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Behavioral Risk Factors of Mortality After Spinal Cord Injury

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Abstract

Objective—To test hypothesized relationships between multiple behavioral indicators and mortality among persons with spinal cord injury (SCI), while controlling for biographic and injury characteristics.

Design—Prospective cohort study with behavioral data collected by mailed survey in late 1997 and early 1998. Mortality status was ascertained as of December 31, 2005.

Setting—A large rehabilitation hospital in the southeastern United States.

Participants—Adults (N= 1386) with traumatic SCI, at least 1 year postinjury.

Interventions—Not applicable.

Main Outcome Measures—Primary outcome was time from survey to mortality or censoring. Mortality status was determined using the National Death Index and the Social Security Death Index. There were 224 deaths (16.2%) in the full sample, and due to missing data, 188 deaths were observed in the 1251 participants included in the final statistical model.

Results—Cox proportional hazards modeling identified several significant behavioral predictors of mortality. In the first set of analyses, the significance of a single behavioral variable was assessed while controlling for biographic and injury predictors. We subsequently built a comprehensive model based on an optimal group of behaviors. The best set of behavioral predictors included: smoking, binge drinking (number of episodes with 5 or more drinks), prescription medication use, and number of hours out of bed per day. Inclusion of these variables improved prediction of survival compared with biographic and injury variables alone, as the pseudo- R^2 increased from .121 to .164 and the concordance from .730 to .769.

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Conclusions—The results affirm the importance of avoiding basic risk behaviors, such as smoking and alcohol misuse, and affirm their importance as targets of intervention in association with SCI rehabilitation.

Keywords

Health behavior; Mortality; Rehabilitation; Risk; Spinal cord injuries

Despite advances in medicine over the past few decades, people with SCI are at high risk for early mortality.¹⁻³ There has been a trend for decreased mortality during the first year postinjury, which is the time during which medical advances may have the greatest effect, but long-term survival rates appear to have plateaued. Enhancing longevity is not solely dependent on advances in medicine but may also result from new knowledge from epidemiologic research that enhances prevention of secondary health conditions that lead to early mortality.

Nearly all studies of mortality have focused primarily on biographic and injury related variables as predictors of mortality. This is primarily due to convenience, because these factors are most readily available on large participant cohorts. Risk of mortality is actually higher in the first year after SCI onset.⁴⁻⁶ The risk during the first year is greatest for those with the most severe injuries, particularly those who are ventilator dependent. However, life expectancy is enhanced through the first few years after onset for those with the most severe injuries.⁷ Higher neurologic level and completeness of SCI, ventilator dependency, and older age at injury are related to an elevated risk of mortality.^{6,8-13}

Causes of Death

DeVivo and Stover¹⁴ classified a total of 1403 deaths recorded on death certificates into categories suggested by the National Center for Health Statistics. Pneumonia and influenza were the primary cause of death (17.7%), followed by nonischemic heart disease (16.5%), and septicemia (12%). They calculated cause-specific standardized mortality ratios to compare causes of deaths of persons with SCI with the number of deaths expected in the general population for each cause. The highest standardized mortality ratios, suggestive of those causes most problematic for people with SCI, included septicemia (64.2 times the general population), disease of the pulmonary circulation (47.1), pneumonia and influenza (35.6), symptoms and ill-defined conditions (13.8), and diseases of the urinary system (10.9). The causes of death that were least likely associated with SCI were homicide, legal intervention, and cancer.

Studies of causes of death after SCI report a sizable proportion of deaths due to preventable factors that appear related to a person's psychologic adjustment or behavior, including suicide.^{14,15} The prevalence of these causes of death provides indirect evidence of the importance of prevention and control of the major psychologic and behavioral risk factors associated with premature mortality. Poor adaptation was found predictive of mortality up to 15 years after SCI. Krause et al¹⁶ found that persons who were unemployed had a 2.38 greater odds of being deceased 11 years later than persons who were employed. One SD on the dependency scale was associated with a 2.04 greater odds of mortality over the study period.

General Risk Model for Prediction of Mortality

Krause¹⁷ developed a model to guide research identifying empirical links between different classes of variables with mortality. At the time of the model development, prediction of mortality was virtually restricted to relationships between biographic and injury characteristics and early mortality. A building block approach was used to develop the multi-stage model that includes 4 levels of predictive factors for mortality, including in descending order: (1) biographic and injury factors, (2) psychologic factors/environmental factors, (3) risk and

protective behavioral factors, and (4) health and secondary conditions. According to the model, the strength of association with mortality is directly related to the proximity of predictive factors to mortality in the model, and each sequential stage of the model both predicts subsequent levels in the model and is predicted by the previous set of factors (the exception to both of these conditions is for the most basic component of the model—biographic and injury factors). Therefore, with regard to strength of association, health factors would be the strongest predictors of mortality, followed by behavioral factors, and then psychologic and environmental factors. Furthermore, health factors are the most immediate predictors of mortality¹⁸ but are themselves predicted by risk and protective behaviors. Behaviors predict health outcomes and are themselves predicted by psychologic and environmental factors.

At least partially as a result of the development of the model, there has been an increase in research that has investigated nonbiographic and noninjury variables in relation to mortality. In one such study, data from the Model SCI Systems indicated that having a violent etiology of SCI onset, a behavioral factor with limited direct implications for prevention, was associated with a greater likelihood of mortality.² In a second study,⁷ the general risk model was tested using data from Model SCI Systems, finding support for the importance of each type of factor in the model but only mixed evidence for the sequencing of factors. As predicted, health factors were the most immediate risk factors for mortality based on increases in the generalized R^2 and concordance rates, but the addition of income (a proxy for environmental factors such as access to resources) was associated with the greatest increase in life expectancy. Adding participation, economic resources, and general health indicators to the model substantially enhanced the prediction. For instance, the predicted life expectancy of a 25-year-old person with C6 complete tetraplegia increased from 33.1 years (64.8% of normal) to 41.2 years (80.6%) when assuming favorable outcomes on this cluster of factors (a substantial protective effect and the type of analysis central to the study). The data used in this study were not collected specifically for the purpose of either testing the model or predicting of mortality, so the set of predictors was very limited.

This study was directly replicated using updated data from Model SCI Systems. Strauss et al¹⁹ found a less powerful effect of economic factors, because one of the primary indicators of economic status (workers compensation) was no longer significant after the addition of more cases and was dropped from the model. Because the focus in this replication was on the importance of economic factors, there was no explicit test of the model. In a study solely directed at economic factors,²⁰ after controlling for biologic, biographic, and injury variables, participants who reported household income of less than \$25,000 per year had a 4.5 times greater odds of dying over a 6-year period than those whose household income was greater than \$75,000 per year.

In the aforementioned prospective cohort study,¹⁸ the predictive efficacy of secondary conditions and other health factors (the set of risk factors most proximal to mortality in the general risk model) were investigated in relation to mortality status. Two sets of Cox proportional hazards modeling analyses were conducted—the first identifying the significance of a single variable of interest (controlling for biographic and injury status) and the second analysis building a comprehensive model based on an optimal group of variables. Several types of health conditions were associated with mortality. The best set of health predictors included probable major depression, surgeries to repair pressure ulcers, fractures and/or amputations, symptoms of infections, and days hospitalized. Several predictive models were generated based on subsets of predictor variables. The model that included only the health factors alone was superior to a model that included injury severity alone, as indicated by the pseudo- R^2 (health factors=.075; injury severity=.016) and the concordance R^2 (health factors=.676; injury severity=.578). Comparison of these models shows the importance of health factors in comparison with injury severity in predicting mortality. When all biographic factors (including

age) were added, the model that included all biographic and injury variables improved, because the pseudo- R^2 increased to .121 and the concordance R^2 to .730. However, a comprehensive model that included the secondary conditions and general health item was the best overall model, because the pseudo- R^2 increased from .121 to .178 and the concordance from .730 to .776. One particularly important aspect of this study is that the selection of variables for investigation was done prospectively, specifically with the intention of evaluating the general risk model. All other studies have investigated existing data in relation to mortality.

Taken together, the findings from these studies suggest that the general risk model is appropriate for guiding research as to risk of mortality. Some of the more important findings relate to the relationships between specific secondary conditions, such as pressure ulcers and depressive symptoms, with early mortality. Economic factors also are important, although these factors largely appear to be proxy variables for other nonspecified variables that may relate to issues such as access to quality care. From the perspective of the risk model, it is important to identify risk and protective behaviors in relation to mortality, because these have increasing implications for prevention.

Purpose

The purpose of this study is to identify the association of several sets of behavioral factors with mortality status controlling for biographic and injury characteristics that have typically been associated with mortality after SCI. A prospective cohort design was used with mortality status determined approximately 8 years after collection of data on predictor variables.

Hypotheses

Our hypotheses were (1) when statistically controlling for biographic and injury characteristics, health behaviors will be associated with hazard of mortality and (2) when building an optimal risk model for mortality, inclusion of behavioral factors will enhance our prediction of hazard for mortality above and beyond that of biographic and injury factors alone.

Methods

Prospective Data Collection Procedures

Institutional review board approval was obtained prior to initiating the study. We identified participants from 3 types of records of a large specialty hospital in the southeastern United States: Model SCI Systems patient database, model systems registry, and outpatient directory. To be eligible, participants were adults with traumatic SCI that occurred at least 1 year prior to the study and resulted in some residual impairment (nonneurologic deficits were excluded). The first contact with participants was by mail; we sent letters to all prospective participants announcing the study and alerting them that they would be receiving a questionnaire within the next few weeks. Four to 5 weeks later, actual materials were sent to all participants. We used aggressive procedures to maximize participation. Two subsequent mailings were initiated for all nonrespondents. Follow-up phone calls were also implemented, and additional materials were sent out, if requested by the participant. Participants were offered a \$20 stipend and were made eligible for drawings totaling \$1500. Data collection began July 1997 and ended April 1998, although the majority of the data had been collected by the end of 1997.

Mortality status was determined approximately 8 years after obtaining the prospective data. December 31, 2005, was the cutoff date for determination of mortality status. At this time, participants were classified as either deceased or presumed alive. We used 2 sources to determine mortality status: the NDI of the National Center for Health Statistics²¹ and the Social Security Death Index of the Social Security Administration.²² The NDI accesses information on decedents through a centralized computer index by searching death records provided by

state offices and provides the state where death occurred, the death certificate number, and the date of death. NDI death records are available approximately 16 months after the conclusion of a given year. In contrast, the Social Security Death Index is more current and may be done on a case-by-case basis through an online search. We did a 1-time search of NDI records through the year 2005 and used the Social Security Death Index during the subsequent year.

Measures

A survey was used to measure health behaviors. It was comprised of items from multiple instruments. The Behavioral Risk Factor Surveillance System²³ is a standardized instrument that is used by the Centers for Disease Control to monitor relevant basic health behaviors within the general population and in specific regions of the country. We used core portions of the Behavioral Risk Factor Surveillance System to measure alcohol behaviors and smoking behaviors. We used the number of occasions in the past month that the participant reported consuming 5 or more drinks (ie, binge drinking). We also identified the number of days in the past month that the person consumed any alcohol. Each of the alcohol items were treated as individual variables.

In contrast, we developed a composite score for 3 smoking items that assessed a participant's smoking behaviors. The first 2 items assessed if the participant had ever smoked on a regular basis or if the participant currently smokes in bed using either "no" (1) or "yes" (2) as the response categories. The number of cigarettes a day currently smoked was assessed as none at all (1), 1 to 9 (less than half a pack) (2), 10 to 19 (<1 pack) (3), 20 to 40 (1–2 packs) (4), or more than 41 (more than 2 packs) (5). The sum of these items was used to indicate higher smoking risk behaviors (standardized Cronbach $\alpha=.76$).

We also administered the CAGE,²⁴ a 4-question screening tool, with yes/no dichotomous items, designed by primary care physicians for detecting alcoholism in the general population. It was used as a proxy measure for alcohol misuse behaviors. The tool asks the patient/participant if they have thought about cutting down on drinking, felt annoyance at others' concern about their drinking, had guilty feelings about drinking, or used alcohol as an eye-opener in the morning. An indicator variable was created to represent a positive CAGE screen (score of 2 or higher) for alcohol use patterns over the past 12 months.

The Spinal Cord Injury Health Survey²⁵ was developed for the study to measure other content domains. Prescription medication usage was measured to identify how frequently participants use prescription medications that may have psychotropic effects. Participants were asked how frequently they used medications for pain, spasticity, depression, and sleep (all frequently prescribed after SCI). Each item had 4 response categories: never, sometimes, weekly, and daily. A composite score was constructed as simple summated rating scales of the 4 items (standardized Cronbach $\alpha=.68$), and a higher score indicates a higher use of medications. This variable has frequently been identified as a risk factor for subsequent injuries in the years and decades after SCI.²⁵

Participants reported on 5 items pertaining to general health-related activities and beliefs. Participants rated their overall lifestyle, their diets' perceived healthiness, and their overall fitness levels on a 5-point scale with the following response options (assigned score): poor (1), fair (2), good (3), very good (4), and excellent (5). The frequency of exercise relative to other people with SCI was rated as much less (1), less (2), about the same (3), more (4), and much more (5). Finally, the frequency of planned exercise was assessed as rarely (1), once per month (2), 2 to 3 times per month (3), 1 to 2 times per week (4), 3 to 4 times per week (5), and 5 or more times per week (6). A composite score was created as the sum of the 5 items (standardized Cronbach $\alpha=.78$), and a higher score indicates greater engagement with healthy lifestyle behaviors.

Lastly, we used a single item reflecting the number of hours out of bed during the day as a general activity indicator. This is a widely used indicator of activity and is in the Craig Handicap Assessment and Reporting Technique.²⁶

Analyses

We used a 3-stage hierarchical strategy to model building in order to identify the association of each health variable with mortality and to define an optimal set of behavioral predictors of mortality. Cox proportional hazards modeling was used with the number of days between the survey and event (ie, mortality) as the dependent variable. The censoring date was December 31, 2005, the date up to which mortality status could be verified.

During the first stage of analysis, a base model consisting of biographic and injury characteristics, including functional injury classification, sex, race (white-minority), age at time of injury, and years lived since injury to the time of survey, were specified.

The second stage of the analysis focused on adding single, biologically-plausible healthy behavior variables to the base model, thereby screening each of these potential predictors for inclusion in the final stage model. All variables significant at the alpha equal to .10 level of significance were considered for subsequent modeling.²⁷ Once all candidate variables had been screened, the ones selected for additional modeling were assessed for multicollinearity.

The final stage of the analysis formulated a Cox proportional hazards model that consisted of the base model in addition to the variables identified in stage 2 of the analysis. Backwards elimination was used to identify the final fitted model. We assessed the proportional hazards assumption of the final model using the Schoenfeld residuals²⁸ and found it to be tenable. The fit of the model was assessed using the likelihood ratio test and the C-statistic.²⁹ The likelihood ratio test was used to calculate Nagelkerke's pseudo- R^2 .³⁰ The value of the C-statistic is closely related to the area under a receiver operating characteristic curve and is interpretable as the probability that the cases (ie, deaths) have higher risks as measured by the linear component of the regression model. Accordingly, a value of 0.5 is used for chance prediction and the discrimination of the model is improved as the C-value approaches 1.0.^{31,32} Once the final model was determined, all pairwise interaction terms of the healthy behaviors were included in a new model to further assess goodness of fit. A Wald linear contrast indicated these interaction terms were not needed in the model ($P=.29$), and, accordingly, these interaction terms were removed. All model building was conducted using the SAS system version 9.1.3.^a The validation of the proportional hazards assumption and the estimation of the C-statistic were performed using STATA version 9.2.^b

Results

Participant Characteristics

A total of 1386 returned usable materials (72% response rate). Of these, 1312 provided complete biographic and injury data and served as the base, or reference, sample for statistical analyses. Of the 74 cases removed, the majority (76%) were removed due to insufficient information related to the injury characteristics. Missing data in the behavioral constructs resulted in a smaller sample size for the final model. The final statistical model consisted of 1251 participants, 188 (15%) of which were events.

^aSuppliers: SAS, 100 SAS Campus Dr, Cary, NC 27513.

^bSuppliers: STATA Corp, 4905 Lakeway Dr, College Station, TX 77845.

In the reference dataset, 74% were male, and 76% were white. Of the minority participants, 87.8% were black. Average age at time of injury was 31.4 years (IQR, 20.6–38.9). At time of prospective data collection, the participants' mean age was 40.3 years (IQR, 30.1–48.4), and they had been injured a mean of 8.9 years (IQR, 3.5–12.3). The primary etiology was vehicular crashes (51%), followed by falls/flying objects (17%), acts of violence (13%), sports (12%), and other (7%).

Fifty-four percent reported cervical injuries, and 21% reported ability to ambulate. Functional injury classification was defined according to a combination of injury level and neurologic completeness of injury that yielded 5 categories that were similar, but not equivalent, to those frequently reported in the SCI mortality literature. Convention has been to use 4 groups, three defined by ASIA grades A to C, with a single group denoting ASIA grade D regardless of injury level. We used ambulatory status in lieu of ASIA grades, which are not available, and then broke ambulatory status down according to cervical and noncervical injuries. Thirteen percent had upper-cervical injuries (C1-4) and were nonfunctional; 31% had a lower cervical injury (C5-8) and were nonfunctional; 35% were nonfunctional with noncervical injuries; 11% had a cervical injury but were ambulatory; and the remaining 10% had non-cervical injuries and were ambulatory.

Modeling

Table 1 summarizes the results of statistical modeling. It includes an analysis of the relationship of the biographic and injury related factors with mortality, followed by consideration of the health behavior parameters evaluated after controlling for the biographic and injury characteristics. Lastly, the final model is summarized evaluating all biographic, injury related, and health behavior parameters simultaneously.

Significant hazard ratios were observed for injury severity, age at injury onset, and years lived since injury, but not race or sex. Although we used a 5-category breakdown for injury severity consistent with that reported in recent research,¹⁸ hazard ratios indicated 3 major groups of participants. Those participants with the most severe injuries (C1-4, nonfunctional) had the greatest hazard (3.22) compared with those with the least severe injuries (ambulatory). The 2 other groups with nonfunctional injuries (C5-8, noncervical) also had significantly elevated hazard ratios compared with those with the least severe injuries, but ratios were actually modestly reversed from what would be expected based on injury severity (C5-8 = 2.35, noncervical=2.71), suggesting substantial similarities between these 2 groups. The 2 ambulatory groups have essentially identical hazards of mortality.

All 6 of the candidate predictors were significant predictors of mortality after adjustment for biographic and injury variables. The means $\pm$ SD for the prescription medications composite score, lifestyle composite score, and smoking composite score were 7.6 ± 3.4 , 14.9 ± 4.4 , and 4.3 ± 1.7 , respectively, and each of these variables significantly predicted mortality in stage 2 of the modeling process. The directions of the effects were consistent with hypothesized associations. The 127 participants (10%) who had a positive CAGE screen had a 64% higher hazard rate than those who did not, but this finding did not persist in the final model. The mean $\pm$ SD binge drinking days in the last 30 days was 1.3 ± 4.0 , but the values covered the full range. Finally, the hazard for participants who spent more time, on average, out of bed was lower than those who did not engage in these activities as frequently.

The final model yielded 4 of the 6 healthy behaviors indicators. The lifestyle composite score and positive CAGE screen failed to remain statistically significant in the final regression model.

Table 2 compares the pseudo- R^2 and the C-statistic for injury severity alone, all biographic and injury variables combined, and for the full model that incorporates all health behaviors.

The most relevant comparison is between the model that includes a traditional biographic and injury variables and that which includes the health behavior predictors. The pseudo- R^2 increased from .121 to .164 when moving from the biographic and injury variables alone to the full model. This C-statistic increased more modestly from .730 to .769.

Figure 1 illustrates the association of health behavior indicators with survival. The first survival curve represents those who are free from risk behaviors and who perform protective behaviors, whereas the second survival curve represents those who perform risk behaviors and do not perform protective behaviors. In essence, the 2 lines represent the extreme ends of the behavioral continuum, combining both risk and protective behaviors, and their relationship with survival.

Discussion

The unique contribution of this study is the identification of the association of risk and protective behaviors for mortality after SCI using prospective cohort design and a priori selection of variables using a general risk model. We identified several behaviors related to risk of mortality and enhanced the prediction of mortality beyond that of simple biographic and injury related factors. This method both identifies people at high risk for early mortality based on their behavioral pattern and identifies the target behaviors that may become the focus of intervention.

Although the overall magnitude of the pseudo- R^2 suggests there is a great deal to learn about prediction of mortality, it is clear that even a handful of behavioral variables enhance the prediction above and beyond biographic and injury characteristics alone. The pseudo- R^2 for the full model (.164) was somewhat higher than that reported in previous research from the Model SCI Systems (.131) where 4 different models were tested,²⁵ but somewhat lower than a recent study using health outcomes and secondary conditions as predictors (.178).¹⁸ An increase in the pseudo- R^2 from .121 to .164 does represent a 36% increase in our ability to explain variations in mortality as a function of the observed behaviors.

Future research will need to identify further variables to account for variations in mortality, although several design factors may have limited the extent to which variables addressed in this study, such as smoking and alcohol misuse, truly relate to mortality (particularly measuring these variables at a single point in time rather than being able to measure their chronicity). Additional factors may relate to individual vigilance in performing health-maintenance behaviors, psychologic traits that lead to healthy or unhealthy behavior patterns, and their environmental supports (eg, health insurance, social support).

Implications

How often does the increased risk of mortality impact clinical programs? This is a core question at the heart of studies of risk of early mortality. In the current study, we identified that both smoking and binge drinking are related to early mortality. Yet, how many rehabilitation programs for people with SCI include smoking cessation or alcohol counseling? Unfortunately, with the decreased lengths of stay, it has become increasingly difficult to address all important areas of health maintenance, both during initial hospitalization and as an outpatient. Nevertheless, it is incumbent on rehabilitation professionals to find a way to address these important issues. It is important that primary care physicians treating people with SCI in community settings also address these issues, although the challenge is finding ways of educating these professionals to the special needs of those with SCI.

We have sufficient research to direct interventions towards early identification of risk based on the presence of both health behaviors and health outcomes. Other research has identified

associations with income. A minimum intervention would be to routinely advise people of their heightened risk for early mortality given the pattern of risk. This type of minimal intervention could easily be incorporated into routine assessments. Other types of interventions may need to be systemic, such as inclusion of smoking cessation and alcohol interventions as part of the initial rehabilitation program. Although the decreased lengths of stay have significantly reduced all options for therapies, a reevaluation of priorities may be important because it is unlikely that people will ultimately benefit from therapies if they have associated behavioral issues that include alcohol misuse or substance abuse. Addressing these issues may need to be the starting point in order to make other therapies more effective.

Study Limitations

There are several noteworthy limitations. First, the data were heavily left censored, so we do not know whether there are systematic differences between those who lived to participate and potential participants who died prior to initiation of the data collection. Second, there were no data in the first postinjury year when many factors such as ventilator-dependency, injury severity, and age exert their greatest influence on the likelihood of mortality. Therefore, mortality likely eliminated many cases that might have been those highest on the risk behaviors highlighted in this study. Third, we cannot assume causality from the design. Although direction of causation is not a concern (ie, mortality could not cause the behaviors), other unknown factors could be contributing to both behaviors and mortality. For instance, the relationship between psychotropic medication use and mortality may be at least partially attributable to the underlying health concerns that were being treated by the medications. In reality, it is likely that both underlying conditions and selective or overuse of the medications contributed to the mortality. Fourth, smoking and alcohol misuse also lead to a greater likelihood of mortality in the general population, and we cannot determine the extent to which it may be elevated among people with SCI, although alcohol misuse is a factor leading to injury and is a particular problem among this population.

The study was also limited in terms of power to identify true relationships between behavioral factors and mortality. First, recall bias may have influenced the accuracy of behavioral reports during the prospective data collection, and this could have led to error in measurement and weakened our ability to identify relationships between health behaviors and mortality. Second, behaviors were only collected once, 8 years before determination of mortality status. This also weakens our ability to identify significant relationships, because behaviors could change during that interval. This concern is similar, but not equivalent, to the aforementioned sampling issue where mortality shortly after injury could have eliminated some of the highest risk cases prior to enrollment into the study. If this occurred, the current findings would underestimate the importance of these behavioral factors in relation to mortality. A third related limitation is the absence of historical data, such as pack-years of smoking or chronic alcohol use. The effects of smoking and drinking on mortality do not typically manifest in the first few years, but rather cumulate over time, and repeated measures would be needed to address this limitation. Lastly, the sample size was smaller in scope than that used with studies from the Model SCI Systems in the United States. Because of these limitations and the power of the study, it may be best to consider the current estimates as conservative.

Future Research

Given that this study is based on a predictive model with multiple components and that the behavioral and health components have been addressed, additional research is needed to further clarify the role of psychologic and environmental factors in mortality. Whereas evaluation of psychologic predictors may include constructs such as personality, locus of control, and efficacy; environmental factors may include social support, access to care, financial resources. Testing of the full model and interactions between all predictive components (ie, health,

behaviors, psychologic, environmental) will also be necessary after modeling variables from each individual component.

Second, it is time for intervention research. We now have a relatively clear picture of the types of behaviors and health factors related to mortality after SCI. We need intervention research to show the success of diverse strategies that both use the predictive equations to identify those people at high risk and directly attempt to change the behavior and health patterns predictive of mortality. It will then become incumbent on clinicians, institutions, and policy makers to find the means for implementing programs that will enhance longevity. How can this not be a high priority?

Conclusions

Using a prospective cohort design guided by a general empirical risk model, we identified 4 types of behaviors related to early mortality, including binge drinking, smoking, psychotropic prescription medication use for 4 types of problems (pain, spasticity, sleep, or depression), and the amount of time per day spent out of bed. Including these factors in the predictive model resulted in modest enhancements in prediction and classification beyond biographic and injury characteristics alone. Taken together along with recent research that identified health and secondary conditions associated with mortality, we are gaining a better understanding of the factors associated with early mortality after SCI and now have a foundation to begin efforts to increase longevity.

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List of Abbreviations

IQR	interquartile range
NDI	National Death Index
SCI	spinal cord injury

Fig 1.

Estimated survival curves from the final fitted Cox model (table 1). More healthy behaviors defined as an SCI medication score of 4 (no use), zero binge drinking days, 17 hours out of bed per day, and a smoking score of 1 (no use). Less healthy behaviors defined as SCI medication score of 11, 30 binge drinking days, 9 hours out of bed per day, and a smoking score of 6. The survival estimates are averaged over the core biographic and injury characteristics.

Table 1
Cox Proportional Hazards Analysis for the Preliminary and Full Model

Biological Domain	Stage 2 Results			Stage 3 Results			
	HR*	95% CI	P	Selected for Stage 3	HR [†]	95% CI	P
Biographic and injury variables [‡]							
Functional status							
C1-4, nonfunctional	NA	NA	NA	Yes	3.22	(1.47–7.05)	0.004
C5-8, nonfunctional	NA	NA	NA	Yes	2.35	(1.10–5.02)	0.027
Noncervical, nonfunctional	NA	NA	NA	Yes	2.71	(1.29–5.70)	0.008
Cervical, ambulatory	NA	NA	NA	Yes	1.00	(0.41–2.47)	0.996
Noncervical, ambulatory (referent)	NA	NA	NA	Yes	—	—	—
White race	NA	NA	NA	Yes	1.00	(0.71–1.41)	0.999
Male	NA	NA	NA	Yes	1.15	(0.81–1.63)	0.440
Age at Injury	NA	NA	NA	Yes	1.06	(1.05–1.07)	<0.001
Years since injury	NA	NA	NA	Yes	1.06	(1.04–1.08)	<0.001
Health behavior variables							
Prescription medications composite score	1.10	(1.06–1.14)	<0.001	Yes	1.08	(1.04–1.13)	<0.001
Number of days binge drinking in last 30 days	1.04	(1.01–1.07)	0.005	Yes	1.04	(1.01–1.07)	0.012
Positive CAGE screen	1.64	(1.04–2.61)	0.035	No	—	—	—
Out-of-bed hours per day	0.92	(0.89–0.95)	<0.001	Yes	0.93	(0.90–0.96)	<0.001
Lifestyle composite score	0.95	(0.92–0.98)	0.002	No	—	—	—
Smoking composite score	1.19	(1.10–1.29)	<0.001	Yes	1.14	(1.05–1.23)	0.002

Abbreviation: CI, confidence interval; HR, hazard ratio; NA, not applicable.

* Hazard ratios from a Cox model predicting the time (in days) from survey to either mortality or censoring (12/31/05) and adjusted for core (biographic and injury) variables listed in the first biologic domain.

[†] Hazard ratios for the stage 3 final model are adjusted for all other variables in which an estimate is provided. Dashes indicate that the variable was not considered for stage 3 analysis.

[‡] Hazard ratios for core adjustment variables not shown for stage 2 results because there is variability of the estimates depending on which of the candidate variables is used in the analysis.

Table 2
Summary of the Pseudo- R^2 , R change, C-Statistic, and Change in the C-Statistic for Each of 4 Stages of Model Building and an Alternative Model

Model	Description	R^2	Change	C-Statistic	Change
1	Injury severity only [*]	0.016	—	0.578	—
2	Core biographic and injury variables [†]	0.121	.105	.730	.152
3	Full Final Stage 3 Model	0.164	.148	.769	.191

^{*} Five category breakdown (C1-4, C5-8, noncervical, etc).

[†] Core biographic variables include white race, male sex, age at injury, and years lived since injury at time of survey.