Association of Mode of Locomotion and Independence in Locomotion With Long-Term Outcomes After Spinal Cord Injury

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Abstract

Background/Objective: To explore the association of mode of locomotion (ambulation vs wheelchair use) and independence in locomotion (independent vs require assistance) with health, participation, and subjective well-being (SWB) after spinal cord injury (SCI).

Research Design: Secondary analysis was conducted on survey data collected from 2 rehabilitation hospitals in the Midwest and a specialty hospital in the southeastern United States. The 1,493 participants were a minimum of 18 years of age and had traumatic SCI of at least 1 year duration at enrollment.

Main Outcome Measures: Three sets of outcome measures were used: SWB, participation, and health. SWB was measured by 8 scales and a measure of depressive symptoms, participation by 3 items, health by general health ratings, days in poor health, hospitalizations, and treatments.

Results: Small but significant associations were observed between independence in locomotion and every outcome. Ambulation was associated with greater participation but a mixed pattern of favorable and unfavorable health and SWB outcomes. Supplemental analyses were conducted on those who ambulated but who were dependent on others to do so ($n = 117$), because this group reported poor outcomes in several areas. Individuals who were independent in wheelchair use reported substantially better outcomes than nonwheelchair users and those dependent on others in wheelchair use.

Conclusions: Although ambulation is often a recovery goal, individuals with SCI who ambulate do not uniformly report better outcomes than wheelchair users, and those who depend on others for assistance with ambulation may experience a unique set of problems.

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INTRODUCTION

Preserved ability to ambulate is frequently observed in individuals with neurologically incomplete spinal cord injury (SCI). However, the quality and amount of ambulation may be affected by spasticity, muscle weakness, and coactivation of muscle groups (1). A number of devices and treatments have been used to improve ambulatory capacity (2,3), including body weight-supported treadmill training (BWSTT), functional

electrical stimulation (FES) (4), lower extremity orthotics, and assistive devices (eg, crutches, walkers). These interventions may be used alone or in combination to achieve optimal training outcomes.

Ambulation training has been associated with improved life satisfaction and physical function (5). However, although walking ability improved with interventions, including BWSTT and FES, carryover to functional ambulation was limited. Less than half of those who increased their walking speed and distance and required less support during BWSTT were able to improve their capacity for over-the-ground walking (5). Even with an increase in gait speed, individuals with incomplete SCI had difficulty attaining the required velocity to safely cross an intersection (6). At their preferred walking speed, individuals also had increased oxygen uptake and increased lactate concentration,

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indicating use of anaerobic pathways and less efficiency when walking (7). Use of an assistive device, such as a walker, was associated with a flexed posture during ambulation, slower walking speed (8), and increased oxygen uptake (9). Altered posture and movement patterns used when ambulating with an assistive device can subsequently lead to musculoskeletal pain (10). The impact of standing and walking exercises on postinjury osteopenia, a common concern after SCI, has not been established (11).

Taken together, these studies provide encouraging results for interventions to promote ambulation after SCI in terms of both direct benefits to ambulation and associated benefits, such as enhanced life satisfaction. However, the results also suggest limitations of the functionality of ambulation and raise questions regarding changes in posture and movement patterns that may eventually lead to complications. It is important to bridge the gap from intervention studies that generally take place in a hospital or other treatment environment and measure short-term treatment effects to studies that measure similar parameters among individuals living in community settings.

Recent studies have identified an association between ambulation in community settings and diverse outcomes, finding a mixed pattern of favorable and unfavorable results. For instance, ambulatory persons with incomplete SCI were found to be at greater risk for falls, because 75% of those with incomplete SCI experienced a fall over the previous year (12). Of those who fell, 18% sustained a fracture and almost half (45%) reported a decline in community and productive activities as the result of the fall. Other studies have suggested substantial differences in the quality of outcomes, depending on the degree to which the ambulation is functional, specifically independence of assistance from other persons. Participants who required no assistance from others to ambulate reported significantly lower pain interference scores in 6 domains when compared with those that required some assistance from another individual (13).

In an extension of this study that included wheelchair-bound participants, ambulators who relied on others for assistance reported higher depressive symptoms than either independent ambulators or wheelchair users (14). However, pain interference mediated the relationship between ambulatory status and depressive symptoms, such that the risk of both clinically significant symptomatology and probable major depression was no longer significant after accounting for differences in pain interference (ie, the observed differences in depressive symptoms between dependent ambulators and independent ambulators were largely due to pain interference). In summary, the limited body of research has identified a greater risk of adverse outcomes among nonindependent community ambulators. There is little, if any, research on independence in locomotion, whether independence is

defined by independence in ambulation or wheelchair use, and long-term outcomes. Having a more complete understanding of the long-term association of both mode of locomotion (as measured by ambulation or wheelchair use) and independence in locomotion is essential if rehabilitation professionals are to understand how locomotion relates to the health and well-being of people with SCI.

Taken together, these studies suggest some types of interventions that promote ambulation have produced successful outcomes, particularly in the short term. In contrast, studies of ambulators in the community suggest that ambulation may be associated with additional complications.

Perhaps the most compelling reason to pursue interventions to promote ambulation is the importance placed on walking by consumers. Ditunno et al (7) have also provided new data to support the value placed on walking by consumers. Using a new technique developed by Stineman et al (15), the futures-resource trade-off game, the investigators found near consensus from panel members endorsing the importance of walking as a focus of recovery early in the rehabilitation process. Bowel and bladder function were also important targets for recovery, whereas other activities, including independence in wheelchair use, were not ascribed the same level of importance. Rehabilitation professionals also placed importance on walking but with less consistency than did those with SCI. These studies underscore the importance of aligning consumer and rehabilitation team goals and the need to have collaboration in goal setting regarding major outcomes.

The purpose of this study was to identify the association of 2 important functional characteristics, mode of locomotion (ambulation; wheelchair use) and independence in locomotion (independent; nonindependent), with multiple aspects of health, participation, and subjective well-being (SWB) among participants with SCI.

Hypotheses

The first hypothesis was that ambulators will report higher levels of SWB, participation, and general health indicators for some variables when compared with those who are nonambulatory. (There is insufficient previous research to hypothesize about which variables may or may not be significant.) The second hypothesis was that those independent in locomotion will report higher levels of SWB, participation, and general health indicators for some variables when compared with those who are not independent. Both of these hypotheses are general in nature, because there simply is not sufficient previous research to guide more specific ones.

METHODS

Participants

This study is based on secondary analysis of data from a 30-year longitudinal study. Participants were selected

Table 1. Breakdown of Responses According to Sub-sample

Status	Cohort					Total
	1 (1974)	2 (1985)	3 (1993)	4 (1993)	5 (2002)	
Working sample ^a	79	96	148	331	1,356	2,010
Respondent	78	91	136	300	963	1,568
Nonrespondent ^b	1	5	12	31	393	442
No address	1	1	8	35	0	45
Deceased	15	7	7	32	0	61
Total	95	104	163	398	1,356	2,116
Response rate	82%	88%	83%	75%	71%	74%
Adjusted response rate ^c	99%	95%	92%	91%	71%	78%

^aThe working sample is the number of individuals who are known to be alive and who had known addresses at the time of data collection.

^bNonrespondent includes those who did not return materials and those who stated an unwillingness to participate.

^cThe adjusted response rate is the portion of respondents in the working sample (ie, adjusted to exclude those who were lost to follow up due to death or inability to locate).

Note: Midwestern participants were enrolled in 1974, 1985, and 1993, and Southeastern participants were enrolled in 1993 and 2002.

from 2 geographic locations: the Midwestern and Southeastern United States. Midwestern participants were selected from 2 institutions (outpatient records were used to identify potential participants), including a university hospital and a private rehabilitation hospital. All Southeastern participants were selected from a large specialty hospital. Three sources were used to identify participants: (a) designated model SCI patients, (b) model SCI system registry, and (c) outpatient admissions. Both model system patients and registry patients received inpatient rehabilitation, although only the model system patients met all specifications for extended follow-up interviews that become part of the national database. There were 3 inclusion criteria to be eligible for enrollment in the study at the point of first contact: (a) traumatic SCI, (b) at least 1 year since occurrence of injury, and (c) a minimum age of 18 years.

Table 1 summarizes the number of cases according to participant sample. The first 3 samples were taken from the Midwestern hospitals, whereas the latter 2 samples were drawn from the Southeastern hospital. Because the first 4 samples were included in earlier longitudinal follow ups, we have information on attrition over time due to mortality and geographic mobility (ie, patients we could not find because they had moved from the previous address). Sample 5 was added during the last follow up and was composed only of individuals who were known to be alive and had current addresses. The total number of participants in the working sample (ie,

people who were alive and with known addresses) was 2,010, whereas the total including those who had died or could not be located since the previous contact was 2,116. There were 1,568 respondents from an initial working sample of 2,010, which is a 78% adjusted response rate (the overall response rate was 74% when including those who died and could not be located from the last follow up). Twenty-five cases were eliminated post hoc based on questionable etiologies, leaving a final working sample of 1,543 participants. Missing data on one of the primary independent variables further reduced the working sample to 1,493 cases (74% of the initial working sample and 71% of the full sample).

Procedures

After the research team obtained approval from the institutional review board, participants were sent preliminary cover letters describing the study and alerting them that materials would be forthcoming. Approximately 4 to 6 weeks later, an initial packet of materials was sent to participants. A second set of materials was mailed to all nonrespondents another 4 to 6 weeks later, followed by a phone call in order to enhance participation. A third mailing was used for participants who had misplaced or discarded materials but consented to participate by phone and requested an additional set of materials. Extensive efforts were made to identify current addresses of all potential participants, including searches of recent addresses and documented changes in addresses in hospital records. Updated addresses were also requested from the United States Postal Service for those who had moved recently. Participants were offered \$25 each as compensation for their participation in the study.

Measures

Several measures were used in this study, including portions of the Life Situation Questionnaire-Revised, the Behavioral Risk Factor Surveillance System, the Brief Pain Inventory (BPI), the Craig Handicap Assessment Reporting Technique, and the Older Adult Health and Mood Questionnaire (OAHMQ).

The Life Situation Questionnaire-Revised (16,17) was used to measure ambulation, independence in locomotion, recent medical history, and SWB. It was originally developed in 1973 to elicit mostly objective information on a wide range of long-term post-SCI outcomes (18) and has since been revised to provide more in-depth information on quality of life (16,17). The goal in the development of the Life Situation Questionnaire-Revised was to provide a general survey of a number of life areas. It has generated valuable data on life adjustment after SCI and served as a basis for identification of changes in outcomes over 30 years, including: (a) employment and education, (b) recent medical history, (c) function, (d) social activities, (e) life satisfaction, and (f) self-rated adjustment.

Fifteen items from the Life Situation Questionnaire-Revised assessed activities of daily living and instrumental

activities of daily living, each of which required participants to indicate level of independence based on the traditional definition of independence: no need for assistance from another person. There were 4 options: independent (you need no help from another person), partially dependent (you need some help), dependent (someone else must do it for you), and not applicable (you do not do the activity at all). Two items, walking and wheelchair use, were used to identify 2 mobility parameters (defined more completely in the section describing the data analyses).

Recent medical history within the year prior to the study was addressed by 2 items: number of nonroutine doctor visits and number of hospitalizations. SWB was measured by 2 sets of scales: 7 factor analytic scales (derived from a factor analysis, or data reduction, of 50 items) and 1 adjustment scale (sum of 2 items). The factor scales were derived from principal axis factor analysis with varimax rotation of 20 satisfaction items and 30 problem items (16,17). This type of rotation is designed to produce orthogonal rather than oblique factors. The 7 scales were converted to T-scores with a mean of 50 and SD of 10. The scales are Engagement, Negative Affect, Poor Health, Career Opportunities, Finances, Home Life, and Interpersonal Relations. Higher scores indicate a more favorable outcome for all scales, except Negative Affect and Poor Health. The alpha coefficients for the 7 scales ranged from 0.79 to 0.92, with an average coefficient of 0.86. An adjustment scale was developed by summing 2 items, each of which required participants to rate their adjustment on a 10-point ladder, with 1 being the worst possible adjustment and 10 being the best possible. One item related to current adjustment and the other required participants to rate what they think their adjustment will be in 5 years. Prediction of adjustment is taken as an indicator of an individual's perception of his or her ability to cope with future events and is highly correlated with other indicators of psychosocial adaptation (19,20).

The Behavioral Risk Factor Surveillance System (21) is a standardized instrument created and used by the Centers for Disease Control and Prevention to monitor relevant basic health behaviors within the general population. Three Behavioral Risk Factor Surveillance System health-related items were used: self-rated health, poor physical health days in past month, and poor mental health days in past month. Only individual items are used in the current study, so no reliability or validity indices are reported.

A subset of items from the BPI (22) was used to assess pain interference. These items were (a) general activity, (b) mood, (c) normal work (both work outside the home and housework), (d) relations with others, (e) sleep, and (f) enjoyment with life. Each item is scored 0 to 10, with 0 indicating no pain interference and 10 indicating complete interference (total score across the 6 items ranges from 0 to 60). The BPI was originally developed to be used

with people living with cancer and was administered as an interview tool or self-administered by the participant. The BPI has good test-retest item correlations over short periods. Williams, Smith, and Fehnel (23) found a 1-week intraclass correlation of 0.81 (95% CI: 0.68–0.90). Expected differences in pain were found in groups of patients who had cancer with the presence of metastases and those without. The BPI is sensitive to the differences in pain associated with different conditions, supporting its validity (22). Raichle et al (24) found evidence to support the modified 7-item, 10-item, and 12-item versions of the BPI scale as reliable and valid measures of pain-related interference in persons with SCI.

The Craig Handicap Assessment and Reporting Technique (25) is a measure of 5 domains: (a) Physical Independence, (b) Mobility, (c) Occupation, (d) Social Integration, and (e) Economic Self-sufficiency. It was designed to provide a measure of the degree to which disability limits participation. Three selected items were taken from the Craig Handicap Assessment and Reporting Technique, each of which is a primary marker of participation: (a) daily hours out of bed, (b) times leaving home per week, and (c) number of nights spent away from home during the previous year (excluding time spent in the hospital). In a validation study of 135 participants recruited from 8 of the model SCI systems, the Craig Handicap Assessment and Reporting Technique demonstrated a high test-retest reliability of 0.93 for the total score and reliability from 0.80 to 0.95 for the subscale measures (26). It has been validated for use with SCI, traumatic brain injury, stroke, multiple sclerosis, amputation, and burns and has been used for rehabilitation generally.

The OAHMQ (27) is a 22-item measure of depressive symptoms. It was designed following Diagnostic and Statistical Manual of Mental Disorders IV-Revised criteria and validated against clinical assessments by psychiatrists and psychologists. By design, there are few physiological ("vegetative") items, because they often parallel the actual physiological complications associated with SCI and other chronic conditions. The OAHMQ cut-off scores are 0–5 (nondepressed), 6–10 (clinically significant symptomatology), and 11–22 (probable major depression). The OAHMQ has highly acceptable internal (0.87) and retest reliability (0.84) and has been used in previous studies of depression among individuals with SCI (28–32).

Analyses

The study included multiple dependent variables of interest, so the analysis plan was devised to minimize the inflation of the type I error that could occur with repeated testing. Traditional multivariate ANOVA was not used for the analysis, because the joint distribution of the dependent variables could not be reasonably assumed to follow a multivariate normal distribution. Thus, O'Brien's nonparametric global test statistics (33) (GTS) was used to identify the significance of mode of locomotion

(ambulatory, nonambulatory) and independence in locomotion (independent, dependent) with health, participation, and SWB outcome measures.

The GTS approach was ideally suited for this analysis for numerous reasons. Primarily, the approach combines the multivariate dependent variables into a single summary index that tests a more specific hypothesis than traditional multivariate ANOVA methods (ie, instead of the general alternative hypothesis of any difference in one or more of the multivariate means, the GTS approach tests that a particular group consistently achieves more favorable outcomes across all dependent variables of interest, hence the name “global test”). Next, the nonparametric GTS does not require the assumption of multivariate normality of the dependent variables, an assumption that was not tenable given the variety of dependent variables selected for the analysis. Third, it allows for the creation of a summary score from multivariate outcomes with different scales. Because the O’Brien nonparametric GTS relies on the underlying rank order of the observed values, the theoretical direction of the dependent variables needed to be considered. Under the SWB construct, 2 of the factor scales (negative affect and health problems) and OAHMQ scores (depression scores) were ranked in descending order to account for the negative direction of the scales (ie, higher scores indicate poorer well-being). Likewise, the general health rating under the health construct was ranked in descending fashion to reflect the negative orientation of the health construct (ie, higher scores indicating greater health-related problems). The primary analysis of hypotheses 1 and 2 were tested using the GTS methodology at the $\alpha = 0.05$ level of significance. However, follow-up analyses were used to better understand the group differences.

In particular, unadjusted 1-way ANOVA models were also computed for comparative purposes with other literature and the estimation of the effect size based on eta squared (34). Tukey’s correction for multiple comparisons was used for comparisons of outcome and the function of ambulation and independence. These analyses, which are reported on the primary tables, should be regarded as exploratory findings, and due to multiple testing, an inflated type I error rate may occur. To be conservative, a more rigorous level of significance, say <0.01 , should be considered if one desires to make stronger conclusions regarding the observed associations.

On average, study respondents left 1.4% of items blank (ie, missing data). Some variables were single items, whereas scales were composed of multiple items (eg, the most items per scale were 22 for the OAHMQ). Prior to creation of summary scores, missing items were imputed using mean replacement (sample mean for the item).

Based on answers to 2 questions, we distinguished dependent and independent walkers and wheelchair users. Participants who responded to the walking

activities of daily living item as either independent or partially dependent were classified as ambulatory for mode of locomotion, whereas all others were classified as nonambulatory. Independence in locomotion was based on whether participants indicated that they were independent in locomotion (ie, independent in walking if ambulatory; independent in wheelchair use if nonambulatory). This resulted in 4 groups: (a) ambulatory-independent, (b) ambulatory-dependent, (c) nonambulatory-independent, and (d) nonambulatory-dependent. Differences amongst the groups on outcomes were explored after the primary analyses.

Because some individuals who were ambulatory required assistance (ie, those classified as dependent) and used a wheelchair for locomotion, supplemental analyses were conducted. Dependent ambulatory participants ($n = 117$) were classified based on wheelchair use as (a) independent in wheelchair use, (b) dependent, or (c) not a wheelchair user (ie, ambulation is the sole means of locomotion). The GTS and ANOVA techniques were then conducted using the same outcome variables to identify differences in outcomes as a function of independence in wheelchair use among those who were ambulatory but required assistance.

All statistical analyses were conducted using SAS software version 9.1 (SAS Institute Inc, Cary, NC). The GTS was computed using SAS macros supplied as an accompaniment to a statistical methodology text (35).

RESULTS

Participant Characteristics

The majority of the participants were men (74%); 79% were white, and 19% were African American. Average age at injury was 29.1 years and at enrollment, 44.7 years (an average of 15.6 years had passed since the onset of injury). The primary cause of injury was motor vehicle crash (54%), followed by falls/falling objects (15%), sporting injuries (12%), and acts of violence (11%). Just more than half of the participants (53%) reported cervical injuries. Twenty-four percent were able to ambulate. Average number of years of education was 13.7.

Table 2 summarizes the participant characteristics as a function of subsample. The characteristics of each subsample reflect the timing in which they were enrolled and geographic location. Samples enrolled first were the oldest, both in terms of age and the number of years lived after injury, and had the most education. Consistent with recent trends, age at injury was greater among those enrolled more recently and there were more motor function injuries (ie, as defined by preserved function below the level of injury sufficient for ambulation) among the most recently enrolled subsample.

Hypothesis 1: Effect of Ambulation Status on Outcomes

The association of the ability to ambulate with the 3 constructs (SWB, participation, health) was assessed by

Table 2. Comparison of Participant Characteristics as a Function of Subsample

	Cohort ^a					Significance ($P < 0.001$) ^a
	1	2	3	4	5	
Number	75	91	134	291	902	
Locomotion	%	%	%	%	%	χ^2 (12, N = 1,493) = 53.7
Ambulatory independent	13.3	19.8	12.7	13.1	23.4	
Ambulatory dependent	1.3	2.2	5.2	5.2	10.3	
Nonambulatory independent	62.7	65.9	63.4	63.2	48.7	
Nonambulatory dependent	22.7	12.1	18.7	18.6	17.6	
Race (= 1 if white)	100	98.9	95.5	63.2	77.3	χ^2 (4, N = 1,493) = 107.5
Sex (= 1 if male)	85.3	81.3	77.6	54.3	77.6	χ^2 (4, N = 1,493) = 72.6
Age (y)	55.9 (7.64)	50.0 (9.47)	48.4 (12.11)	46.5 (13.07)	42.0 (14.07)	F (4, N = 1,476) = 30.2
Age at injury (y)	20.2 (5.95)	24.4 (9.48)	27.9 (12.3)	29.8 (12.84)	30.3 (13.46)	F (4, N = 1,479) = 14.8
Years since injury	35.7 (4.66)	25.6 (4.83)	20.5 (7.67)	16.8 (6.51)	11.7 (9.94)	F (4, N = 1,471) = 186.0
Years of education	15.2 (3.24)	14.8 (3.10)	14.7 (2.56)	13.4 (3.04)	13.4 (2.80)	F (4, N = 1,479) = 16.9

^a Standard deviation is in parentheses.

the rank sum GTS. SWB and participation were higher for walkers (GTS, $P = 0.016$ and $P < 0.001$, respectively); however, no clear pattern was observed regarding the general health variables (GTS, $P = 0.82$) (Table 3). Follow-up analyses were conducted for all dependent variables to determine both statistical significance and the effect sizes.

For the SWB construct, the univariate ANOVAs demonstrated that some, but not all, of the dependent variables differed by walking status. Ambulatory participants reported higher levels of interpersonal relations and fewer health problems ($P < 0.001$ for both), but they also had higher levels of depression ($P = 0.047$).

The patterns of association for the participation construct were clearer for ambulatory participants. Overall, ambulatory participants had higher levels of participation (GTS, $P < 0.001$). This finding was well supported by the follow-up ANOVAs. On all 3 dependent variables, ambulatory participants had higher mean scores than nonambulatory participants ($P < 0.001$ for all dependent variables). The association of ambulation with the health construct, however, was not clear. Overall, there was a nonsignificant GTS finding. This is a direct result of a lack of a uniform pattern of responses on the 6 dependent variables. Although ambulatory individuals reported having fewer hospitalizations ($P < 0.001$) and nonroutine doctor visits ($P = 0.007$), they did report having more poor mental health days ($P = 0.043$) and higher levels of pain interference ($P < 0.001$).

Overall, the effect sizes indicated that walking accounted for less than 3% of the variation in all the dependent variables, suggesting that ambulation status alone is not a highly significant factor associated with outcomes of health.

Hypothesis 2: Effect of Independence of Locomotion on Outcomes

The association of independence in locomotion with the 3 constructs was well pronounced in this sample (Table 3). All 3 GTS were highly significant ($P < 0.001$), indicating strong evidence for a systematic difference in the individual dependent variables. All univariate ANOVAs were highly significant and, notably, in the assumed direction of independent participants reporting better health outcomes, with the sole exception of the number of nonroutine doctor visits. For this dependent variable, the direction was consistent with the hypothesized direction of the effect, but the observed difference of less than 0.5 visits, or approximately 10% fewer visits, was not statistically significant.

Exploratory Analyses

Ambulatory Status Crossed With Independence of Locomotion on Outcomes. Table 4 summarizes the univariate comparisons for each dependent variable, including significance of the 3-degrees-of-freedom test for the ambulation by independence classifications and effect sizes (eta squared). All 3 GTS indicate that there are systematic differences in dependent variables across the 4 classifications of ambulation by independence (independent ambulatory, dependent ambulatory, independent wheelchair user, dependent wheelchair user). Consistent with the reports of the main effect of independence, the 2 classifications that included participants with independence in mobility had better outcomes. The nonindependent, nonambulatory participants, on average, had worse outcomes. For example, in posthoc comparisons of the means, the nonindependent/nonambulatory participants had lower general health ratings and an increased number of

Table 3. Outcomes as a Function of Ambulatory Status and Independence in Locomotion

	Ambulation Status					Independence in Locomotion				
	Walking (N = 412)		Not Walking (N = 1,081)		ANOVA (N = 1,493)	Independent (N = 1,109)		Not Independent (N = 384)		ANOVA (N = 1,493)
	Mean (SD)	F	Mean (SD)	F		Mean (SD)	P	Mean (SD)	F	P
Subjective well-being										
Engagement	48.67 (10.87)	1.79	47.85 (10.49)	1.79	0.181	49.44 (10.11)	<0.001	44.13 (10.99)	75.23	<0.001
Negative affect	49.92 (10.80)	0.92	50.50 (10.38)	0.92	0.338	49.15 (10.17)	<0.001	53.78 (10.69)	57.52	<0.001
Health problems	48.59 (9.92)	27.12	51.61 (10.07)	27.12	<0.001	49.35 (9.70)	<0.001	54.91 (10.18)	91.35	<0.001
Finances	51.08 (10.03)	2.43	50.21 (9.54)	2.43	0.119	51.12 (9.63)	<0.001	48.52 (9.58)	20.72	<0.001
Career opportunities	51.30 (9.96)	7.69	49.76 (9.38)	7.69	0.006	51.23 (9.27)	<0.001	47.19 (9.79)	52.63	<0.001
Home life	48.98 (10.24)	<0.01	49.00 (10.10)	<0.01	0.971	49.81 (9.74)	<0.001	46.64 (10.86)	28.54	<0.001
Interpersonal relations	50.47 (9.16)	26.24	47.59 (9.87)	26.24	<0.001	48.96 (9.91)	<0.001	46.72 (9.13)	15.13	<0.001
Depression (OAHMQ)	6.63 (5.37)	3.95	6.05 (4.98)	3.95	0.047	5.65 (4.87)	<0.001	7.83 (5.40)	54.33	<0.001
Adjustment	15.73 (4.04)	0.49	15.89 (3.96)	0.49	0.485	16.39 (3.66)	<0.001	14.28 (4.43)	84.55	<0.001
Rank sum global test statistics		5.81		5.81	0.016				88.02	<0.001
Participation										
Days out of the house per week	5.05 (2.07)	36.76	4.23 (2.40)	36.76	<0.001	4.87 (2.18)	<0.001	3.27 (2.37)	146.54	<0.001
Nights away in past year	13.16 (11.48)	27.59	9.88 (10.52)	27.59	<0.001	11.86 (10.90)	<0.001	7.70 (10.29)	42.73	<0.001
Hours out of bed	13.35 (3.90)	22.83	12.22 (4.16)	22.83	<0.001	13.22 (3.73)	<0.001	10.53 (4.53)	132.47	<0.001
Rank sum global test statistics		48.63		48.63	<0.001				165.20	<0.001
Health										
Pain interference	20.11 (18.56)	13.94	16.36 (16.85)	13.94	<0.001	15.86 (16.73)	<0.001	21.84 (18.56)	34.46	<0.001
General health ratings	3.07 (1.06)	1.80	3.15 (1.03)	1.80	0.18	3.22 (1.03)	<0.001	2.87 (1.02)	32.84	<0.001
Poor physical health	6.94 (9.19)	0.45	6.58 (8.99)	0.45	0.501	6.06 (8.67)	<0.001	8.48 (9.84)	20.72	<0.001
days last month										
Poor mental health days last month	7.32 (9.59)	4.12	6.24 (9.06)	4.12	0.043	5.79 (8.84)	<0.001	8.69 (9.94)	28.68	<0.001
Number of nonroutine doctor visits	4.71 (4.15)	7.33	5.36 (4.22)	7.33	0.007	5.07 (4.22)	<0.001	5.50 (4.19)	2.89	0.089
Number of hospitalizations										
Rank sum global test statistics	0.95 (1.87)	12.48	1.37 (2.14)	12.48	<0.001	1.11 (1.91)	<0.001	1.68 (2.46)	22.10	<0.001
		0.05		0.05	0.82				47.50	<0.001

OAHMQ, Older Adult Health and Mood Questionnaire.

Table 4. Comparisons as a Function of Ambulatory Status and Independence in Locomotion

	Independent/ Walking Mean (SD) (a)	Not Independent/ Walking Mean (SD) (b)	Independent/ Not Walking Mean (SD) (c)	Not Independent/ Not Walking Mean (SD) (d)	ANOVA (N = 1,493)		
					Overall F Test		Contrasts (Tukey)
					F	P	
	N = 294	N = 118	N = 815	N = 266			
Subjective well-being							
Engagement	50.78 (9.91)	43.42 (11.39)	48.96 (10.14)	44.45 (10.81)	27.67	<0.001	a>b,c,d; c>b,d
Negative affect	48.15 (10.14)	54.33 (11.16)	49.51 (10.16)	53.53 (10.49)	20.62	<0.001	b,d>a,c
Health problems	46.6 (9.18)	53.54 (9.99)	50.34 (9.69)	55.51 (10.22)	42.92	<0.001	b,d>c,a; c>a
Finances	52.47 (9.98)	47.62 (9.32)	50.63 (9.46)	48.93 (9.68)	10.12	<0.001	a>c,d,b; c>b
Career opportunities	52.99 (9.19)	47.09 (10.59)	50.59 (9.22)	47.23 (9.44)	22.40	<0.001	a>b,c,d; c>b,d
Home life	50.22 (9.68)	45.9 (10.94)	49.67 (9.76)	46.97 (10.83)	10.04	<0.001	a,c>b,d
Interpersonal relations	51.77 (8.97)	47.21 (8.86)	47.95 (10.04)	46.51 (9.25)	16.68	<0.001	a>b,c,d
Depression	5.89 (5.08)	8.49 (5.65)	5.56 (4.79)	7.55 (5.28)	19.41	<0.001	b,d>a,c
Adjustment	16.29 (3.73)	14.33 (4.44)	16.42 (3.63)	14.26 (4.44)	28.24	<0.001	a,c>b,d
Rank sum global test statistics					33.81	<0.001	
Participation							
Days out of the house per week	5.46 (1.87)	4.02 (2.20)	4.66 (2.25)	2.94 (2.38)	66.50	<0.001	a>c,b,d; c>b,d; b>d
Nights away in past year	14.26 (11.44)	10.44 (11.19)	10.99 (10.57)	6.48 (9.64)	25.10	<0.001	a>c,b,d; c,b>d
Hours out of bed	13.97 (3.48)	11.81 (4.45)	12.95 (3.78)	9.96 (4.46)	56.00	<0.001	a>c,b,d; c>b,d; b>d
Rank sum global test statistics					78.81	<0.001	
Health							
Pain interference	17.01 (17.34)	27.84 (19.30)	15.44 (16.50)	19.18 (17.61)	19.23	<0.001	b>d,a,c; d>c
General health ratings	3.15 (1.01)	2.87 (1.17)	3.25 (1.04)	2.87 (0.95)	11.52	<0.001	a,c>d,c>b
Poor physical health days last month	5.8 (8.29)	9.76 (10.65)	6.15 (8.80)	7.91 (9.43)	8.18	<0.001	b,d>c,a
Poor mental health days last month	6.2 (9.10)	10.1 (10.22)	5.64 (8.74)	8.06 (9.77)	11.21	<0.001	b>a,c; d>c
Number of nonroutine doctor visits	4.34 (4.04)	5.63 (4.30)	5.34 (4.25)	5.44 (4.15)	5.15	0.002	b,c,d>a
Number of hospitalizations	0.67 (1.52)	1.64 (2.42)	1.26 (2.01)	1.7 (2.48)	13.46	<0.001	d>c,a; b,c>a
Rank sum global test statistics					17.85	0.001	

Table 5. Outcomes as a Function of Wheelchair Use Among Participants Dependent in Ambulation

	Full Sample Mean (SD) N = 117 ^a	Nonwheelchair Users Mean (SD) (a) N = 30	Independent Wheelchair Users Mean (SD) (b) N = 56	Dependent Wheelchair Users Mean (SD) (c) N = 31	ANOVA			
					Overall F Test			Contrasts (Tukey)
					F	P	Eta Squared	
Subjective well-being								
Engagement	43.42 (11.39)	38.23 (11.48)	47.45 (10.74)	41.63 (10.00)	7.87	0.001	0.121	b>a; b>c
Negative affect	54.33 (11.16)	60.29 (10.79)	50.58 (10.40)	54.92 (10.38)	8.46	<0.001	0.129	a>b
Health problems	53.54 (9.99)	57.25 (9.87)	49.18 (9.14)	56.99 (7.65)	11.43	<0.001	0.167	a,c>b
Finances	47.62 (9.32)	43.06 (9.00)	49.15 (9.03)	49.67 (8.73)	5.53	0.005	0.088	b,c>a
Career opportunities	47.09 (10.59)	42.88 (11.71)	49.63 (9.71)	47.13 (9.58)	4.26	0.016	0.070	b>a
Home life	45.9 (10.94)	42.85 (10.53)	47.83 (11.33)	46.25 (9.10)	2.16	0.120	0.037	
Interpersonal relations	47.21 (8.86)	45.39 (9.74)	49.2 (8.22)	45.89 (8.39)	2.48	0.088	0.042	
Depression	8.49 (5.65)	11.2 (5.95)	6.17 (4.96)	9.65 (4.58)	10.63	<0.001	0.157	a,c>b
Adjustment	14.33 (4.44)	13.4 (4.71)	16.06 (3.25)	12.25 (4.93)	9.58	<0.001	0.144	b>a,c
Rank sum global test statistics					34.87 <0.001			
Participation								
Days out of the house per week	4.02 (2.20)	3.37 (2.04)	4.75 (2.09)	3.43 (2.17)	6.07	0.003	0.096	b>a,c
Nights away in past year	10.44 (11.19)	9.29 (9.89)	13.16 (12.41)	6.89 (9.00)	3.50	0.033	0.058	b>c
Hours out of bed	11.81 (4.45)	11.22 (4.43)	13.39 (3.31)	9.34 (5.06)	10.00	<0.001	0.149	b>c
Rank sum global test statistics					112.00 <0.001			
Health								
Pain interference	27.84 (19.30)	32.67 (19.44)	22.33 (20.03)	32.08 (14.78)	4.25	0.017	0.069	a>b
General health ratings	2.87 (1.17)	2.5 (1.25)	3.39 (1.02)	2.35 (0.95)	12.11	<0.001	0.175	b>a,c
Poor physical health days last month	9.76 (10.65)	14.47 (12.28)	6.18 (9.20)	11.02 (8.95)	7.13	0.001	0.111	a>b
Poor mental health days last month	10.1 (10.22)	14.4 (10.91)	7.35 (9.19)	10.28 (9.58)	5.12	0.007	0.082	a>b
Number of nonroutine doctor visits	5.63 (4.30)	5.88 (4.19)	4.92 (4.18)	6.46 (4.46)	1.41	0.248	0.024	
Number of hospitalizations	1.64 (2.42)	1.8 (2.37)	1.39 (2.61)	1.71 (1.83)	0.35	0.705	0.006	
Rank sum global test statistics					16.74 <0.001			

^a One observation in “Not Independent/Walking” in Table 4 does not fall into any of the 3 categories in this table, such that the total “Full Sample” decreases by 1 to 117.

hospitalizations compared with either of the 2 groups consisting of independent participants.

There were also significant differences among the 4 groups when looking specifically at diagnostic categories for depression (Chi [6, $n = 1,370$] = 56.5, $P < 0.001$). Participants who were dependent in ambulation reported the greatest prevalence of clinically significant symptomatology (65.7%), as defined by scores of 5 or higher, followed by those who were dependent in wheelchair use (58.3%). Much lower rates of clinically significant symptomatology were observed for those who are independent in ambulation (41.2%) or independent in wheelchair use (40.7%). A similar pattern was observed for probable major depression (scores of 11 or higher), as 38.2% of dependent ambulators reported scores in this

range compared with 33.8% for dependent wheelchair users, 19.5% for independent ambulators, and 17.1% for independent wheelchair users.

Ambulation and Wheelchair Use. Table 5 summarizes the follow-up analyses that were conducted exclusively among ambulatory participants who required assistance with ambulation ($n = 117$). The overall main effect among the 3 groups (independent wheelchair users, dependent wheelchair users, and nonwheelchair users) was significant (GTS, $P < 0.001$ for all 3 constructs). In contrast with the primary analyses (ie, comparisons among all participants based on ambulatory status and independence and mobility), the effect sizes were substantially larger, ranging from 0.006 to 0.175 for variables that reached statistical significance.

Follow-up tests indicated significant differences on all 3 of the participation variables, 4 of the 6 health variables (pain interference, self-rated health, poor physical health days, and poor mental health days), and all but 2 of the SWB variables (home life and interpersonal relations were nonsignificant). Posthoc tests revealed that participants who were nonwheelchair users and those who were dependent in wheelchair use were not significantly different from each other on any outcomes. In contrast, independent wheelchair users reported better outcomes than nonwheelchair users for each of the SWB outcomes on which there were significant differences; they left their homes more frequently and reported higher overall general health and fewer bad physical and mental health days. In contrast with dependent wheelchair users, those independent in wheelchair use reported higher adjustment scores, higher well-being related to health, and fewer depressive symptoms; spent more hours out of bed; left their homes more frequently; and rated their overall health higher.

DISCUSSION

The purpose of this article was to identify the association of 2 important mobility parameters (mode, independence) and long-term outcomes after SCI. Despite the emphasis placed on ambulation as a primary mode of mobility, there has been an absence of critical evaluation of the long-term consequences of ambulation and the commonly held assumption among both patients and providers that it leads to better outcomes and a higher quality of life. Similarly, although independence in mobility has been a traditional rehabilitation goal, it has received relatively little attention in relation to long-term outcomes.

The 2 study hypotheses addressing associations between mode of locomotion and independence in locomotion received mixed support. The first hypothesis, that ambulation would be associated with favorable outcomes in each of the 3 outcome areas, was not fully supported. The effect sizes were small, suggesting that the relationships were somewhat limited in terms of clinical significance, and we also found that *nonambulatory* participants reported better outcomes on select indicators of both SWB and health, suggesting limits to which ambulation is associated with better outcomes. We had not anticipated that ambulation would be significantly related to both favorable outcomes and unfavorable outcomes (eg, higher pain interference scores, higher depression scores).

Complicated patterns, such as better participation yet poorer mental health and higher pain interference, are intriguing and worthy of notice. They raise questions about whether greater participation and higher activity levels may actually lead to some less desirable outcomes. Unfortunately, this cannot be determined in the current study.

The small effect sizes are consistent with previous research, in that disability measures historically have low correlations with other outcomes (36). The second hypothesis, that independence in locomotion would be associated with better outcomes, was supported (although we did not hypothesize that it would be associated with more favorable outcomes on literally all variables).

Whereas our results identify significant limits to the benefits of ambulation, they provide support for the importance of independence in locomotion. This affirms the importance of functional independence as a primary rehabilitation goal, at least as related to mode of locomotion.

Follow-up comparisons that focused solely on participants who needed help with ambulation generated the most compelling results in terms of effect sizes (8 of these effect sizes exceeded 0.10, whereas none of the effect sizes exceeded 0.06 in the primary analyses). These effect sizes suggest much greater clinical relevance of comparisons *among* ambulators, rather than effect sizes between ambulators and nonambulators and those independent and dependent in mode of mobility. Among those participants who needed assistance with ambulation, those independent in wheelchair use reported substantially better outcomes than those who were either dependent wheelchair users or nonwheelchair users. The poor outcomes among those who relied solely on ambulation for mobility, yet were dependent on others for assistance, suggest that this is a subgroup of the SCI population that may be in particular need of follow-up services. There were simply no data in the current study to further clarify the circumstances surrounding these problems and the detrimental outcomes for these participants.

Implications

Without question, ambulation is a viable goal for many people with SCI and is associated with favorable outcomes in some areas. However, we must determine when ambulation is an appropriate functional goal. Our results suggest that ambulation may not be an appropriate goal as a *primary* mode of mobility for some people based on its association with adverse outcomes, and it is incumbent upon rehabilitation professionals to ensure that their clients are aware of the potential negative consequences in these cases.

Adherence to traditional rehabilitation goals is supported by our findings. Independence in locomotion remains an important variable in the lives of people with SCI. We need to continue to promote this and other similar goals and help clients understand the importance of independence in locomotion.

Limitations

There are several noteworthy limitations. First, all data are cross-sectional. Therefore, we have essentially a snapshot

of the association of the 2 primary study variables, mode and independence in locomotion, with the outcome variables. We cannot assume that these 2 factors have a causal relationship with the outcomes. Second, all outcome data were self-reported. This is not problematic with the majority of outcome measures, particularly those related to SWB, which are, by definition, self-reported. Reports of hospitalizations and treatments may be more influenced by retrospective recall than subjective variables. Third, our operationalizations of ambulation and independence in locomotion were similarly limited to self-report and based on a small number of items. More detailed information on ambulation would have allowed us to look at a greater number of facets of independence. Nevertheless, the consistency of the findings clearly indicates that independence in locomotion is an important correlate of study outcomes. Fourth, there was a modest amount of missing data. Fifth, we have no data on the duration that participants had been in their current ambulatory/locomotion category. Sixth, although the overall sample size was relatively large, the number of ambulatory participants who required some assistance was limited to 117 cases. This restricted posthoc comparisons among this group. These comparisons are particularly important for people with SCI who are ambulatory but require help, because they clarify the types of complications experienced by people who use a combination of ambulation and wheelchair use for mobility. Another limitation is that we have chosen to focus on 2 particular variables, rather than a diverse choice of other factors (eg, age) that potentially could have added to the explanatory power of the model, but we chose not to do this in order to produce results that clearly address the role of ambulation and independence in locomotion (2 important, yet not heavily studied, factors). Finally, multiple testing was conducted on the same data, so an inflated experiment-wide error rate is a result. The analysis plan, however, did follow a structured analysis that attempted to minimize the number of statistical tests performed for the primary hypotheses.

Future Research

Among the many needs for future research is a focus on long-term outcomes. The literature on intensive ambulation trials has been growing, and substantial benefits have been identified. We need to follow participants longitudinally after these trials to determine the extent to which benefits are maintained and the extent to which new complications arise.

We also need to pay closer attention to ambulators who may experience significant problems. The current findings suggest those who require assistance from others are at particular risk for poor outcomes, but we also need to evaluate the extent to which certain types of supportive devices (eg, canes, walkers, braces) are related to outcomes similar to those addressed in this study.

We should consider the rehabilitation landscape and changes on the horizon as more aggressive restorative interventions are validated and become more readily available. New discoveries will add pressure to produce “better” outcomes, such as increasing the proportion of people with SCI who ambulate, and these outcomes need to be critically evaluated. The time to learn more about complications that are associated with ambulation is not after breakthroughs occur. Rather, we must commit ourselves to steadfast investigation of currently available populations of individuals who have been ambulatory for years or even decades since SCI.

CONCLUSIONS

The results of this study suggest that both mode of locomotion and independence in locomotion are associated with differences in SWB, participation, and health. However, whereas independence in locomotion was modestly, but favorably, related to diverse outcomes, mode of locomotion was associated with a mixed pattern of favorable and unfavorable outcomes, with the best outcomes associated with independent ambulation. Much less favorable outcomes were observed among those who ambulated but were dependent on assistance from others.

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