Relationship Between Neurological Injury and Patterns of Upright Mobility in Children With Spinal Cord Injury

Ross S. Chafetz, PT, PhD, DPT, MPH,¹ John P. Gaughan, PhD,² Christina Calhoun, MSPT,¹
Jennifer Schottler, MS, PT,³ Lawrence C. Vogel, MD,³ Randal Betz, MD,¹
and M.J. Mulcahey, PhD, OTR/L¹

¹Shriners Hospitals for Children, Philadelphia, Pennsylvania; ²Temple University Medical School, Philadelphia, Pennsylvania;

³Shriners Hospitals for Children, Chicago, Illinois

Background: The predictors and patterns of upright mobility in children with a spinal cord injury (SCI) are poorly understood. **Objective:** The objective of this study was to develop a classification system that measures children's ability to integrate ambulation into activities of daily living (ADLs) and to examine upright mobility patterns as a function of their score and classification on the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) exam. **Methods:** This is a cross-sectional, multicenter study that used a convenience sample of subjects who were participating in a larger study on the reliability of the ISNCSCI. A total of 183 patients between 5 and 21 years old were included in this study. Patients were asked if they had participated in upright mobility in the last month and, if so, in what environment and with what type of bracing. Patients were then categorized into 4 groups: primary ambulators (PrimA), unplanned ambulators (UnPA), planned ambulators (PlanA), and nonambulators. **Results:** Multivariate analyses found that only lower extremity strength predicted being a PrimA, whereas being an UnPA was predicted by both lower extremity strength and lack of preservation of S45 pinprick sensation. PlanA was only associated with upper extremity strength. **Conclusions:** This study introduced a classification system based on the ability of children with SCI to integrate upright mobility into their ADLs. Similar to adults, lower extremity strength was a strong predictor of independent mobility (PrimA and UnPA). Lack of pinprick predicted unplanned ambulation, but not being a PrimA. Finally, upper extremity strength was a predictor for planned ambulation. **Key words:** ambulation, ISNCSCI, pediatrics, spinal cord injury

After a spinal cord injury (SCI), learning to walk often becomes the focus of rehabilitation for children and their families.^{1,2} Although the majority of children with SCI do not return to full-time functional ambulation, those who accomplish some level of walking report positive outcomes such as feeling "normal" again, being eye-to-eye with peers, and having easier social interactions.³ Although not frequently reported by patients, there is some evidence of physiological benefits as well.³⁻⁹ Regardless of age, upright mobility has been positively associated with community participation and life satisfaction.¹⁰⁻¹² For children, upright mobility allows them to explore their physical environment, which facilitates independence and learning as part of the typical developmental process.^{13,14}

With the use of standers, walkers, and other assistive devices, as well as a variety of lower extremity orthoses, it is a reasonable expectation that some children with spinal injuries achieve upright stance and mobility.^{7,9,13-21} However, there are 2 main challenges for clinicians and patients:

understanding the factors that either encourage or discourage upright activities, and identifying how best to determine whether upright mobility is successful and meaningful. The literature on adults suggests that upright mobility is dependent on physiological and psychosocial factors. Physiological factors include the patient's current age, neurological level, muscle strength, and comorbidities.^{14,22-27} Psychosocial factors include satisfaction with the appearance of the gait pattern, cosmesis, social support for donning/doffing braces, and assistance with transfer and during ambulation.^{3,9,19,28-32}

The identification of outcome measures that provide a meaningful indication of successful upright mobility has been difficult. The World Health Organization (WHO) describes 2 constructs for considering outcomes – capacity

and performance.³³ *Capacity* refers to maximal capability in a laboratory setting. An example of a capacity measure is the Walking Index for Spinal Cord Injury (WISCI), which is an ordinal scale used to quantify walking capacity based on assistive device, type of orthosis, and amount of assistance required.^{34,35} Other capacity measures include the Timed Up and Go test and the 6-minute walk test.^{36,37} On the other hand, *performance* refers to actual activity during a patient's daily activities in typical, real-life environments.³³ For example, the FIM is an observation scale that scores the patient's typical daily performance.^{36,38-40} The FIM is considered a burden of care measure that determines the amount of actual assistance provided to a patient during typical routines and environments, which may or may not reflect maximal ability or capacity. Performance measures provide an adequate clinical snap-shot of a patients' daily function (evaluates what they do), whereas capacity measures are better research tools, as they are able to detect subtle changes in ambulation (evaluates what they *can* do).

In children, no capacity outcome measures of ambulation have been tested for validity or reliability. Availability of reliable and valid performance measures is also lacking. The WeeFIM is a performance measure for children, but it is not SCI specific. It is scored on the child's burden of care, that is, on the maximal assistance required rather than the child's maximal independence or the highest capacity of performance during a typical day. For children, another commonly used scale is the Hoffer Scale, which relies on the physician's or therapist's subjective determination of the purpose of the upright mobility activities (for function or for exercise).^{41,42} Because parents and school systems are encouraged to integrate "exercise" ambulation into daily activities, it may not be possible to distinguish between therapeutic and functional ambulation in the home, school, or community environments. In the schools, a teacher/therapist should incorporate upright mobility into the classroom setting by donning a child's braces and then having her/him ambulate a short distance to stand at an easel in art class or to stand upright when talking to friends during recess. In this situation, walking serves the dual purpose of being functional and therapeutic.

For this study, it was decided not to rely on a subjective determination of therapeutic versus functional ambulation as the main outcome measure. Instead, we were interested in the children and adolescents who have successfully integrated independent mobility into their daily activities, regardless of frequency, distance, or purpose. Recent literature in studies of children and adolescents suggests that spontaneity is important for participation in functional and social activities. For example, a survey of patients using functional electrical stimulation for hand function found a reduction in the dependence on others for donning splints, which facilitated independence with activities of daily living (ADLs) in adolescents.⁴³⁻⁴⁵ In a more recent study, Mulcahey et al⁴⁶ found that a reduction of spontaneity in adolescents was a barrier for social activity; during cognitive interviews, children reported not participating in sleepovers due to planning their bowel/bladder programs.

To date, there are no measures that integrate spontaneity of standing and/or upright mobility into the daily activities of children. Toward that aim, this study introduces a new scale that attempts to categorize children into 4 mutually exclusive groups: primary ambulators, unplanned ambulators, planned ambulators, and nonambulators. The purpose of this study was to examine ambulation patterns among children and adolescents with SCI as a function of neurological level, motor level, and injury severity, as defined by the motor, sensory, and anorectal examinations of the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI). A secondary aim of the study was to determine how performance on the ISNCSCI exam was associated with the ability of children to independently integrate ambulation into their daily routines.

Methods

This is a cross-sectional prospective study from 2 tertiary hospitals. Patients were included in the study if they had completed full ISNCSCI exams, were 3 months post injury, did not have a containment brain injury, and were between the ages of 3 months and 21 years. Of the initial 187 children and adolescents included in the reliability

Table 1. Descriptions of the Hoffer Scale and Shriners Ambulation Scale⁴¹

Scale	Description
Hoffer Scale	Community ambulators: These patients walk indoors and outdoors for most of their activities and may need crutches or braces, or both. They use a wheelchair only for long trips out of the community.
	Household ambulators: These patients walk only indoors and with apparatus. They are able to get in and out of the chair and bed with little if any assistance. They may use the wheelchair for some indoor activities at home and school and for all activities in the community.
	Non-functional ambulatory: Walking for these patients is a therapy session at home, in school, or in the hospital. Afterward they use their wheelchairs to get from place to place and to satisfy all their needs for transportation.
	Non-ambulators: These patients are wheelchair-bound but usually can transfer from chair to bed
Shriners Ambulation Scale	Primary ambulators: They use wheelchairs for long distances.
	Unplanned ambulators: They are primary users of a wheelchair but can stand to perform upright activities without preparation or assistance. Activities can range from standing at a sink for grooming to ambulating with braces and an assistive device on a school playground.
	Planned ambulators: They use a wheelchair but cannot participation in any upright activities without preparation. Preparation includes arranging others to be present to assistance (for guarding during sit to stand transfer or during ambulation) or planning ahead to ensure braces are worn on specific day or at a specific time.
	Nonambulators: They do not participate in any standing activities.

Note: Scale does not depend on receiving therapy service (presence of a health care provider), environmental setting, or subjective determination of functional vs therapeutic activities.

study only, 183 had complete ISNCSCI exams and completed the interview questions regarding upright mobility. The sample age range was 5 to 21 years of age. Full institutional review board (IRB) approval at each participating site was established. Written informed consent was obtained from all parents or legal guardians of all subjects under 18 years of age. As per IRB guidelines, written informed assents were obtained for subjects between 7 and 14 years, and subjects older than 14 years provided their own written consent. At the time of the exam, a convenience sample of subjects who were participating in a larger study on the reliability of the ISNCSCI in children⁴⁷⁻⁴⁹ were questioned about their patterns of upright mobility. The following questions were asked: (1) Have you participated in upright activities in the past month? (2) In which environment have you participated in upright activities: home, school, therapy, community outdoors, and/or during recreation activities? (3) Which devices were used for upright activities: reciprocal gait orthosis

(RGO), hip-knee-ankle orthosis (HKAFO), knee-ankle-foot orthosis (KAFO), ankle-foot orthosis (AFO), and/or stander? (4) Have you participated in any upright activities in the past? If so, please list. The interview was completed in the presence of the caregiver. For younger children, at the discretion of the interviewer, answers were solicited from the parent.

Initially, patients were to be grouped according to the Hoffer Scale, which is loosely described as community, home, and therapeutic ambulation (Table 1). We found the Hoffer Scale difficult to use, because the children's ambulation varied by setting (home vs school), availability of others (parent, teacher, therapist in school), and time (weekday vs weekend; school year vs summer) and also varied for functional and therapeutic reasons. While attempting to group children into mutually exclusive groups, we found that a clear distinction emerged related to children's successful integration of independent mobility into their daily activities. Using the interview ambulation

questions, chart reviews, and the interviewers' knowledge of the patient's upright mobility abilities from past evaluations and treatments sessions, we categorized patients into 4 groups: (1) primary ambulators (PrimA); (2) unplanned ambulators (UnPA); (3) planned ambulators (PlanA); and (4) nonambulators (**Table 1**; Shriners Ambulation Scale). PrimA used wheelchairs only for long distances. An UnPA was defined as any child or adolescent who could participate in any upright mobility without preparation or assistance of another person. For example, a primary wheelchair user who has motor sparing of bilateral hip flexors and/or quadriceps and who can stand and move around a bathroom was categorized as an UnPA. Those patients have the option to successfully integrate upright mobility into their day, although, by choice, they use their wheelchair for a majority (if not all) of their activities. In contrast, PlanA participants could stand and/or walk, but only if they planned ahead for the activity. Those patients have the capacity to stand/walk, but need to have equipment (braces or a walking device) or assistance (therapist, teacher, parent, or family member).

Data management and analysis

Data were entered into a secured database, and scores and classifications were validated by computer software designed specifically for this study. All data analysis was completed using SAS, version 9.1 (SAS Institute Inc, Cary, North Carolina). Analyses of variance (ANOVAs) and Fisher's exact tests were used to compare demographic data by ambulation classification. The dependent variable in this study was the classification of upright mobility. The classification of upright mobility was analyzed as a nominal variable using a multinomial logit model in SAS. This procedure uses a single model to produce multiple contrasts of a polytomous outcome measure (dependent variable). For this study, nonambulators were contrasted with PrimA, UnPA, and PlanA. The independent variables (predictors) in this study were basic demographics (gender, age, age at injury, years since injury) and elements of the ISNCSCI exam: neurological

level (NL), sensory level (SL), motor level (ML), tetraplegia vs paraplegia (TvsP), anal contraction (AC), anal sensation (AS), sacral dermatome levels 4 and 5 light (S4-5LT), sacral dermatome levels 4 and 5 pinprick (S4-5PP), total upper extremity motor score (UEMS), and total lower extremity motor score (LEMS). A multinomial model produces an odds ratio (OR) that describes the odds of a patient having a specific independent variable if he or she is PlanA, UnPA, or PrimA when compared to nonambulators.

Results

A total of 183 patients between the ages of 5 and 21 years were included in this study. Of those, 57% (n=105) were male, 43% (n=78) were female, 52% (n=95) had tetraplegia, and 48% (n=88) had paraplegia (**Table 2**). In this study, 50% (n=91) of subjects report participating in upright activities, either currently or in the past (**Table 2**). Twenty-seven percent (n=47) of children had participated in upright mobility in the past month, with 10% (n=18) being PrimA, 5% (n=9) UnPA, 11% (n=20) PlanA, and 74% (n=136) nonambulators. When compared across ambulation status, there was a statistically significant difference by age, LEMS, UEMS, presence of AC, AS, S4-5LT, and S4-5PP.

With nonambulators as the reference group, univariable analysis found that being PrimA and UnPA were associated with the AC, AS, S4-5LT, S4-5PP, and LEMS (**Table 3**). Univariable analysis of PlanA found associations with 2 predictors – age at time of evaluation and UEMS. Multivariate analyses found that only LEMS predicted being a PrimA, whereas UnPA was predicted by both LEMS and S4-5PP (**Table 4**). PlanA was only associated with having a greater UEMS. Although not statistically significant, there was a trend toward younger patients participating in upright mobility. In the PrimA group, 39% (n=7) used an AFO and 11% used KAFOs (**Table 5**). Similarly, in the UnPA group, 44% (n=4) used AFO and 11% (n=1) used KAFOs. No participants in the PrimA nor UnPA groups used HKFOs or RGOs. In the PlanA group, HKFO, RGO, and KAFO use was 10% (n=2), 45% (n=9), and 45% (n=9), respectively.

Table 2. Potential predictors by ambulation category

	Total	Current ambulation status			P
		Primary ambulator	Unplanned ambulator	Planned ambulator	
Total	183				
Past/current ambulator ^a	91 (50%)				
Current ambulator ^a	47 (27%)				
Current ambulation status ^b	183	18 (10%)	9 (5%)	20 (11%)	136 (74%)
Mean age (SD)	183	13.2 (4.8)	17 (3.6)	12.4 (4.7)	14.9 (4.1) .01
Mean years since injury (SD)	183	5.3 (4.7)	5.9 (5.6)	3.8 (2.7)	5 (4.5) .74
Age at injury	183	8.1 (5.8)	11.6 (7.2)	9.2 (5.8)	10.3 (6.2) .24
Male ^b	105	11 (11%)	4 (4%)	10 (10%)	80 (77%) .74
Female ^b	78	7 (9%)	5 (7%)	10 (13%)	56 (72%)
Tetraplegia ^b	95	12 (13%)	6 (7%)	6 (7%)	71 (75%) .10
Paraplegia ^b	88	6 (7%)	3 (4%)	14 (16%)	65 (74%)
Sensory level	183	C3	C4	T4	C8 .85
Neurological level	183	C3	C4	T4	C8 .07
Motor level	183	C3	C4	T4	C8 .08
Anal contraction (+) ^b	23	11 (48%)	5 (22%)	2 (9%)	5 (22%) <.01
Anal contraction (-) ^b	160	7 (5%)	4 (3%)	18 (12%)	131 (82%)
Anal sensation (+) ^b	88	15 (18%)	8 (10%)	7 (8%)	58 (66%) <.01
Anal sensation (-) ^b	95	3 (4%)	1 (2%)	13 (14%)	78 (83%)
S4-5 light touch(-) ^b	128	5 (4%)	3 (3%)	17 (14%)	103 (81%) <.01
S4-5 light touch (+) ^b	55	13 (24%)	6 (11%)	3 (6%)	33 (60%)
S4-5 pinprick (-) ^b	151	5 (4%)	6 (4%)	17 (12%)	123 (82%) <.01
S4-5 pinprick(+)	32	13 (41%)	3 (10%)	3 (10%)	13 (41%)
Mean lower extremity motor score (SD)	183	29 (14.4)	25.6 (12.1)	2.4 (6.7)	0.97 (3.2) <.01
Mean upper extremity motor score (SD)	183	43.2 (10.3)	42.5 (9.7)	47.9 (6.2)	37.1 (16.9) .04

^aNumber in parenthesis represents the percent of the entire cohort.^bNumber in parenthesis represents the percent of the row.

Table 3. Univariable multinomial logistic regression for predictors of ambulation categories as compared to nonambulators^a

	Primary ambulator	Unplanned ambulator	Planned ambulator
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age	0.91 (0.82, 1.02)	1.18 (0.95, 1.46)	0.88 (0.79, 0.98)
Years since injury	1.02 (0.91, 1.13)	1.04 (0.91, 1.21)	0.92 (0.81, 1.05)
Age at injury	0.94 (0.87, 1.02)	1.04 (0.93, 1.17)	0.97 (0.90, 1.05)
Female	1.00	1.00	1.00
Male	1.10 (0.40, 3.01)	0.56 (0.14, 2.18)	0.70 (0.27, 1.79)
Tetraplegia	1.00	1.00	1.00
Paraplegia	0.55 (0.19, 1.54)	0.55 (0.13, 2.27)	2.55 (0.93, 7.02)
Sensory level	0.93 (0.84, 1.02)	1.00 (0.89, 1.12)	1.06 (0.98, 1.14)
Neurological level	0.93 (0.84, 1.02)	1.01 (0.90, 1.12)	1.07 (0.99, 1.15)
Motor level	0.92 (0.83, 1.01)	1.01 (0.91, 1.14)	1.06 (0.98, 1.14)
Anal contraction (-)	1.00	1.00	1.00
Anal contraction (+)	41.2 (11.2, 151)	32.75 (6.68, 160)	2.92 (0.53, 16.1)
Anal sensation (-)	1.00	1.00	1.00
Anal sensation (+)	6.72 (1.86, 24.3)	10.8 (1.31, 84.4)	0.72 (0.27, 1.93)
S4-5 light touch (-)	1.00	1.00	1.00
S4-5 light touch (+)	8.12 (2.69, 24.6)	6.24 (1.48, 26.36)	0.55 (0.15, 2.00)
S4-5 pinprick (-)	1.00	1.00	1.00
S4-5 pinprick (+)	24.6 (7.57, 79.9)	4.73 (1.06, 21.2)	1.67 (0.43, 6.47)
Lower extremity motor score	1.30 (1.18, 1.42)	1.27 (1.16, 1.39)	1.08 (0.98, 1.18)
Upper extremity motor score	1.03 (0.99, 1.07)	1.03 (0.97, 1.08)	1.08 (1.01, 1.16)

Note: CI = confidence interval; OR = odds ratio.

^aSignificant predictors are in bold.

Discussion

This study found that half of the children had participated in upright activities at some point after their SCI. Those children who were participating in upright mobility at the time of the interview could be categorized into 4 distinct groups based on wheelchair use and integration of independent ambulation into their daily activities. There was a positive association between lower extremity strength and being a PrimA or UnPA. UnPAs were also more likely to not have pinprick sensation at S4-5, as compared to nonambulators. Only upper extremity strength was associated with PlanA when compared to nonambulators. There was a trend toward an association between age and being a PlanA, but it did not reach statistical significance.

The prevalence of children participating in upright mobility in this study is comparable to the findings in Vogel et al's⁴² 2007 retrospective chart review of 169 patients, in which 73% of children participated in standing or upright mobility. Also consistent with previous research, a large percentage (50%) of children eventually stop participating in upright activities. Further, of the 50% (91) who did participate in upright mobility at any time in the past, only 27% (47 of 183 subjects) were currently doing so at the time of the appointment. This is substantially lower than the 57% reported by Vogel et al.⁴² The difference between our studies most likely reflects the operational definition of ambulating. Vogel et al's study was a retrospective chart review and defined ambulatory as any patient using braces in the last year. Our study was completed via interview

Table 4. Multinomial multivariable regression for predictors of ambulation categories as compared to nonambulators^{a,b}

	Primary ambulator	Unplanned ambulator	Planned ambulator
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Age	0.81 (0.63, 1.05)	1.03 (0.76, 1.38)	0.89 (0.79, 1.01)
Anal contraction (-)	1.00	1.00	1.00
Anal contraction (+)	0.12 (0.01, 2.88)	0.28 (0.01, 6.21)	1.81 (0.15, 21.2)
Anal sensation (-)	1.00	1.00	1.00
Anal sensation (+)	0.45 (0.03, 7.49)	4.13 (0.14, 124)	0.91 (0.24, 3.47)
S4-5 light touch (-)	1.00	1.00	1.00
S4-5 light touch (+)	4.77 (0.31, 72.5)	8.24 (0.58, 117.4)	0.18 (0.01, 4.77)
S4-5 pinprick (-)	1.00	1.00	1.00
S4-5 pinprick (+)	0.36 (0.01, 12.91)	0.01 (<0.01, 0.83)	9.28 (0.27, 315)
Lower extremity motor score	1.41 (1.20, 1.65)	1.42 (1.19, 1.69)	1.03 (0.90, 1.18)
Upper extremity motor score	1.07 (0.96, 1.20)	1.11 (0.97, 1.27)	1.07 (1.01, 1.14)

Note: CI = confidence interval; OR = odds ratio.

^aSignificant predictors are in bold.

^bMultinomial model only included predictors that were statistically significant in the univariable model (Table 3).

Table 5. Orthotic use by type of ambulation

	Primary ambulation (n=18)	Unplanned ambulation (n=9)	Planned ambulation (n=20)
	n (%)	n (%)	n (%)
HKAFO	0 (0)	0 (0)	2 (10)
RGO	0 (0)	0 (0)	9 (45)
KAFO	2 (11)	1 (11)	9 (45)
AFO	7 (39)	4 (44)	0 (0)
No orthotic	9 (50)	4 (44)	0 (0)

Note: AFO = ankle-foot orthoses; HKAFO = hip-knee-ankle-foot orthoses; KAFO = knee-ankle-foot orthoses; RGO = reciprocal gait orthoses.

and asked about upright mobility during the last month.

This study introduces a new method for categorizing children who participate in varying degrees of upright mobility. It is easy to categorize children as primary wheelchair users or nonambulators. However, categorizing children who are ambulators is less intuitive, because

upright mobility depends on several factors, including, but not limited to, environment (home vs school), time (weekend vs weekday; summer vs winter), and availability of others for assistance (parent, teachers, family members, etc). Capacity scales are based on distances walked, speed of mobility, or assistance required. For other scales, such as Spinal Cord Independence Measure (SCIM) or FIM, children are scored on typical performance, which does not necessarily reflect their capacity. Our clinical experience suggests that there are populations of children who can stand and/or walk short distances without preparation or assistance but who, for a variety of reasons, choose to use a wheelchair for daily activities.

In our study, 47 children were currently participating in upright mobility, with 57% (n=27) successfully integrating independent mobility into their day (PrimA or UnPlan). Of these children, a third remained primary wheelchair users. This subgroup of independent ambulators who chose to remain primary wheelchair users is distinctly different from the 45% of PlanA who also are

primary wheelchair users but have to plan ahead to ambulate. On performance measures, such as FIM or SCIM, both UnPlan and PlanA are scored based on their wheelchair use, since that is their typical mode of mobility. For UnPA, their scores do not reflect their capacity to independently be upright during the day. A capacity measure, such as a WISCI, captures the ability to walk but does not reflect the ability to integrate ambulation into daily activities. Future work is planned to evaluate this categorization.

It was not surprising that lower extremity strength was an important predictor for both primary walkers and unplanned ambulation. From this and previous studies, it is clear that patients with the greatest lower extremity strength are likely to become ambulators in their home or community.^{50,51} As expected, bracing in this cohort was minimal, with 90% of patients using no braces or only AFOs. Our finding in the pediatric population is similar to that in adults. Prospectively tracking incomplete injuries, Crozier et al found that recovery of more than three-fifths of quadriceps strength was an excellent predictor of community ambulation.⁵² Similarly, Hussey and Stauffer found that a minimum of antigravity strength in the quadriceps was present in 90% of household and community ambulators.⁵³ Both Crozier et al and Hussey and Stauffer found that hip extensors are important for predicting ambulation.^{52,53} Our study focused only on muscle groups in the ISNCSCI exam; therefore, hip extensors were excluded, but they should be included in future studies.

It is notable that the components of sacral sparing were not predictors of becoming a primary ambulator. Recently, the utility of severity testing has been questioned.^{49,54} Van Middendorp et al looked at the predictability of each component of sacral sparing test (deep anal pressure, anal contraction, light touch, and pinprick sensation) for future ambulation.⁵⁴ They found that only light touch, pinprick, and anal contraction were statistically significant predictors of future ambulation. They conclude that presence of anal sensation had poor positive predictive value for ambulation. Furthermore, they suggest that anal sensation may be eliciting a visceral sensation via the autonomic nervous sensory, essentially incorrectly identifying

patients as incomplete. Questioning the utility of severity testing in children, Vogel et al found poor intrarater reliability of sacral sparing across multiple ages.⁴⁹ Also, in children and adolescents with chronic injuries, Samdani et al found poor negative predictability between the presence of anal sensation and S45 dermatome sensation.⁵⁶

Upper extremity strength was the only predictor of planned ambulation. In this group, 90% of patients required braces that span the knee and/or the hip. Typically, such extensive bracing requires excellent upper extremity strength for the use of walkers/crutches. The use of extensive braces typically requires assistance for donning/doffing the braces and help with transitions from sit to stand as well as assisting with mobility.^{3,9,19,28-32} Although it did not reach statistical significance, there was a strong inverse relationship between PlanA and age. Considering the dependence on others to achieve upright mobility, it is not surprising that planned ambulation decreases with increased age.^{9,14,21,42} During preadolescence, parents have a stronger influence on their child's activity. As children transition to adolescence, they are more likely to seek activities that require less dependence on others. Because PlanA is scheduled ambulation, it may be viewed as a therapeutic/exercise activity. It has been well established in the nondisabled population that physical activity decreases with age.⁵⁷ The age dependence of PlanA may reflect the normal reduction of physical activity that is expected in adolescents.

An unexpected finding in this study was that 11 (5%) of patients had not participated in upright mobility in the past but, at the time of the interview, were being admitted for casting for an orthosis or for first-time gait training. This small cohort of patients was on average 19.4 (± 3.7) years old and 2.0 (± 1.6) years post injury. It is unclear why these patients had not participated in upright mobility earlier in their rehabilitation. Future research should explore different thresholds for recommending, prescribing, and obtaining reimbursement for orthoses to aid in ambulation following pediatric SCI.

A limitation of this study is that the newly developed Shriners Ambulation Scale was not developed before completion of the interview nor was information consistently collected regarding

the type of assistive devices used in the variety of environments in which children participated. For UnPA, little to no bracing was required (Table 5). By the patients' general comments, we discovered that their independent ambulation was limited to standing at countertops for support or traveling short distances with crutches. Information regarding the environments and assistive devices that children and adolescents use would help operationalize this distinct group of ambulators. Furthermore, reliability and validity testing is also required to determine utility of this classification as a clinical and/or research tool.

To date, this is the only large-scale study using confirmed ISNCSCI exams to explore predictors of ambulation in children and adolescents. This study introduced a novel method of categorizing ambulation that was mutually exclusive and combined patients' capacity and their performance in daily activities. This study found that the categorization or classification

could be used to identify 4 distinctly different populations that are not delineated by current outcome measures.

To understand the determinants of successful ambulation in children and adolescents, a larger multicenter study is required that includes comorbidities (contractions, pressure sores, fracture, scoliosis), intrinsic personal intrinsic factors (expectations, goals, perceived ease of use), and environmental contexts. In addition to examining the predictors of success, the benefits of upright activities also need to be understood from a developmental perspective (ie, cognitive development, peer interactions, and exploration of environment).

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