be more common than tetraplegia in this group. We also observed a larger proportion of individuals with NTSCI who were not “walkers” at discharge to have paraplegia, than among those who were “walkers”; however, this may simply be due to the neurological status of the individuals with NTSCI at admission.

We found no significant difference in the inpatient rehabilitation LOS between NTSCI and TSCI groups, also seen in two other single institution studies.^{16,20} However, this finding could be attributed to the practice environment rather than rehabilitation requirements. Other studies, including population-based analyses,^{18,27} single-institutions²⁸ and matched-pair/matched-block designs^{21,29} have shown longer inpatient rehabilitation LOS for individuals with TSCI than with NTSCI. As discharge criteria, discharge considerations (e.g. availability of community supports, supported living environments and attendant care needs) and overall health funding models may differ by region and institution, it is difficult to tease apart the reasons for this variation between studies. More insight into inpatient rehabilitation LOS in our study may emerge from the finding that while inpatient rehabilitation LOS did not differ by etiology, non-walkers in the TSCI group (with a similar trend likely in the NTSCI group) stayed longer as an inpatient compared to the walkers. Although we were not able to investigate the causes for this difference explicitly, it is plausible that more numerous medical complications^{16,21} and the more complex discharge requirements of non-walkers (e.g. accessible housing, funding for wheelchair(s), additional

adaptive equipment needs, and need for physical assistance) may explain their prolonged inpatient rehabilitation LOS.

Individuals with NTSCI presented with significantly higher total motor scores and total FIM scores at admission than did individuals with TSCI, similar to previous comparative studies.^{16,19,20,27–29} All groups (NTSCI, TSCI, walkers, and non-walkers within each) showed statistically significant improvement from admission to discharge on the SCIM-III total and FIM total scores, although the largest improvements in motor scores (total motor score, UEMS, and LEMS) appeared to be shown within the TSCI group, walkers, and non-walkers. We observed similar median inpatient rehabilitation LOS between etiology groups; however, inpatient rehabilitation LOS is not a surrogate measure of therapy type, frequency, or intensity. For example, individuals with NTSCI due to malignancy may have participated in fewer SCI therapy hours per week than individuals with TSCI as a consequence of attending off-site chemo- or radiation therapy sessions. Hence, simple calculations of functional efficiency based on LOS could be misleading and it would be important in future to assess time in therapy directed toward functional mobility rather than just LOS.

To gain insight into walking status at discharge, several variables were correlated with SCIM-III mobility items. LEMS showed the strongest correlation with walking ability, framed here in the context of SCIM-III mobility indoors. Other studies have shown that LEMS is an important predictor of walking ability;³⁰ LEMS at 1-month post-injury appears to hold prognostic value of an individual's ability to walk in the community at 1 year.^{31,32} A clinical prediction rule for walking outcomes measured on the SCIM-III mobility indoors, developed and tested on individuals with TSCI, appears to have good utility and includes two components of the LEMS (motor score for knee extension (L3) and for plantar flexion (S1)), along with a dichotomous variable for age and light touch sensation at L3 and S1.³³ This type of prognostic equation will likely be useful to clinicians and holds promise as it was developed through a large, international sample of individuals; validation with individuals with NTSCI will be useful given this large and growing population.

Like LEMS, inpatient rehabilitation LOS and total inpatient LOS were associated with walking outcomes on the SCIM-III MI scale, although with an inverse relationship. As shown above, non-walkers with TSCI tended to have longer inpatient rehabilitation LOS than walkers; this is likely true within NTSCI as well. Hence, LOS should not be considered a simple predictor

of walking ability, but rather a reflection of the complex needs of individual inpatients. The issue of rehabilitation LOS is highly sensitive, as inpatient rehabilitation of SCIs is resource-intensive, and health system decision-makers may look increasingly to rehabilitation therapy provision in outpatient settings. Outpatient therapy is critical, as functional gains may be realized over 18 months or longer from the time of SCI^{32,34} and inpatient rehabilitation for this time span is likely inappropriate. However, early discharge from inpatient rehabilitation may impact on patient outcomes substantially when appropriate outpatient services are not available, when early decisions regarding choice of wheelchairs/gait aids required by individuals in the community are forced, and when important, achievable functional milestones are not yet met during inpatient rehabilitation. Achieving the ability to walk should be a rehabilitation goal whenever possible, as individuals with SCI who remain primarily wheelchair users are deemed to be at higher risk than those who are functional walkers for severe and costly health complications. Hence, walking is important not solely for function and independence, but also for maintenance of health status.

To date, there is a lack of consistency in the literature regarding the definition of walking status after SCI.^{19,30,35,36} The definition of “walker” used in this study, SCIM-III MI ≥ 3 , was chosen to encompass individuals that have the ability to walk within their homes at discharge. Among the three mobility items on the SCIM-III, the strongest signal of improvement from admission to discharge among walkers was shown on the MI (SCIM-III MI) item, for individuals with either NTSCI or TSCI. SCIM-III MI has been used previously as the measure of walking ability in a predictive equation³³ and SCIM-II MI has been shown to be a good indicator of an individual’s ambulatory function in daily life.²⁶ Efforts to quantify “community ambulation” indicate that the ability to ambulate distances of at least 200 m,³⁷ or even greater than 600 m (e.g. in warehouse-style stores),³⁸ are necessary in North American communities. Hence, we recommend use of SCIM-III MI in concert with moderate distances and mobility outdoors to give insight into an individual’s ability to ambulate in the broader community. Explicit testing at these longer “community” distances for high-functioning individuals would give further insight and help mediate the ceiling effect, which can occur with categorical measures.⁹ We feel that the ordering of levels within MI, mobility outdoors, and moderate distances is of key importance. An individual must be able to ambulate without assistance to attain higher

levels, as the need for assistance greatly affects an individual’s perceived independence, self-sufficiency, transportation, and housing options following discharge from inpatient rehabilitation. Indeed, a recent survey of individuals living with TSCI on an average nine years post-injury showed that the best predictors of achieving community ambulation distances were independence with walking and use of one crutch or cane.³⁹ Understanding the true impact at a patient level of a requirement for supervision (as opposed to physical assistance or independence) during walking will be important for prognosticating future care needs, and to inform the design of further studies.

As this study encompassed only individuals treated at a single rehabilitation facility, outcomes may vary in other centers. However, other studies were found to report similar demographics and impairment profiles and reported a similar proportion of functional walkers, which may indicate that our findings are generalizable. We did not specifically compare the type and intensity of rehabilitation services provided to the two groups in order to achieve similar outcomes. It is assumed that practice is similar across units within a single institution. We also recognize that the sample size did not allow stratification of analyses by other factors, which are expected to influence walking outcomes (e.g. completeness of SCI, paraplegia/tetraplegia, comorbidity burden). As the prognosis of functional outcomes and discharge considerations can vary widely within and between these groupings, a large, multi-site study is recommended to enable careful examination of the influence of these factors on walking outcomes.

Conclusion

Individuals with NTSCI can attain similar ambulatory outcomes as individuals with TSCI. It is important to ensure that individuals with either NTSCI or TSCI are offered a sufficient intensity and duration of therapy to achieve walking ability whenever possible, for functional independence, quality of life, and maintenance of health status. We recommend the SCIM-III for wide use in SCI rehabilitation due to its increased relevance over the FIM for individuals with SCI, and the importance it places on independence within mobility subscores. The choice of the outcome measure can have a significant impact on the physical therapy provided and the outcomes and economics of rehabilitation for individuals with SCI.

Acknowledgments

This article is based on the presentation at the 5th National Spinal Cord Injury Conference held in

Toronto, Ontario, Canada in October 2012. Funding was provided by the Ontario Ministry of Health and Long-Term Care (MOHLTC) and the Ontario Neurotrauma Foundation (Grant # SCI-2005-REG-02) for this research as part of the Ontario Spinal Cord Injury Informatics Strategy. The views expressed within this article are not necessarily those of the MOHLTC. The authors thank the participants for their cooperation and the physical therapists at Toronto Rehabilitation Institute – UHN Lyndhurst Centre for their commitment to collecting standardized walking data to assist both their clients and the growth of knowledge in SCI rehabilitation.

References

- 1 Ditunno PL, Patrick M, Stineman M, Ditunno JF. Who wants to walk? Preferences for recovery after SCI: a longitudinal and cross-sectional study. *Spinal Cord* 2008;46(7):500–6.
- 2 Maric O, Zörner B, Dietz V. Levodopa therapy in incomplete spinal cord injury. *J Neurotrauma* 2008;25(11):1303–7.
- 3 Hornby TG, Zemon DH, Campbell D. Robotic-assisted, body-weight-supported treadmill training in individuals following motor incomplete spinal cord injury. *Phys Ther* 2005;85(1):52–66.
- 4 Barbeau H, Nadeau S, Garneau C. Physical determinants, emerging concepts, and training approaches in gait of individuals with spinal cord injury. *J Neurotrauma* 2006;23(3–4):571–85.
- 5 Scivoletto G, Romanelli A, Mariotti A, Marinucci D, Tamburella F, Mammone A, et al. Clinical factors that affect walking level and performance in chronic spinal cord lesion patients. *Spine* 2008;33(3):259–64.
- 6 Mehrholz J, Kugler J, Pohl M. Locomotor training for walking after spinal cord injury. *Spine* 2008;33(21):E768–77.
- 7 Dobkin B, Apple D, Barbeau H, Basso M, Behrman A, Deforge D, et al. Weight-supported treadmill vs over-ground training for walking after acute incomplete SCI. *Neurology* 2006;66(4):484–93.
- 8 Jackson AB, Carnel CT, Ditunno JF, Read MS, Boninger ML, Schmeler MR, et al. Outcome measures for gait and ambulation in the spinal cord injury population. *J Spinal Cord Med* 2008;31(5):487–99.
- 9 Lam T, Noonan VK, Eng JJ, SCIRE Research T. A systematic review of functional ambulation outcome measures in spinal cord injury. *Spinal Cord* 2008;46(4):246–54.
- 10 Alexander MS, Anderson KD, Biering-Sorensen F, Blight AR, Brannon R, Bryce TN, et al. Outcome measures in spinal cord injury: recent assessments and recommendations for future directions. *Spinal Cord* 2009;47(8):582–91.
- 11 van Hedel HJ, Wirz M, Dietz V. Assessing walking ability in subjects with spinal cord injury: validity and reliability of 3 walking tests. *Arch Phys Med Rehabil* 2005;86(2):190–6.
- 12 Dittuno PL, Ditunno JF, Jr. Walking index for spinal cord injury (WISCI II): scale revision. *Spinal Cord* 2001;39(12):654–6.
- 13 Itzkovich M, Gelernter I, Biering-Sorensen F, Weeks C, Laramée MT, Craven BC, et al. The spinal cord independence measure (SCIM) version III: reliability and validity in a multi-center international study. *Disabil Rehabil* 2007;29(24):1926–33.
- 14 Catz A, Itzkovich M, Tesio L, Biering-Sorensen F, Weeks C, Laramée MT, et al. A multicenter international study on the spinal cord independence measure, version III: rasch psychometric validation. *Spinal Cord* 2007;45(4):275–91.
- 15 Pagliacci MC, Celani MG, Spizzichino L, Zampolini M, Aito S, Citterio A, et al. Spinal cord lesion management in Italy: a 2-year survey. *Spinal Cord* 2003;41(11):620–8.
- 16 Ones K, Yilmaz E, Beydogan A, Gultekin O, Caglar N. Comparison of functional results in non-traumatic and traumatic spinal cord injury. *Disabil Rehabil* 2007;29(15):1185–91.
- 17 Osterthun R, Post MW, van Asbeck FW, Dutch-Flemish Spinal Cord Society. Characteristics, length of stay and functional outcome of patients with spinal cord injury in Dutch and Flemish rehabilitation centres. *Spinal Cord* 2009;47(4):339–44.
- 18 Guilcher SJ, Munce SE, Couris CM, Fung K, Craven BC, Verrier M, et al. Health care utilization in non-traumatic and traumatic spinal cord injury: a population-based study. *Spinal Cord* 2010;48(1):45–50.
- 19 Scivoletto G, Farchi S, Laurenza L, Molinari M. Traumatic and non-traumatic spinal cord lesions: an Italian comparison of neurological and functional outcomes. *Spinal Cord* 2011;49:391–6.
- 20 Gupta A, Taly AB, Srivastava A, Vishal S, Murali T. Traumatic vs non-traumatic spinal cord lesions: comparison of neurological and functional outcome after in-patient rehabilitation. *Spinal Cord* 2008;46(7):482–7.
- 21 Scivoletto G, Lapenna LM, Di Donna V, Laurenza L, Sterzi S, Foti C, et al. Neoplastic myelopathies and traumatic spinal cord lesions: an Italian comparison of functional and neurological outcomes. *Spinal Cord* 2011;49(7):799–805.
- 22 Verrier M, Ahn H, Craven C, Drew B, Fehlings M, Ford M, et al. Ontario spinal cord injury informatics: informing practice, research and innovations. Ontario Neurotrauma Foundation. November 2009 [cited 2011 Oct 24]. Available from: <http://www.onf.org/documents/OSCIR.pdf>.
- 23 Couris CM, Guilcher SJ, Munce SE, Fung K, Craven BC, Verrier M, et al. Characteristics of adults with incident traumatic spinal cord injury in Ontario, Canada. *Spinal Cord* 2010;48(1):39–44.
- 24 American Spinal Injury Association. International standards of neurological classification of the spinal cord injury revised 2011. *J Spinal Cord Med* 2011;34(6):535–46.
- 25 Flett HM. Relationship between clinical measures of sensorimotor function and walking in individuals with chronic incomplete spinal cord injury [Master's Thesis]. Toronto, Ontario, Canada: Graduate Department of Rehabilitation Science, University of Toronto; 2009.
- 26 van Hedel HJ, Dietz V, European Multicenter Study on Human Spinal Cord Injury (EM-SCI) Study Group. Walking during daily life can be validly and responsively assessed in subjects with a spinal cord injury. *Neurorehabil Neural Repair* 2009;23(2):117–24.
- 27 New PW, Simmonds F, Stevermuer T. A population-based study comparing traumatic spinal cord injury and non-traumatic spinal cord injury using a national rehabilitation database. *Spinal Cord* 2011;49(3):397–403.
- 28 Cosar SN, Yemisci OU, Oztop P, Cetin N, Sarifakioglu B, Yalbuздag SA, et al. Demographic characteristics after traumatic and non-traumatic spinal cord injury: a retrospective comparison study. *Spinal Cord* 2010;48(12):862–6.
- 29 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.
- 30 Zörner B, Blanckenhorn WU, Dietz V, EM-SCI Study G, Curt A. Clinical algorithm for improved prediction of ambulation and patient stratification after incomplete spinal cord injury. *J Neurotrauma* 2010;27(1):241–52.
- 31 Waters RL, Adkins R, Yakura J, Vigil D. Prediction of ambulatory performance based on motor scores derived from standards of the American Spinal Injury Association. *Arch Phys Med Rehabil* 1994;75(7):756–60.
- 32 Waters RL, Adkins R, Yakura J, Sie I. Functional and neurologic recovery following acute SCI. *J Spinal Cord Med* 1998;21(3):195–9.
- 33 van Middendorp JJ, Hosman AJ, Donders AR, Pouw MH, Ditunno JF, Jr, Curt A, et al. A clinical prediction rule for ambulation outcomes after traumatic spinal cord injury: a longitudinal cohort study. *Lancet* 2011;377(9770):1004–10.
- 34 Waters RL, Adkins RH, Yakura JS, Sie I. Motor and sensory recovery following incomplete paraplegia. *Arch Phys Med Rehabil* 1994;75(1):67–72.
- 35 Kay ED, Deutsch A, Wuermser LA. Predicting walking at discharge from inpatient rehabilitation after a traumatic spinal cord injury. *Arch Phys Med Rehabil* 2007;88(6):745–50.
- 36 Sturt RN, Holland AE, New PW. Walking ability at discharge from inpatient rehabilitation in a cohort of non-traumatic spinal cord injury patients. *Spinal Cord* 2009;47(10):763–8.
- 37 Brown CJ, Bradberry C, Howze SG, Hickman L, Ray H, Peel C. Defining community ambulation from the perspective of the older adult. *J Geriatr Phys Ther* 2010;33(2):56–63.

- 38 Andrews AW, Chinworth SA, Bourassa M, Garvin M, Benton D, Tanner S. Update on distance and velocity requirements for community ambulation. *J Geriatr Phys Ther* 2010;33(3):128–34.
- 39 Brotherton SS, Saunders LL, Krause JS, Morrisette DC. Association between reliance on devices and people for walking and ability to walk community distances among persons with spinal cord injury. *J Spinal Cord Med* 2012;35(3):156–61.