Original Article

Ageing with spinal cord injury: cross-sectional and longitudinal effects

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Study design: Longitudinal and cross-sectional.

Objective: To determine whether, for studies of ageing with a spinal cord injury, the cross-sectional differences in outcomes across both age and years post injury (YPI) differ from the longitudinal change.

Setting: Two SCI centres in England: the National Spinal Injuries Centre in Aylesbury, and the Regional Spinal Injuries Centre in Southport.

Methods: A total of 315 people who sustained spinal cord injuries prior to 1971 underwent comprehensive health and psychosocial status interviews at one or more of the study assessments (1990, 1993, 1996, and 1999). A range of continuous and dichotomous outcomes was analyzed to detect both cross-sectional differences by age and average individual changes over multiple measurements.

Results: Frequently, outcomes changed longitudinally without showing any cross-sectional differences. Cross-sectional age was more commonly associated with the worsening of a condition while cross-sectional YPI was commonly associated with improvement. After controlling for cross-sectional effects, psychological measures generally showed minor deterioration, measures of community integration both improved and deteriorated, upper extremity pain increased, lower extremity pain decreased, and participants tended to quit smoking.

Conclusion: Using longitudinal findings that control for cross-sectional differences produces a more complete description of ageing with a spinal cord injury.

Spinal Cord (2001) **39**, 301–309

Keywords: ageing; SCI

Introduction

The study of ageing with a spinal cord injury (SCI) is highly relevant to SCI survivors, but also of interest to health care providers, and insurance companies. In addition to the effects that ageing has on all people, SCI survivors may face changes related to the additional wear and tear on their body that living with such an injury imposes. As with general studies of ageing, cross-sectional studies of SCI and ageing typically recruit a sample of people living with a spinal cord injury, evaluate them, and then attribute any differences associated with age to ageing of the body and differences associated with years post injury (YPI) to ageing unique to SCI. Other studies which use longitudinal methods follow a group of SCI survivors over time and attribute observed changes to the ageing process. Both approaches can provide useful inferences, but neither controls for cohort differences that may

mistakenly be interpreted as ageing. This study attempts to control for cohort differences while evaluating the effects of ageing with a spinal cord injury.

Cross-sectional studies of age-related changes in SCI assess differences across the ages and/or YPI of the enrolled subjects. In these studies, increased age has been associated with bowel complications,¹ urinary changes,² rates of ventilator use, independence in self care and mobility, rehospitalisations, nursing care admissions,³ cholesterol levels,⁴ functional changes, decreased social role performance, increased cost,^{5,6} prevalence of pressure sores,⁷ and measures of community integration.⁸ In contrast, increased age has been found to be associated with improved life satisfaction.^{9,10} Increased YPI – essentially age of the injury – has been associated with worsening urinary changes,² functional declines, decreased social role performance, increased costs,^{5,6} and improvements in community integration.⁸

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Longitudinal designs measure changes in individuals from one assessment to another. These studies attribute such changes to an ageing or maturation process. These studies have shown that community integration changes longitudinally;⁸ post SCI adjustment drops,¹¹ while depression also declines.¹² By looking at the average change of the individual, these studies more directly evaluate the ageing process. However, these longitudinal studies do not completely isolate the ageing process from cohort effects such as era of injury or era of birth. One study began to approach this problem by showing that changes in ability to perform activities of daily living are negatively associated with baseline age.¹³

Adjustment to spinal cord injury has been examined by a number of approaches with conflicting results.^{11,14–16} Several studies report an inverse relationship of age to level of adjustment to SCI.^{15,16} However, Krause and Crewe report improvements in adjustments over an 11-year passage of time.¹⁴ Krause later suggests that the cross-sectional and longitudinal differences may represent different causes.¹¹

Charlifue and colleagues found differences in the same study between cross-sectional and longitudinal analyses.¹⁷ In their study, constipation was reported more frequently by older subjects at both times interviewed, but, fewer respondents report constipation at the second interview, when they are 5 years older, than they do at the first interview. Scores for the Index of Psychological Well Being show no discernable relationship to age at either interview, yet scores improve significantly over the 5-year period. These differences extend to analyses of years post injury where, for example, higher YPI corresponds, cross-sectionally, to a higher proportion needing more assistance, but, longitudinally, the proportion needing assistance increases nearly twice as much as the cross-sectional analysis would predict.

The effects of age and YPI often have contradictory relationships with outcomes. Adjustment after SCI has been shown to have different effects associated with age and time since injury.^{14,18,19} Pain and fatigue have been associated with age; economic stability and number of symptoms reported were associated with time since injury; and economic stability and perceived health were associated with an interaction between age and time since injury.¹⁰ A general study of health status and SCI showed that outcomes were more associated with age than with time since injury.³ Age and time since injury have opposite cross-sectional relationships with various aspects of community integration.⁸

Cohort differences might make today's long-term SCI survivor different from yesterday's equally long-term survivor. Changes in emergency care have resulted in more people with more severe neurologic impairment surviving the initial injury.^{20–22} Post-rehabilitation survival patterns have changed too, sometimes in different ways for different age or injury cohorts.^{22–26} For example, those with high cervical

injuries have had a larger improvement in survival than those with lower injuries. Rehabilitation itself has changed where the standard practice of today differs quite substantially from prior standards.^{20,27}

'Cohort effects', or differences between cohorts, include changing emergency medicine, survival, and rehabilitation, and complicate the study of ageing with a spinal cord injury. Today's 40 year SCI survivor might differ from today's 20 year survivor in part because of differences in the era of injury. Such differences could incorrectly be attributed to differences in time post SCI. Similar problems may exist with age, for example, where individuals currently aged 40 may have a higher employment rate today than individuals currently aged 50 did 10 years ago. These cohort differences along with contradictory findings between longitudinal and cross-sectional studies suggest the need for an analysis strategy that better deals with these problems.

In order to account for some of the difficulties mentioned above, the present analysis concentrates on separating the cross-sectional and longitudinal components of ageing with spinal cord injury. It is hypothesised that the cross-sectional effects of both age and YPI differ from the longitudinal effects. It is further hypothesised that such a difference will result in different interpretations of the effects of ageing with spinal cord injury.

Methods

Subjects

Participants in the study were enrolled as part of a longitudinal study of ageing with spinal cord injury and were drawn from a population-based sample of 412 SCI survivors. All participants were adult and non-elderly at the time of injury, survived more than 20 years post SCI, and the rehabilitation of their initial injury occurred at a major spinal injuries centre.

Specifically, participants met the following criteria:

- (a) residence, at the time of injury, in one of 13 counties served by the Northwest Regional Spinal Injuries Centre in Southport or the National Spinal Injuries Centre at Stoke Mandeville Hospital in Aylesbury, UK;
- (b) onset of SCI prior to the end of 1970
- (c) age at SCI onset between 15 and 55 years;
- (d) admission to one of the two participating SCI centres within 1 year of injury.

At the first round of data collection in 1990, 282 participated. In 1993, 232 were involved, 227 seen for the second time. By 1996, 258 participated in some manner, 198 for the third time. At the last data collection point, 210 were interviewed, 168 for the fourth time. Across all data collection points, 314 participants were interviewed at least once. The mean number of times interviewed was 3.1; the median was 4.

Instruments

The Craig Handicap Assessment and Reporting Technique (CHART) measures the level of community reintegration for individuals with disabilities.²⁸ The lack of community integration is defined as 'handicap', that is, the degree to which individuals with disabilities are prevented from being able to fulfill expected social roles which are considered normal for their age, gender and culture. This study used a five dimension version of CHART where each dimension is scored on a 100-point scale. While each CHART subscore does not have a direct clinical interpretation *per se*, lower scores indicate less community integration. Those who score lower generally require more physical and financial assistance to meet their daily needs. The physical independence subscore measures the degree to which an individual independently manages or supervises physical needs and activities of daily living. The mobility subscore measures the ease with which a person can physically move within his or her environment. The occupation subscore measures the degree to which a person occupies time in socially beneficial activities such as work, school, housekeeping or parenting. The social integration subscore measures how extensively an individual interacts with others. The economic self-sufficiency subscore measures the economic independence of the household unit. The CHART has been shown to have good psychometric properties.²⁹

The Index of Psychological Well-Being (IPWB) consists of eight items – five negative and three positive – and asks respondents to indicate how often (never, sometimes, often) they feel certain ways.³⁰ Scores range from 1 to 7 where a lower score indicates a better outcome. The items include statements such as 'very lonely or remote from other people', 'bored', 'on top of the world', and 'pleased about having accomplished something'. The IPWB has been previously used within SCI research in studies of adjustment and ageing and stress.^{17,31,32}

The Perceived Stress Scale (PSS) assesses the degree to which respondents' lives are perceived as stressful, unpredictable, uncontrollable, and overloading. With five responses per question ranging from 'never' to 'very often', the PSS asks 14 questions about how often subjects say they have had particular thoughts or feelings during the past month. Scores for the PSS can range from 0 to 56, with higher scores indicating more perceived stress.

The PSS has performed well in various psychometric evaluations. It has been shown to have good internal validity and test-retest reliability in addition to correlating with life-event scores, depressive and physical symptomatology, health services utilisation, and social anxiety.³³ The PSS has been used in previous SCI research.^{32,34}

The Center for Epidemiological Studies Depression Scale (CES-D)³⁵ is a 20-item scale which assesses the degree of depressive symptomatology in respondents. The CES-D asks how many days during the past week

that respondents have experienced symptoms like feeling happy or fearful, or being unable to 'shake off the blues'. Scores range from 0 to 60 with higher scores indicating greater depressive symptomatology. The CES-D has been shown to have good reliability in both general use³⁵ and among elderly populations.³⁶ The CES-D correlates with clinical depressing ratings, with other measures of depression as well as with actual diagnoses of depression.^{37–40} Furthermore, the CES-D has been used within studies of SCI and adjustment,³¹ pain,⁴¹ substance abuse,⁴² as well as to assess the overall levels of depression.^{43,44}

The Life Satisfaction Index (LSI-Z)⁴⁵ assesses morale or satisfaction with life by asking respondents to agree or disagree with 13 statements like, 'These are the best years of my life', and 'The things I do are as interesting to me as they ever were'. This instrument was developed after item analysis of the longer LSI-A version and correlates adequately with the Life Satisfaction Rating.^{45,46} Its validity and reliability have been studied, and have been found to be satisfactory, particularly among elderly populations where it has been used extensively.^{47–53} The LSI-Z has also been used in studies of ageing and SCI.^{54,55}

The SCI survivors were divided into three groups with similar severity of injury using their neurologic level and the American Spinal Injury Association (ASIA) classification system.⁵⁶ These groups were:

- (1) those with functionally complete paraplegia ('Para ASIA ABC') who typically had intact upper extremities but used wheelchairs for all of their mobility ($n=158$);
- (2) those with functionally complete tetraplegia ('Tetra ASIA ABC') who similarly used wheelchairs but also had impaired function in their upper extremities ($n=83$);
- (3) those with spinal cord injuries at any level ('All ASIA D') who had functional neurological sparing such that ambulation was typically possible ($n=73$).

While some questions have been raised about both the ASIA classification reliability⁵⁷ and the method of categorising severity of SCI,⁵⁸ the prior use of this scheme⁵⁹ suggests its appropriateness for the identification of differences within groups of SCI survivors.

Analysis

The analytic approach consisted of three primary goals: (1) to assess the sample for demographic differences; (2) to measure the cross-sectional differences in outcomes across age and YPI; and (3) to measure the longitudinal change in outcomes.

The entire sample was assessed for differences in the distribution of demographic factors across neurologic group. Comparisons were made using χ^2 tests or analysis of variance depending on the variables being compared.

Cross-sectional and longitudinal differences were modelled using a statistical model that accounts for the multiple measurements on subjects.⁶⁰ This approach is a subset of a linear mixed-effects longitudinal model that accounts for both group-level differences and individual deviation from the group averages.⁶¹ This model used four predictors of outcome: (1) neurological group; (2) mean subject age; (3) mean subject YPI; and (4) the difference from the mean age at a single time point from the mean age were entered into all models. To account for random variations between people random intercept and age slope terms were included. Although these terms themselves act like a mini-regression within each subject, their averages over the entire model help illuminate the general trend of ageing.

Mean subject age and YPI at all measurements were entered to assess for cross-sectional, between-subject effects. Significant effects on these two terms would be interpreted as in a traditional cross-sectional study where more (or less) age or YPI would correspond to more (or less) of the outcome.

The difference in age from the subject's age at each time point and the subject's mean age was used to assess the longitudinal within-subject effect of age. This longitudinal effect represents the average age-related changes any individual would be expected to experience. If this effect were significant, it would show that, on average, subjects experience more (or less) of an outcome at one interview than they did at prior interviews.

Results

Demographics

Of the 314 participants, 50.3% had functionally complete paraplegia (Para ABC), 26.4% had functionally complete tetraplegia (Tetra ABC), while the remaining 23.2% were functionally incomplete (all Ds). Table 1 shows the mean subject mean age, subject mean years post injury, and number of interviews. As Table 1 and Figure 1 show, the participants differed across neurological groups by age, years post injury, and number of times interviewed.

Continuous outcomes

For continuous outcomes, Table 2 shows the regression coefficients and the *P* value for the three effects: cross-

Table 1 Means (SD) across neurological groups

	Para ABC (n = 158)	Tetra ABC (n = 83)	All Ds (n = 73)	Overall (n = 314)
Mean age	57.9 (9.1)	53.5 (7.2)	58.1 (10.2)	56.8 (9.1)
Mean YPI	32.3 (6.7)	29.7 (4.8)	30.9 (6.2)	31.3 (6.2)
Number of interviews	3.1 (1.1)	3.4 (1.0)	2.8 (1.3)	3.1 (1.1)

Figure 1 Number of interviews by injury

sectional age, cross-sectional YPI, and longitudinal. Each coefficient represents the change in the outcome for each unit of change in the predictor. For example, the first number listed for Physical Independence shows that, for two participants who differ in age by a year, the older participant would be expected to have a CHART Physical Independence score 0.507 points lower. Similarly, the last column shows that for each year an individual participant ages, the CHART Physical Independence score would, on average, decline by 0.488 points.

Several continuous outcomes show significant differences across cross-sectional age after adjusting for the effects of injury, years post injury and longitudinal trends, indicating that older people at a specific time point have different outcomes than younger people at the same time point. Four out of five of the CHART subscores are negatively associated with age – physical independence, mobility, occupation, and economic self-sufficiency – ranging from half a point to one and a half points a year. Similarly, LSI-Z scores also are lower for those who are older.

Despite the negative relationship with cross-sectional age, some of these same outcomes are positively related to cross-sectional years post injury. CHART physical independence has a nearly opposite relationship with years post injury with each additional year post injury associated with a 0.412 point higher score, nearly negating the cross-sectional age effect. For CHART mobility, only half of the age effect is negated, while for economic self-sufficiency, the entire age effect is negated. The Index of Psychological Well Being also shows better outcomes – represented by lower scores – for those who are further post SCI.

Longitudinally, the effects on the continuous outcomes have a variety of directions and magnitudes. On average, after controlling for age, years post injury,

Table 2 Continuous outcomes

Outcome	C-X age	C-X years post injury	Longitudinal
Physical independence	-0.507 ($P<0.001$)	0.412 ($P<0.009$)	-0.488 ($P<0.001$)
Mobility	-0.962 ($P<0.001$)	0.409 ($P<0.017$)	-0.250 ($P<0.006$)
Occupation	-1.449 ($P<0.001$)	0.377 ($P<0.217$)	-1.241 ($P<0.001$)
Social integration	-0.231 ($P<0.074$)	-0.094 ($P<0.631$)	0.329 ($P<0.005$)
Economic self-sufficiency	-0.762 ($P<0.001$)	0.895 ($P<0.005$)	1.402 ($P<0.001$)
LSI-Z	-0.129 ($P<0.001$)	0.083 ($P<0.056$)	-0.097 ($P<0.001$)
PWB	0.001 ($P<0.959$)	-0.035 ($P<0.017$)	-0.001 ($P<0.912$)
PSS	0.015 ($P<0.814$)	-0.123 ($P<0.191$)	0.153 ($P<0.135$)
CESD	0.040 ($P<0.545$)	-0.152 ($P<0.093$)	0.314 ($P<0.021$)
#UTIs	-0.021 ($P<0.816$)	0.006 ($P<0.957$)	-0.350 ($P<0.026$)

and neurological group, CHART physical independence scores decline, as do the CHART mobility, occupation, and economic self-sufficiency scores. CHART social integration scores, however, improve over time as do the number of urinary tract infections (UTI) per year. Despite the positive changes, LSI-Z scores get worse as do CESD scores indicating lower morale and higher depressive symptomatology.

Examples of these results appear in Figures 2 and 3. Each graph represents the predicted values of the CHART economic score based on the model results summarised in Tables 2 and 3. The long diagonal lines represent the cross-sectional effects for each injury group, the first or second column of numbers in Tables 2 and 3. The short diagonal lines are the longitudinal effects. Steeper lines indicate a larger magnitude of effect. Figure 3 shows that longitudinal change and cross-sectional difference by YPI are both positively associated with the CHART economic score. More specifically, the graph shows that economic self-sufficiency is higher for people who have been injured longer and, on average, improves for each individual. Furthermore, the similarity in slopes shows that these two effects are nearly identical. Figure 2 shows that the longitudinal change and the cross-sectional difference by age have similar magnitudes but opposite directions. These lines show that older participants are less economically self-sufficient than those who are younger. As with Figure 2, each individual is, on average, improving his or her situation over time.

Dichotomous outcomes

For dichotomous outcomes, shown in Table 3, two figures are reported for each effect: the odds ratio for that effect and its associated P value. Odds ratios greater than 1 indicate a positive association; risk increases as the predictor increases. Odds ratios less than 1 indicate the opposite effect; risk decreases as the predictor increases. For example, the first number listed for elbow pain and stiffness (the third row of results) shows that for two participants who differ in age by 10 years, the older participant would be expected to have odds of shoulder pain or stiffness

Figure 2 Predicted CHART economic self-sufficiency scores by injury and age

0.810 times that of the younger participant (approximately 20% lower risk). The last column in the same row shows that for each decade an individual participant ages, the odds of elbow pain or stiffness increases by 1.645 times, an increase in risk of approximately two-thirds.

Cross-sectional age effects are similar in dichotomous outcomes – higher age is associated with worse outcomes. The odds for hip pain or stiffness and self-report of bowel accidents both increase more than 1.5 times per 10 years while the odds of a need for more assistance increases twice over 10 years.

With respect to cross-sectional years post injury, the small number of significant associations follow a similar trend to the continuous outcomes, where more time post SCI is associated with better outcomes. Hip pain or stiffness and self-reports of bowel accidents are both associated with a twofold

improvement in the odds for each additional decade post SCI.

Longitudinally, dichotomous outcomes show a similar diversity of directions and magnitudes as mentioned above. The odds of hip pain or stiffness improve approximately threefold, while the odds for pain or stiffness in the shoulder get worse over a 10 year period. Pain and stiffness in the elbow increases moderately while hand pain or stiffness increases more dramatically. Postural changes and equipment changes both become nearly half as frequent over a 10 year period. More dramatically, self-report of smoking improves more than 10-fold over a 10 year period.

Figure 3 Predicted CHART economic self-sufficiency scores by injury and years post injury

Discussion

The presented analyses show that the effects of age are different across the different measures of age and ageing. This study found that the cross-sectional effects of age and years post injury – the most commonly reported ageing effects – are different and often opposite each other. Furthermore, the longitudinal effect – representing actual change over time within an individual – is often quite different from the cross-sectional effects of age or YPI. To understand the impact of these differences, consider the CHART economic self-sufficiency score. When interpreting the decline by age – the long diagonal lines in Figure 2 – in a cross-sectional analysis, it would be easy to say that increased age leads to deterioration. Adding in the opposite effects of year post injury – the long diagonal lines in Figure 3 – one might then claim that physiologic age causes deterioration while experience with spinal cord injury leads to improvement. However, when also incorporating longitudinal changes as this study does – the short diagonal lines in Figures 2 and 3 – it then becomes possible to say that, despite the differences in cross-sectional age and years post injury effects, the outcome is still getting better – a more complete description of the ageing process. Change, as measured by the longitudinal effect, and baseline age and years post injury, as measured by the cross-sectional effects, all play a part in describing the ageing process.

However, this study remains subject to another problem in measuring the ageing effect of spinal cord injury: separation into effects resulting from age alone, time since injury alone, or some combination of both. Because there are relatively fewer people who are young and long-term SCI survivors than there are who are older and recently injured, age and years post injury are often correlated, as they are in this study. This correlation can make it difficult to measure the independent effects of age and age of the injury on outcomes. Such difficulties have been encountered in

Table 3 Dichotomous outcomes (OR per 10 years)

Outcome	C-X age	C-X years post injury	Longitudinal
Back/neck pain/stiffness	1.145 ($P < 0.282$)	0.733 ($P < 0.090$)	1.084 ($P < 0.689$)
Shoulder pain/stiffness	1.076 ($P < 0.593$)	1.075 ($P < 0.719$)	2.004 ($P < 0.001$)
Elbow pain/stiffness	0.810 ($P < 0.240$)	1.209 ($P < 0.463$)	1.645 ($P < 0.025$)
Hand pain/stiffness	0.837 ($P < 0.352$)	0.900 ($P < 0.702$)	14.411 ($P < 0.001$)
Hip pain/stiffness	1.611 ($P < 0.009$)	0.0557 ($P < 0.031$)	0.375 ($P < 0.001$)
Smoke now	0.691 ($P < 0.282$)	0.457 ($P < 0.125$)	0.074 ($P < 0.001$)
Palpitations	1.201 ($P < 0.476$)	0.684 ($P < 0.312$)	0.700 ($P < 0.249$)
Exhaust	1.081 ($P < 0.607$)	0.708 ($P < 0.124$)	0.828 ($P < 0.356$)
Posture	1.067 ($P < 0.713$)	1.157 ($P < 0.567$)	0.439 ($P < 0.006$)
Help	2.762 ($P < 0.001$)	0.657 ($P < 0.091$)	1.340 ($P < 0.282$)
Equipment	1.030 ($P < 0.792$)	1.110 ($P < 0.537$)	0.490 ($P < 0.001$)
Constipation	1.117 ($P < 0.489$)	1.015 ($P < 0.948$)	0.990 ($P < 0.959$)
Bowel accidents	1.533 ($P < 0.002$)	0.678 ($P < 0.042$)	0.738 ($P < 0.153$)
Stomach pain	1.033 ($P < 0.862$)	0.704 ($P < 0.199$)	1.730 ($P < 0.064$)
Nausea	1.171 ($P < 0.547$)	0.723 ($P < 0.418$)	1.079 ($P < 0.814$)

previous studies of the prevalence of SCI,⁶² mortality of SCI⁵⁵ and adjustment after SCI.¹⁷ Two cross-sectional studies have attempted to address this with some success by dividing participants into four groups based both on age, older *versus* younger, and years post injury, more *versus* less recently injured.^{5,11} Although this remains problematic for cross-sectional effects in this study, the longitudinal effect, interpreted here as the true ageing effect, is independent of either age or years post injury and, thus, sidesteps the problem of attribution.

It is important to point out that some of the criteria for admission to this study may affect its findings or generalisability. This study focused on a population of long-term spinal cord injury survivors. As long-term survivors, they may have experienced different medical system and practices than more recently injured people. The survivors studied here were all injured between the ages of 15 and 55, so it is difficult or inappropriate to apply these findings to those injured as a child or past age 55. Since those outside this study's age criteria often experience different types of injuries and, therefore, different physiologic manifestations of their injuries, it is reasonable to believe that their changes with age might also differ. As long-term survivors, the ageing experience of these subjects differs from those who were lost to follow-up or died. It is plausible to expect that those who die closer to injury would have different ageing experiences than those who survive longer periods. It may be that the ageing effects documented here are the effects of those who age most slowly and, therefore, survive to be included in this study.

Although extending results to people who differ from study participants can be problematic, these findings do imply broad trends likely to apply to those who are more recently injured or younger than this study sample. The longitudinal changes shown in this study are, on average, likely to be similar for all people with spinal cord injuries despite cohort differences such as changing treatment regimens. A young man injured in 1990 is likely to improve (or deteriorate) at a similar rate by 2010 as these study participants already have at their 20th anniversary of injury. It is more difficult to use these findings to predict what those more recently injured will experience in their first 20 years post SCI – a realm completely unexplored by this analysis.

The measures of community integration (CHART scores) show an apparently contradictory pattern where cross-sectional differences by age and year post injury go in opposite directions. These findings are consistent with other findings from the National Spinal Cord Injury Model Systems Database in the United States.⁹ The same pattern is apparent for bowel accidents. In this case, however, the cross-sectional effects, in the presence of the longitudinal effects, may be an artifact of the distribution of age and years post injury rather than representing true expected changes associated with ageing.

In many studies it is the cross-sectional effect that is interpreted as evidence of ageing effects.^{2–5,10} The

longitudinal effects, however, show true changes over time within individual SCI survivors. Finding significant cross-sectional effects in the presence of the longitudinal effect would suggest that a cross-sectional study would be appropriate to measure ageing with SCI. The fact that this study rarely found significant cross-sectional age or years post injury effects without significant longitudinal ageing supports the need for longitudinal designs to more completely assess ageing with SCI.

When the longitudinal and cross-sectional effects are different enough to warrant use of this relatively new methodology, there are four possible scenarios. Figures 2 and 3 show two possible patterns. Figure 3 shows an increasing effect for both, while Figure 2 shows a decreasing cross-sectional effect and an increasing longitudinal effect. Figure 3 shows that individual people change faster than cross-sectional YPI differences might suggest. Figure 2 shows individual people changing as fast and even cancelling out the effect that cross-sectional age differences might suggest. The discrepancies between the longitudinal effect may come from some change between measurements as Krause suggests in post-SCI adjustment¹¹ or from some era-related period effect where those undergoing rehabilitation in one era differ from others only because of some characteristic of that era.

Conclusion

While longitudinal study may best describe the effects of ageing with spinal cord injury, careful examination of the data for cohort effects remains important. When an early factor of rehabilitation or emergency medicine, or a changing standard of care influences current findings, it can confuse or obscure the interpretation of results. From a historical point of view, cohort effects do help explain what happened in the past and how it affects today's outcomes. They can also inform us about the impact of choices made today. However, since research that helps to predict what is or will be happening is more useful for use in policy, treatment, and education, analysis of ageing with a spinal cord injury must remove the effects of history to find the true underlying patterns of change.

Acknowledgements

This research was supported, in part, by the National Institute on Disability and Rehabilitation Research of the US Department of Education under grant number H133N5001, the National Institute of General Medical Studies under grant number GM38519, and the National Institute on Aging under grant numbers AG-04418 and AG-10755. The opinions contained in this publication are those of the authors and do not necessarily represent those of the funding agencies. The authors are grateful for the extensive assistance in data collection provided by the staff of the National Spinal Injuries Centre, Stoke Mandeville, UK, and the Regional Spinal Injuries Centre, Southport, UK.

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