ORIGINAL ARTICLE

Patterns, Predictors, and Associated Benefits of Driving a Modified Vehicle After Spinal Cord Injury: Findings From the National Spinal Cord Injury Model Systems

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ABSTRACT. Norweg A, Jette AM, Houlihan B, Ni P, Boninger ML. Patterns, predictors, and associated benefits of driving a modified vehicle after spinal cord injury: findings from the National Spinal Cord Injury Model Systems. Arch Phys Med Rehabil 2011;92:477-83.

Objectives: To investigate the patterns, predictors, and benefits associated with driving a modified vehicle for people with spinal cord injuries (SCIs).

Design: Cross-sectional retrospective survey design.

Settings: Sixteen Model SCI Systems (MSCISs) throughout the United States.

Participants: People (N=3726) post-SCI from the National MSCIS Database.

Interventions: Not applicable.

Main Outcome Measures: Driving, employment, and community reintegration post-SCI.

Results: The study found that 36.5% of the sample drove a modified vehicle after SCI. Significant predictors of driving a modified vehicle post-SCI included married at injury, younger age at injury, associate's degree or higher before injury, paraplegia, a longer time since the injury, non-Hispanic race, white race, male sex, and using a wheelchair for more than 40 hours a week after the injury (accounting for 37% of the variance). Higher activity of daily living independence (in total motor function) at hospital discharge also increased the odds of driving. Driving increased the odds of being employed at follow-up by almost 2 times compared with not driving postinjury (odds ratio, 1.85). Drivers tended to have higher community reintegration scores, especially for community mobility and total community reintegration. Driving was also associated with small health-related quality-of-life gains, including less depression and pain interference and better life satisfaction, general health status, and transportation availability scores.

Conclusions: The associated benefits of driving and the relatively low percentage of drivers post-SCI in the sample provide evidence for the need to increase rehabilitation and assistive technology services and resources in the United States devoted to facilitating driving after SCI.

Key Words: Automobile driving; Employment; Rehabilitation; Spinal cord injuries.

PEOPLE WITH SPINAL cord injuries have identified transportation as the second highest environmental barrier after the natural environment[1] and the biggest barrier to employment.[2] Transportation also influences access to health care services in the community for people with SCI.[3] The availability of transportation has been associated strongly with the need for institutional care,[4] QOL,[5] and depression.[6]

The ADL of driving an adapted vehicle specifically has been associated significantly with community reintegration, especially in the areas of productivity in the home and community,[7] employment,[7,8] and higher QOL in people with SCI.[9] Having an adapted car has also been associated with higher patient satisfaction.[10] Vehicle modifications may include hand-operated controls, lift systems, adaptive seating, and a raised roof. In a study from Denmark[11] that included 236 participants with traumatic SCI, most participants used hand-operated brakes and accelerators for their adapted vehicles. Twenty percent reported using vehicle lift systems, whereas only 1.7% used manual ramps for accessing their vehicles. Participants also used adapted seating (8.9%) and adapted heating systems or heated seats in their vehicles (6%).

Similarly, in a study from Sweden,[12] common vehicle modifications used by drivers with disabilities, 75% of whom had lower-limb disabilities, including 16% with SCIs, were investigated. Common vehicle modifications used by the participants included power steering (69%), combined hand-controlled levers for brakes and accelerators (47%), adapted driver's seats (27%), ramps or lift systems for wheelchairs (14%), spinner knobs or other handles for the steering wheel (26%), electrically operated side windows (31%), and electrically operated rearview mirrors (27%).

Community reintegration is an important rehabilitation outcome post-SCI. The World Health Organization International

List of Abbreviations

ADLs	activities of daily living
CHIEF	Craig Hospital Inventory of Environmental Factors
HRQOL	health-related quality of life
MSCIS	Model Spinal Cord Injury Systems
NSCI	National Spinal Cord Injury
OR	odds ratio
PHQ-9	Patient Health Questionnaire-9
QOL	quality of life
SCI	spinal cord injury
SF-12	Medical Outcomes 12-Item Short Form Health Survey

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Classification of Functioning, Disability, and Health defines participation as being involved in a life situation, which can include, for example, communicating, using transportation, driving, domestic life, relationships, education, employment, and community and civic life (eg, recreation and leisure).[13] The International Classification of Functioning, Disability, and Health recognizes that environmental factors, such as the availability of assistive technology, affect participation and can serve as facilitators or barriers.

More research is needed to understand important predictors of driving and community reintegration.[1,14] There is a need to further research factors that influence the important rehabilitation outcome of community reintegration, including the impact of environmental factors and assistive technology, for adults with SCI. Research that focuses on participation patterns and experiences of people with SCI is especially needed.[14] Despite its importance, few studies have analyzed driving patterns and predictors in adults post-SCI. The relationship of driving to community reintegration for people with SCI requires further investigation.[1]

We are not aware of another study in the United States that focused on distributions, determinants, and associated benefits of driving status in adults post-SCI.

The aims of this research were to explore patterns, predictors, and associated benefits of driving for adults after SCI by using a cohort of adults from the national MSCIS Database. This study specifically addressed the following research questions: What are the patterns of driving a modified vehicle by people with SCI? What proportion of people post-SCI drive? Which sociodemographic and injury-related variables predict driving? What are the benefits associated with driving? To what extent is driving associated with community reintegration and employment post-SCI?

METHODS

National MSCIS Database

The National MSCIS Database offers a unique opportunity to evaluate driving variables in a U.S. sample. The database, initiated in 1975, is funded by the U.S. Department of Education's National Institute on Disability and Rehabilitation Research. Data are collected by model systems throughout the United States, which are managed and distributed by the NSCI Statistical Center in Alabama. Standardized data collection procedures are used by all systems. Data for such outcomes as impairment, functional status, community reintegration, QOL, mortality, health care use, and medical complications are collected up to 30 years postinjury.[15]

Participants

The study used a cross-sectional retrospective survey design. Total sample size of the study was 3726 participants. Subjects were eligible for inclusion in the NSCI database if they met the following criteria: sustained an SCI of a traumatic nature, were admitted to a MSCIS within 1 year of the SCI, and were U.S. citizens or permanent residents. Study subjects also needed to have provided driving data. Questions about driving status were added to the MSCIS database in 2004, and analyses therefore included data collected from April 1, 2004, to September 30, 2006. Because 22 subjects had more than 1 data point for the driving variables, we used the latest driving data available for this study. All other participants in the data set had completed only 1 anniversary evaluation with driving questions.

Our exclusion criteria included persons with minimal or no neurologic damage at discharge (ie, paraplegia and tetraplegia of minimal deficit or normal neurologic function; n=10) and those with sacral SCI at discharge (n=11) because these person most likely did not require a modified vehicle to drive post-SCI. We also excluded those with an unknown degree of neurologic impairment at discharge (n=80) and person who were not of legal driving age at their follow-up evaluation (ie, aged <16y; n=7).

Measures

The driving variable in the NSCI database was defined as participants or their family owning at least 1 modified vehicle and the participant driving the modified vehicle. The 2 questions in the database were as follows: (1) What type of modified vehicle do you or your family own? (2) Do you drive the modified vehicle? Participants who reported not owning a modified vehicle for the driving question were coded as not driving.

Employment status was treated as a dichotomous variable, consistent with other studies.[16,17] Those who reported working in the competitive labor market (coded as 1) were compared with all other categories (coded as 2; homemaker, unemployed, on-the-job training, sheltered workshop, volunteers, disability, medical leave). On-the-job training and sheltered workshops were categorized as not working because of their temporary nature and low pay.[16] Students were excluded from this variable. Those who retired preinjury were excluded from the employment status at injury variable.

Community reintegration was measured by using the Mobility, Occupation, and Social Integration subscales, total community reintegration score, and the economic self-sufficiency question of the Craig Handicap Assessment and Reporting Technique Short-Form.[18] Higher scores indicated greater community reintegration.

Perceived physical barriers were measured using the Physical/Structural subscale and the transport availability question of the CHIEF.[19] Respondents rated how often and how much the availability of transportation was a problem in the past 12 months by using a 4-point scale (with 0 = never and 4 = daily). The 2 items of the Physical/Structural subscale of the CHIEF asked respondents to rate the frequency and magnitude that the natural environment (such as temperature and terrain) and physical aspects of their surroundings (such as lighting and noise) made it difficult to perform desired or needed activities. Scores for this subscale ranged from 0 to 8.

We used 2 measures for injury severity. The level of preserved neurologic function variable was defined as the most caudal segment of the spinal cord with normal sensory and motor function. It was modified to consist of 3 categories: cervical, thoracic, and lumbar (with the sacral SCI category omitted). The category of neurologic impairment measured the degree of neurologic damage present at discharge and included 4 categories: paraplegia incomplete, paraplegia complete, tetraplegia incomplete, and tetraplegia complete. Neurologic impairment was also treated as a dichotomous variable (tetraplegia and paraplegia).

Independence in ADLs was measured using both the Bed, Chair, Wheelchair Transfer Ability score (composed of 1 question) and the ADL total motor score of the FIM[20,21] at hospital discharge. The ADL total motor score was the summated score of the 13 motor items of the FIM.

The brief version of the PHQ-9,[22] consisting of 9 items, was used to measure severity of depression. PHQ-9 depression scores ranged from 0 to 27, with lower scores indicating less depression.

General health and pain interfering with normal work were measured using 2 items from the SF-12.[23] For the general health question, respondents rated their health in general by using a 5-point scale (ranging from 1 = excellent to 5 = poor). For the pain question, responders rated how much their pain interfered with normal work during the past 4 weeks on a 5-point scale (0 = not at all, 4 = extremely).

Total score of the Satisfaction With Life Scale[24] was used to measure satisfaction with life. The scale consisted of 5 statements and response options ranging from 1 (strongly disagree) to 7 (strongly agree). The score range was 5 to 35, with higher scores indicating more life satisfaction.

Statistical Analyses

SPSS software, Version 16.0 for Windows[a] was used for statistical analyses. The dependent variable for initial analyses was driving status. Driving was coded as a dichotomous variable, for which 1 indicates currently driving a modified vehicle and 0 indicates not driving a modified vehicle post-SCI. We used descriptive statistics, including chi-square analyses, to summarize the sample demographics and driving variables. Age group at injury included 4 categories, which were chosen based on frequency distributions.

Binary logistic regression (backward Wald) analyses were used for the predictive model of driving status post-SCI. The following independent variables were entered into the model to predict driving at the annual postinjury evaluation: age at injury, marital status at injury, education at injury, category of neurologic impairment at discharge (1 = paraplegia, 2 = tetraplegia), completeness of SCI at discharge (1 = incomplete, 2 = complete), postinjury year, racial group, Hispanic origin (0 = no, 1 = yes), sex (male = 1, female = 2), and wheelchair use for more than 40 hours a week (0 = no, 1 = yes). The marital status at injury variable was dummy coded; the category (married at injury) was omitted for logistic regression to serve as the reference group. Education at injury was dichotomized, in which 1 indicates high school diploma or lower and 2 indicates associate's degree or higher. Racial group was also dichotomized, for which 1 indicates white and 0 indicates nonwhite. Because of large amounts of missing data, the variables ADL ability and transfer ability were excluded from multiple logistic regression models and were analyzed separately.

We used binary logistic regression to evaluate the association of driving status (as an independent variable) with the dependent variable employment status post-SCI. Analysis controlled for the covariates employment status at injury, neurologic impairment type (tetraplegia or paraplegia), education at follow-up, and race.

We used linear regression to evaluate associations of driving with community reintegration outcome variables, measured by using the Craig Handicap Assessment and Reporting Technique Short-Form. Linear regression was also used to evaluate associations of driving with HRQOL outcome variables, derived from the PHQ-9, Satisfaction With Life Scale, SF-12 (general health and pain interference questions), and the CHIEF (transport availability and physical/structural barriers questions). Driving was an independent variable for these analyses. Control variables in the linear regression models included postinjury year, sex, neurologic impairment at discharge, marital status at follow-up, education at follow-up, race, and occupation at follow-up.

Table 1: Sociodemographic and Injury Descriptions for Subjects by Driving Status

Variable	Do Not Drive	Drive	P*
Age group at injury (y); n=3726			<.001
<16	65 (53.7)	56 (46.3)	
16–29	1108 (57.2)	829 (42.8)	
30–59	1020 (69.2)	455 (30.8)	
≥60	174 (90.2)	19 (9.8)	
Sex; n=3726			<.001
Male	1793 (61.4)	1125 (38.6)	
Female	574 (71.0)	234 (29.0)	
Race; n=3637			<.001
White	1643 (58.5)	1166 (41.5)	
African American	577 (82.7)	121 (17.3)	
Native American, Eskimo, or Aleut	17 (68.0)	8 (32.0)	
Asian or Pacific Islander	39 (78.0)	11 (22.0)	
Other, unclassified	40 (72.7)	15 (22.3)	
Ethnicity; n=3699			<.001
Hispanic origin	218 (75.1)	72 (24.8)	
Not Hispanic	2131 (62.5)	1278 (37.5)	
Marital status at injury; n=3719			.11
Single, never married	1213 (62.0)	745 (38.0)	
Married	821 (65.4)	435 (34.6)	
Divorced/separated/widowed	329 (65.1)	176 (34.9)	
Level of education at injury; n=3590			<.001
≤High school	716 (67.5)	345 (32.5)	
High school diploma or GED	1246 (60.9)	799 (39.1)	
Associate's or bachelor's degree	222 (58.3)	159 (41.7)	
Master's or doctorate degree	75 (72.8)	28 (27.2)	
Employment status at injury; n=2898			
Employed	1472 (61.5)	921 (38.5)	
Unemployed	404 (80.0)	101 (20.0)	
Neurologic impairment at discharge; n=3726			<.001
Paraplegia incomplete	435 (70.8)	179 (29.2)	
Paraplegia complete	477 (41.8)	663 (58.2)	
Tetraplegia incomplete	884 (76.9)	265 (23.1)	
Tetraplegia complete	571 (69.4)	252 (30.6)	
Level of preserved neurologic function at discharge; n=3661			<.001
Cervical	1403 (73.7)	501 (26.3)	
Thoracic	658 (46.7)	751 (53.3)	
Lumbar	250 (71.8)	98 (28.2)	

NOTE. Values expressed as n (%).
Abbreviation: GED, General Educational Development diploma.
*Pearson chi-square.

RESULTS

Our sample consisted of 3726 participants post-SCI from the National MSCIS Database. Overall, 36.5% of this database sample drove a modified vehicle postinjury. Most (53.6%) participants (or their families) owned a modified vehicle. Of nondrivers with a modified vehicle, 83.7% had tetraplegia (n=638).

Sociodemographic and injury-related variables for drivers and nondrivers are listed in table 1. A higher percentage of nondrivers were older (≥30y), women, nonwhite, of Hispanic origin, and unemployed at injury and had a lower level of education at injury (high school or less), and cervical level of injury. Sixty-one percent of drivers were classified into the 16- to 29-year age group. Ninety percent of drivers were employed at injury. Eleven percent of participants with complete C4 SCI

Table 2: Multivariate Predictors of Driving Status

Variable	β	OR	95% CI	P
Single status	−0.42	0.66	0.53–0.82	<.001
Associate's degree or higher	0.54	1.72	1.33–2.21	<.001
Tetraplegia	−1.19	0.31	0.26–0.36	<.001
Postinjury year	0.05	1.05	1.04–1.06	<.001
White race	1.19	3.28	2.60–4.08	<.001
Hispanic origin	−0.41	0.67	0.43–1.02	.064
Female sex	−0.49	0.61	0.50–0.75	<.001
Wheelchair use >40h	2.47	11.88	8.85–15.95	<.001
Age at injury	−0.03	0.97	0.96–0.98	<.001
Constant	−1.29	NA	NA	NA
Nagelkerke R^2	0.37			

NOTE. N=3462. Driving is coded as 0 (no) and 1 (yes).
Abbreviations: CI, confidence interval; NA, not applicable.

reported driving (n=228); 17 of them drove from a wheelchair and the remaining 8 drove out of their wheelchairs.

Driving method and type of modified vehicle driven differed by level of preserved neurologic function. For those with cervical-level SCI, there was an even split between those driving in their wheelchairs (49%) and those driving out of their wheelchairs (51%). As expected, most drivers (89.5% and 96.9%, respectively) with thoracic and lumbar SCIs drove out of their wheelchairs. Driving from a wheelchair was the preferred method for most participants with C4, C5, and C6 SCI (56%, 69%, and 52%, respectively), whereas those with C7 and C8 SCIs preferred driving out of their wheelchairs (72.8% and 87%, respectively), most likely because of their increased mobility and transfer skills and type of wheelchair. Most drivers with cervical SCI (70.2%) owned a van, allowing them to drive from their wheelchairs as needed and to load and transport their wheelchairs with more ease. In contrast, 45% of participants with paraplegia drove modified cars.

The multiple logistic regression model (table 2) shows the predictors of driving a modified vehicle. The model accounted for 37% of the variance. The model's sensitivity (of correctly predicting driving) was 81.3%, and specificity (of correctly predicting nondriving) was 64.1%. The following predictors were associated with increased likelihood of driving an adapted vehicle after an SCI: having an associate's degree or higher before the injury (OR, 1.72), longer time postinjury (OR, 1.05), white race (OR, 3.28), full-time wheelchair use (OR, 11.88), being married at injury, having paraplegia (compared with tetraplegia), male sex, and younger age at injury. Individuals who were single at the time of injury were 34% less likely to drive (OR, .66) at the follow-up interview compared with those who were married. The odds of driving increased by 72% for those with at least an associate's degree at the time of injury compared with those with a high school diploma or less education at the time of injury. Compared with those with paraplegia, participants with tetraplegia were 69% less likely to drive at follow-up. Each additional postinjury year increased the odds of driving at follow-up by 5%. Being of white race increased the odds of driving at follow-up by 3.3 times compared with nonwhite race. Women were 39% less likely to drive at follow-up than men. The odds of driving at follow-up decreased by 3% for each additional year of age at the time of injury (OR, .97). The completeness of an SCI was not a significant predictor of driving at follow-up.

In separate analyses, total ADL motor independence at discharge measured by using the FIM predicted driving postinjury. Each additional point on the 13 to 91 Total Motor Scale score of the FIM increased the odds of driving by 2% (OR, 1.02). However, a subject's transfer ability was not a significant predictor of driving.

Driving a modified vehicle was associated with being employed post-SCI. Driving increased the odds of being employed at follow-up by almost 2 times compared with not driving postinjury (OR, 1.85). The model accounted for 23% of the variance (table 3).

Driving was associated significantly with improved community reintegration post-SCI (table 4). Compared with nondrivers, drivers tended to be more socially integrated, mobile, appropriately occupied, and economically self-sufficient and have better overall community reintegration. The multiple regression models accounted for 10% to 43% of the variance for community reintegration variables. In particular, the community mobility and total community reintegration scores of drivers were higher by one-fifth of an SD compared with nondrivers (β=.20). That is, drivers' scores were 10.5 units higher on the community mobility scale of 0 to 100 and 46.2 units higher on the total community reintegration scale of 0 to 600 (600 indicates no dysfunction) compared with nondrivers.

The association of driving after adjusting for covariates was significant for all HRQOL dependent variables, except for physical/structural environmental barriers (table 5). Drivers tended to have slightly better HRQOL outcome scores than nondrivers. The percentages of variance ($R_{2\text{adj}}$) explained by these independent variables for HRQOL dependent variables were small, ranging from 4% to 12%, but overall associations with HRQOL variables were significant.

DISCUSSION

To our knowledge, this is the only study in the United States to present national data for driving trends, predictive factors, and associated benefits for people with SCI. Of the 638 participants not driving who owned a modified vehicle, 83.7% had tetraplegia and therefore most likely used it for passenger transportation only. This finding most likely reflects additional barriers to driving for people with tetraplegia, such as the increased number and expense of sophisticated vehicle modifications needed, additional safety concerns, and limited availability of specialized driving rehabilitation and training services for people with high-level tetraplegia. The cost of vehicle modifications varies widely; however, extensive vehicle modifications, especially of a minivan, can cost up to $65,000 or more.[25]

The highest neurologic level at which driving was feasible for at least several participants post-SCI was C4. That is, 25

Table 3: Association of Driving With Employment Post-SCI After Controlling for Confounding Variables

Independent Variables	β	OR	95% CI	P
Driving	0.62	1.85	1.50–2.29	<.001
Not employed at injury	−0.78	0.46	0.33–0.64	<.001
Tetraplegia	−0.26	0.77	0.62–0.95	.013
Associate's degree or higher at follow-up	1.40	4.04	3.29–4.96	<.001
White race	0.70	2.01	1.51–2.68	<.001
Constant	−2.35	NA	NA	NA
Nagelkerke R^2	0.23			

NOTE. N=2194. Employment postinjury is coded as 1 (yes) and 0 (no) (students were omitted from analysis). Driving is coded as 0 (no) and 1 (yes).
Abbreviations: CI, confidence interval; ; NA, not applicable.

Table 4: Associations of Driving With Community Reintegration Post-SCI by Using the Craig Handicap Assessment and Reporting Technique Short-Form

Variable	Social Integration β	Mobility β	Occupation β	Economic Self-Sufficiency β	Total Community Reintegration β
Driving	.13*	.20*	.14*	.07*	.20*
Postinjury year	−.07*	−.05†	.05†	−.02	.05†
Sex	.02	−.05†	.06*	−.03	−.01
Neurologic impairment	−.01	−.10*	−.11*	.05†	−.16*
Marital status	−.10*	−.08*	−.07*	−.002	−.03
Education	.12*	.09*	.05†	.21*	.12*
Race	−.06†	−.06*	−.02	−.12*	−.09*
Occupation	−.18*	−.35*	−.50*	−.36*	−.45*
Adjusted R^2	.10	.25	.37	.26	.43

NOTE. Parameter estimates are shown in table. Driving is coded as 0 (no) and 1 (yes). Covariates, marital status, education, and occupation are at anniversary; students are excluded from occupation variable.
*$P<.001$; †$P<.01$.

participants (11%) with complete C4 SCI reported driving a modified vehicle. This finding provides evidence for driving rehabilitation practice guidelines and appropriate patient selection for driving rehabilitation and training services. Peters[26] similarly found that people with SCI below the C4 vertebra had good potential for driving. Our finding appears to be in contrast to a Japanese study in which C6 was the highest level for independent driving.[27] This difference may be explained by the definition by Kiyono et al[27] in 2001 of independent driving, which included independence with transferring and loading the wheelchair into the car.

Several demographic and injury variables were significant predictors of driving post-SCI. The higher odds of driving for full-time wheelchair users may indicate the importance of driving for these people to achieve independent community mobility.[12] In an earlier MSCIS study,[28] researchers also found sex differences in functional outcome measures in people after SCI. Men tended to achieve better functional outcomes overall compared with women at discharge. A Dutch study[11] also found that fewer women had an adapted vehicle and were driving post-SCI.

Our findings are consistent with the literature that documents disparities in rehabilitation outcomes and health care, influenced by such socioeconomic factors as education, income, and employment status.[29,30] Hunt et al[29] found that people post-SCI with low socioeconomic status and from minority backgrounds were more likely to have inappropriately received noncustomized wheelchairs. Similarly, racial disparities were found between African Americans and whites in an NSCI Database study before and after SCI.[30] African Americans had lower economic self-sufficiency and social integration scores post-SCI. Future research is needed to study ways to improve driving outcomes post-SCI for people in minority ethnic groups. More effective policies may help improve the cultural sensitivity, overall quality, funding, and availability of clinical care and driving rehabilitation services for SCI groups with diverse cultural needs.

We found several benefits associated with driving. Our finding that driving was associated with working post-SCI is important, especially given that employment after SCI has been very low overall.[30-33] In their review of 60 studies, Ottomanelli and Lind[33] found the average employment rate of people post-SCI to be 35%. Our findings provide evidence for the value of rehabilitation and community programs focused on driving independence as a means of facilitating employment post-SCI. Similarly, in a study from Taiwan,[32] participants who were independent in using public or private transportation post-SCI had a greater chance of employment.

Driving was associated with increased availability of transportation, which is significant because transportation is perceived as one of the biggest barriers to employment for people with SCI.[2] Similarly, in another study,[7] transportation was a significant predictor of productivity (accounting for up to 20% of the variance), which was defined as including gainful employment, studying, homemaking and family activities, participation in community organizations, and leisure activities. In particular, the ability to drive a car was the most significant transportation variable in explaining variance in productivity in

Table 5: Associations of Driving With HRQOL Outcome Indicators

Variables	Depression β	Life Satisfaction β	General Health Status β	Pain interference β	Transport Availability β	Physical/Structural Barriers β
Driving	−.07*	.06†	−.10*	−.05‡	−.11*	−.01
Postinjury year	−.08*	.14*	.01	−.05‡	−.10*	−.13*
Sex	.07*	.03	−.03	.04	.02	.05†
Neurologic impairment	−.06†	.01	−.08*	−.08*	.01	.05‡
Marital status	.02	−.05†	.10*	.06†	−.02	.02
Education	−.06†	.03	−.06†	−.04‡	−.01	−.01
Race	−.03	−.002	.05†	.03	.06†	.02
Occupation	.12*	−.25*	.15*	.13*	.12*	.09*
Adjusted R^2	.05	.12	.06	.05	.07	.04

NOTE. Parameter estimates are shown in table. Covariates, marital status, education, and occupation are at anniversary; students were excluded from occupation variable.
*$P<.001$; †$P<.01$; ‡$P<.05$;

people with SCI (with the exception of those with complete tetraplegia).

The association between driving and improved community reintegration is particularly notable given that community reintegration is considered the ultimate long-term goal of rehabilitation for people with SCI.[34] Kiyono et al[27] also found that driving facilitated increased social integration for such activities as playing sports. In another study, driving was also associated with improved access to educational, social, recreational, and community health care environments for adults with SCI.[9] Participants with SCI have reported that the ability to drive facilitated their social activity and community participation.[35] However, they also identified social policies, especially related to inadequate funding, as adversely affecting their community reintegration.[35]

We found higher life satisfaction associated with driving post-SCI. Similarly, another study[35] found an association between high life satisfaction and vehicle ownership with people post-SCI. Franceschini et al,[9] in their cross-sectional study, similarly found higher QOL to be associated with driving ability. Chan and Chan[34] also found that driving correlated with all dimensions of QOL for their sample of 31 Chinese community wheelchair users with SCI. Transportation use, in contrast to driving, correlated only moderately with the psychological dimension of QOL.

Tate et al[6] also found an association between transportation, including driving and mental health. They reported that depressed and psychologically distressed subjects with SCI from Michigan had less readily available transportation 4.5 years post-SCI. In addition, we found a small association between driving and less pain. This finding may be clinically meaningful given the high incidence of upper-extremity pain and overuse injuries in manual wheelchair users post-SCI.[36]

Our research findings can potentially be used to inform social policies in support of greater financial provisions for modified vehicles, assistive technology, and driving rehabilitation services and training to promote driving independence post-SCI. The findings provide evidence of the value of allocating clinical resources for driving rehabilitation and assistive technology services and encouraging patients to work toward driving as a goal. There needs to be greater focus on driving as an outcome given its association with postinjury employment, community reintegration, reduced transportation barriers, and improved mental and overall health. Because driving status can be influenced directly by rehabilitation, helping people drive post-SCI warrants more attention in the health care system. In contrast, many demographic and injury variables also associated with employment and community reintegration cannot be influenced by rehabilitation efforts.

Study Limitations

Our study has some limitations. Because our data were cross-sectional, we cannot infer causality or effects of driving. We did not have information for when people first drove postinjury and their driving independence with such tasks as operating a lift system or loading a wheelchair into a vehicle. We had high missing data for some variables, such as FIM scores and annual income. Some of our findings therefore may be biased by the missing data. Driving questions were added recently to the NSCI Database, and longitudinal analyses were therefore not possible. We also do not know whether the associated benefits of driving are clinically meaningful. Although our sample was large and derived from multiple centers across the United States, it may not be representative of all people with SCI.

We have several recommendations for future SCI driving research. Future research is needed to specifically study and confirm the barriers to driving post-SCI and ways to effectively reduce them, with particular attention to the special needs of people with tetraplegia. Longitudinal research is needed to further study driving trends, such as when people post-SCI first start driving, how long they continue to drive, and the duration of the driving rehabilitation process.[37] As more driving data become available in the NSCI Database, it would be beneficial to confirm the findings from this study. It would be valuable to compare driving cessation for people with SCI compared with healthy populations in late life. Clinical trials are needed that determine the effectiveness of driving rehabilitation interventions (including attention to cultural disparities) in facilitating increased driving post-SCI. Qualitative research is also needed to study the perceptions and consumer satisfaction of adults with SCI regarding driving rehabilitation and assistive technology and ways to reduce barriers to driving.[10]

CONCLUSIONS

Our study findings highlight the importance of driving as an ADL and means of transportation for people post-SCI. Driving a modified vehicle was associated with a higher likelihood of working post-SCI and better community reintegration, in addition to better mental and general health and life satisfaction and less pain and transport barriers. Driving outcomes postinjury can be influenced by driving rehabilitation and assistive technology services. Increased attention is needed in the health care system and governmental policy on facilitating adaptive driving post-SCI.

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