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Risk Factors for Chest Illness in Chronic Spinal Cord Injury:

A Prospective Study

Kelly L. Stolzmann, MS, David R. Gagnon, MD, MPH, PhD, Robert Brown, MD, Carlos G. Tun, MD, and Eric Garshick, MD, MOH

Research and Development Service (KLS, DRG, CGT, EG), Department of Veterans Affairs, VA Boston Healthcare System; Programs in Research at VA Boston (KLS), Harvard Medical School; VA, Cooperative Studies Program (DRG), VA Boston Healthcare System, Department of Biostatistics, Boston University School of Public Health; Pulmonary and Critical Care Medicine Unit and Department of Medicine (RB), Massachusetts General Hospital; Rehabilitation Medicine Service (CGT), VA Boston Healthcare System and Harvard Medical School; Pulmonary and Critical Care Medicine Section (EG), Medical Service, VA Boston Healthcare System; Channing Laboratory (EG), Department of Medicine, Brigham and Women's Hospital; and Harvard Medical School (RB, CGT, EG), Boston, Massachusetts

Abstract

Objective—Chest illnesses commonly cause morbidity in persons with chronic spinal cord injury. Risk factors remain poorly characterized because previous studies have not accounted for factors other than spinal cord injury.

Design—Between 1994 and 2005, 403 participants completed a respiratory questionnaire and underwent spirometry. Participants were contacted at a median of 1.7 yrs [interquartile range: 1.3–2.5 yrs] apart over a mean (SD) of 5.1 ± 3.0 yrs and asked to report chest illnesses that had resulted in time off work, spent indoors, or in bed since prior contact.

Results—In 97 participants, there were 247 chest illnesses (0.12/person-year) with 54 hospitalizations (22%). Spinal cord injury level, completeness of injury, and duration of injury were not associated with illness risk. Adjusting for age and smoking history, any wheeze (relative risk = 1.92; 95% confidence interval: 1.19, 3.08), pneumonia or bronchitis since spinal cord injury (relative risk = 2.29; 95% confidence interval: 1.40, 3.75), and physician-diagnosed chronic obstructive pulmonary disease (relative risk = 2.17; 95% confidence interval: 1.08, 4.37) were associated with a greater risk of chest illness. Each percent-predicted decrease in forced expiratory volume in 1 sec was associated with a 1.2% increase in risk of chest illness ($P = 0.030$).

Conclusions—In chronic spinal cord injury, chest illness resulting in time spent away from usual activities was not related to the level or completeness of spinal cord injury but was related to reduced pulmonary function, wheeze, chronic obstructive pulmonary disease, a history of pneumonia and bronchitis, and smoking.

Correspondence: All correspondence and requests for reprints should be addressed to: Eric Garshick, MD, MOH, Pulmonary and Critical Care Medicine Section, VA Boston Healthcare System, 1400 VFW Parkway, West Roxbury, MA 02132.

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Keywords

Spinal Cord Injury; Chest Illness; Pulmonary Function; Morbidity

Chest illnesses are common causes of morbidity and mortality in chronic spinal cord injury (SCI).^{1,2} These findings are based largely on mortality and rehospitalization rates that are greatest in the years after initial injury, particularly in persons with higher and more complete injury.^{3–5} Furthermore, the extent that neurological level and completeness of injury contribute to the impact of chest illness is unknown, because previous studies assessing respiratory-related illness were retrospective and failed to consider personal information, including information about cigarette smoking, a known risk factor for chest illness. Other unstudied potentially important risk factors include concomitant heart disease, underlying lung disease, or chronic respiratory symptoms such as chronic cough, chronic phlegm, and wheeze.

Since 1994, we have been assessing pulmonary function and the occurrence of chest illness prospectively in a chronic SCI cohort. In this report, we provide descriptive information regarding frequency and predictors of chest illness. For the purposes of this study, chest illness is defined as a self-report of a chest illness that interfered with the ability to participate in usual activities.

PATIENTS AND METHODS

Patient Population

Between October 1994 and December 2005, 586 participants free from acute illness were recruited for enrollment in a longitudinal study to examine the determinants of pulmonary function and chest illness. Participants were persons with SCI who had received care from the SCI Service for either traumatic or nontraumatic injury of the Department of Veterans Affairs (VA) Medical Center, West Roxbury, MA, and, by advertisement, from the community (methods presented previously).⁶ Recruitment was restricted to persons who were one or more years post-SCI⁷ and excluded participants requiring mechanical ventilation, with a tracheostomy, other neurological conditions (a history of polio, multiple sclerosis, or stroke, $n = 27$), lung resection ($n = 5$), or without a detectable SCI level ($n = 8$). Repeat testing began in 1998 with a goal of contacting persons yearly, alternating between test visits and telephone questionnaires. At each contact, persons were asked whether (since prior contact) they had experienced chest illness. A respiratory questionnaire based on the ATS DLD-78⁸ was used to define a chest illness as one that kept a participant off work, indoors at home, or in bed. Participants were also asked whether chest illness resulted in hospitalization or contact with a physician and whether antibiotics or inhaled medication were required. The longitudinal cohort for this analysis was restricted to 403 participants (356 with traumatic injury and 47 with nontraumatic injury) with at least one follow-up contact after study entry. The number of follow-up contacts varied: 122 participants were contacted once, 208 participants between two and four times, and 73 participants between five and eight times. The approval for this study was obtained from our Institutional Review Boards, and informed consent was obtained. Efforts were made to obtain hospital discharge summaries, and electronic VA records were reviewed corresponding to the time period for reported hospital admissions.

Neurological Examination, Stature, and Weight

At entry, motor level and completeness of injury were assessed based on the American Spinal Injury Association Impairment Scale (AIS).⁹ Motor incomplete SCI included AIS C

(most key muscles below the neurological level grade <3/5) or AIS D (most muscles below the neurological level grade $\geq 3/5$). Persons were further grouped into severe tetraplegia (cervical motor complete [AIS A or B] and cervical AIS C), severe paraplegia (thoracic or lower motor complete [AIS A or B] and thoracic or lower AIS C), and all others (AIS D).

Participants were weighed, and supine length was measured.¹⁰ Self-reported weights were used for 32 participants (8%), and weights from a corresponding medical clinic visit were used in 1%. In individuals who declined length measurement or who had severe joint contractures that precluded accurate assessment, stature was self-reported (17%). Body mass index was defined as normal (body mass index < 25 kg/m²), overweight (body mass index ≥ 25 to <30 kg/m²), or obese (body mass index ≥ 30 kg/m²).

Health Questionnaire

The respiratory health questionnaire (ATS DLD-78)⁸ with supplemental questions was completed at entry and used to obtain a history of cigarette smoking, physician-diagnosed chronic obstructive pulmonary disease (COPD) (emphysema or chronic bronchitis), asthma, hypertension, heart disease treated in the 10 yrs before study entry, and pneumonia or bronchitis since SCI. Obstructive lung disease (OLD) was defined as a history of either physician-diagnosed COPD or asthma. Any wheeze was that which occurred on most days/nights, or with a cold, or occasionally apart from a cold. Chronic cough was defined as cough on most days for 3 consecutive months of the year, and chronic phlegm was defined similarly. The use of pulmonary medications was defined as the use of long- or short-acting bronchodilators, inhaled or oral corticosteroids, or cromolyn at study entry.

Pulmonary Function Tests

Spirometry was based on ATS standards¹¹ modified for use in SCI. Those with SCI are more likely than the able-bodied to have short expiratory efforts and to exhibit excessive back extrapolation¹² (the volume exhaled before the development of maximal expiratory flow after the start of a forced expiratory maneuver). We accepted excessive back extrapolation and efforts lasting <6 secs if the effort appeared maximal, if there was an acceptable flow-volume loop, and if there was at least a 0.5-sec plateau at residual volume. Forced expiratory volume in 1 second (FEV₁) and forced vital capacity (FVC) values derived from such efforts are highly reproducible, and the degree of excessive back extrapolation is small.^{12,13}

Testing was done using a 10-l water-seal spirometer (DSII) in 88% of the sessions or an 8-l water-seal portable spirometer (Survey III) in 2%. Starting in March 2004 (10% of sessions), testing was done using a dry-rolling seal spirometer (CPL system). Equipment was manufactured by Collins Pulmonary Diagnostics (currently, nSpire Health, Longmont, CO). Of the 403 participants, 361 (90%) had at least three acceptable expiratory efforts with the two best values of FEV₁ and FVC each within 200 ml, 39 (9%) had two acceptable expiratory efforts (approximately half reproducible), and 3 (1%) performed one acceptable effort. The highest values of FEV₁ and FVC were used, and predicted values for FEV₁ and FVC were calculated using Hankinson's equations.¹⁴ Maximum inspiratory pressure and maximum expiratory pressure were reported as the maximum of three values.¹⁵

Statistical Analysis

The outcome variable in all analyses was the number of chest illnesses counted from study entry through participants' latest follow-ups. Predictors of chest illnesses were assessed using negative binomial regression models (PROC GENMOD, SAS 9.1 statistical software; SAS Institute, Cary, NC). The models were fit as log-linear regressions, and an offset option

was included in all models to adjust for the length of follow-up. Variables significant at the 0.1 level were assessed in a multivariate model.

RESULTS

Participant Characteristics

Of the 403 participants assessed longitudinally (287 veterans), 92% were white, 6% were African American, and 2% were of other races (Table 1). There was no significant difference in age, injury duration, or level of injury compared with the persons in our cohort who did not participate in the longitudinal assessment of chest illness. Mean follow-up was 5.1 yrs (SD: 3.0; range: 0.8–11.3) with 2064 person-years of follow-up, and persons were contacted at a median of 1.7 yrs [interquartile range: 1.3–2.5; range: 0.8–8.4 yrs] apart. There were 247 chest illnesses reported (overall rate 0.12 illnesses/person-year) in 97 of 403 persons (24%) for a median of two chest illnesses/person-year (interquartile range: 1–3; range: 1–25). Of these illnesses, 54 (22%) illnesses in 36 persons were reported to have resulted in hospitalization, 174 (70%) illnesses lasted 1 wk or more, and a doctor or other healthcare provider was contacted for 169 (68%) illnesses. There were 150 (61%) chest illnesses treated with antibiotics and 91 (37%) treated with inhaled medication. The mean (SD) for percent-predicted FEV₁ among persons with severe tetraplegia, severe paraplegia, and AIS D was 62.9% (17.0), 84.5% (16.3), and 80.1% (17.9), respectively, and the mean (SD) for percent-predicted FVC was 60.8% (16.3), 82.9% (14.8), and 81.9% (16.6), respectively.

Predictors of Chest Illness

Rates of chest illness were similar among persons with severe tetraplegia (0.15 illnesses/person-year) and AIS D SCI (0.17 illnesses/person-year). Persons with severe paraplegia had fewer illnesses (0.07 illnesses/person-year). In unadjusted regression models (Table 2), there was no difference in the risk of chest illness between those with severe tetraplegia and AIS D, but persons with severe paraplegia had a lower risk of chest illness compared with AIS D. We also considered SCI level and completeness in additional subgroups, including a separate category for persons with cervical motor complete SCI and with a zone of partial preservation of two segments or less. The rate of chest illness in this group was 0.13 illnesses/person-year, and the risk was not significantly increased compared with AIS D ($P = 0.469$). Duration of injury, history of hypertension, FEV₁/FVC, maximum inspiratory pressure, and maximum expiratory pressure were not significantly associated with chest illness in univariate models ($P > 0.10$), but obesity ($P = 0.079$), heart disease ($P = 0.002$), asthma ($P = 0.002$), COPD ($P < 0.001$), OLD (obstructive lung disease) ($P < 0.001$), chronic cough ($P = 0.002$), chronic phlegm ($P = 0.002$), any wheeze ($P < 0.001$), and the use of pulmonary medications ($P = 0.003$) at study entry were all significantly related to future chest illness. There was a lower risk of chest illness with greater age ($P = 0.003$). A higher percent-predicted FEV₁ and FVC ($P = 0.030$ and $P = 0.080$, respectively) were protective (Table 2). Current and former smokers (<3 yrs before study entry) had a significantly elevated risk of chest illness. In models adjusting for age and smoking (Table 3), chronic cough, chronic phlegm, asthma, and obesity were no longer significant.

The final multivariate model included age and smoking history, respiratory symptoms (any wheeze), a history of pneumonia or bronchitis since SCI, COPD, and percent-predicted FEV₁ or FVC (Table 4). A history of heart disease was no longer significant ($P = 0.201$). There was a significant inverse relationship between the risk of chest illness and percent-predicted FEV₁ (relative risk [RR]: 0.988; 95% confidence interval [CI]: 0.977, 0.999; $P = 0.030$) (Table 4), and results were similar when percent-predicted FVC was substituted (RR: 0.986; 95% CI: 0.975, 0.997; $P = 0.013$). When reassessed in the final model, the risk of

chest illness was not significantly different among persons with severe tetraplegia ($P = 0.614$) or severe paraplegia ($P = 0.107$) compared with AIS D. Any wheeze (RR: 1.92; 95% CI: 1.20, 3.08), a history of COPD (RR: 2.18; 95% CI: 1.01, 4.37), and a history of pneumonia or bronchitis since SCI (RR: 2.29; 95% CI: 1.40, 3.75) were associated with a significant increase in risk. Former smokers, who quit <3 yrs before study entry, had a nearly 2-fold increase in the risk of chest illness compared with participants who had never smoked (RR: 1.69; 95% CI: 1.07, 2.68; Table 4).

We were able to review VA medical records or obtain non-VA discharge summaries corresponding to the time period related to 41 hospitalizations. We verified hospitalization for causes related to chest illnesses in 28 cases (68%), including one for congestive heart failure reported as a chest illness. There were two outpatient visits for chest illness reported as admissions and including these would result in verification of a chest-related illness in 30 of the 41 reports (73%). In five additional cases, there was hospitalization for causes apparently unrelated to chest illness. The reasons that other records were not available varied but included wrong hospital name or location or an expired medical release.

DISCUSSION

In chronic SCI, we performed a prospective assessment of risk factors for the occurrence of chest illness resulting in time off work, spent indoors, or in bed. Smoking, self-reported wheeze, COPD, pneumonia or bronchitis after SCI, and reduced pulmonary function were significant predictors of future chest illness. Most illnesses lasted 1 wk or more were treated with antibiotics and resulted in a physician being contacted.

Identification of longitudinal risk factors for chest illness in chronic SCI is important because of their morbidity and the possibility that in some individuals these illnesses will result in death.^{3,16–18} In a recent study of patients with spinal cord disorders, using VA records between 1997 and 2000, a visit for an acute respiratory illness was significantly associated with an increased risk of a respiratory-related hospitalization and death 60 days later.² Our data add to these findings, showing that persons experiencing pneumonia or bronchitis after SCI will have more than twice the risk of reporting an additional chest illness. Previously, wheeze has not been reported to be a longitudinal predictor of chest illnesses in chronic SCI. However, this result is consistent with the findings in the able-bodied in whom a history of wheeze is a marker for respiratory hospitalization,¹⁹ and risk of future asthma,²⁰ and a predictor of mortality from obstructive lung disease and pneumonia.²¹

We found a decreasing trend in the risk of chest illness with increased age. A previous study in SCI found an increase in respiratory hospitalizations with greater age² and another showed that older participants were more likely to have pneumonia and influenza visits.¹ The ascertainment of chest illness in our study depended on participants returning to our hospital or responding to a phone questionnaire. This may have precluded contacting very ill (and possibly older) participants, thereby mitigating the effects of age on the overall risk of chest illness.

We did not observe an increased risk of chest illness in persons with the highest levels and more complete injuries. Because these persons have the weakest expiratory muscles and least effective cough, it is possible that they would be more likely to stay in bed or at home because of a chest illness to receive additional respiratory care. Because our cohort included persons recruited a mean of 17 yrs after injury (Table 1), it is possible that a survivor effect contributed to the lack of an effect of injury severity because most studies demonstrating the greatest effect of level and completeness of SCI on respiratory mortality and hospitalization

risk^{3,5,22,23} included persons assessed relatively soon after injury. In addition, our cohort excluded persons with the highest and most complete injuries because these persons would require chronic ventilatory support. Although neurologic level and completeness of SCI are a determinant of pulmonary dysfunction in our cohort,⁶ our results indicate that FEV₁ provides a more accurate assessment of future chest illness risk when compared with differences in SCI level and completeness of injury.

Some limitations need to be considered. This study assessed chest illness based on a self-report and as an illness that resulted in time off work, indoors, or in bed. Therefore, a chest illness that did not interfere with daily activities or that was not recalled did not contribute to this analysis. We were not able to distinguish between lower and upper respiratory illness or distinguish among various types of lower respiratory tract illnesses. Despite these limitations, the overall rate of illness we report (0.12 illness/person-year) is remarkably similar to the total rates observed for upper respiratory infections, lower respiratory tract infections, and pneumonia and influenza reported by Smith et al.¹ (~0.10 illness/person-year) based on VA SCI out-patient administrative records.

As noted in our review of hospitalization records, illnesses recorded in our study may not have been primarily respiratory in etiology because cardiac disease may also present with symptoms of chest illness. We elected to review hospitalization records because these were most likely to have sufficient documentation and more easily obtained compared with outpatient clinic or physician records. When records were available, we confirmed that the event reported was related to a chest illness in most cases.

In conclusion, we found that chest illnesses resulting in time off work, spent indoors, or in bed (i.e., interfering with daily activities) in persons with chronic SCI are not directly attributable to differences in level and completeness of injury but are related to smoking history, reduced pulmonary function, COPD, wheeze, and a previous history of pneumonia and bronchitis. Our results suggest that measuring pulmonary function and obtaining a history of these risk factors will identify persons with the greatest risk of future chest illness.

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TABLE 1

Cohort characteristics

Characteristics	Persons With Chest Illnesses (N = 97)	Number of Illnesses	Persons Without Chest Illness (N = 306)	Total Persons (N = 403)
Males	88 (90.7)	207	288 (94.1)	376 (93.3)
Race/ethnicity				
White	92 (94.9)	238	279 (91.2)	371 (92.1)
African American	3 (3.1)	5	20 (6.5)	23 (5.7)
Others ^a	2 (2.1)	4	7 (2.3)	9 (2.2)
Age (yrs) ^b	48.7 [14.9]		51.7 [14.9]	51.0 [14.9]
Injury duration ^b	16.8 [13.3]		17.5 [13.1]	17.3 [13.1]
Level of injury				
Cervical motor complete and cervical AIS C	38 (39.2)	85	76 (24.8)	114 (28.3)
Thoracic/lower motor complete and AIS C	28 (28.9)	67	138 (45.1)	166 (41.2)
AIS D	31 (32.0)	95	92 (30.1)	123 (30.5)
Body mass index (kg/m ²) ^b	26.8 [6.1]		26.9 [5.4]	26.9 [5.6]
Normal/underweight (<25)	39 (40.2)	101	123 (40.2)	162 (40.2)
Overweight (25–<30)	34 (35.1)	70	108 (35.3)	142 (35.2)
Obese (≥30)	24 (24.7)	76	75 (24.5)	99 (24.6)
Cigarette smoking				
Current smoker	28 (28.9)	90	57 (18.6)	85 (21.1)
Past smoker	36 (37.1)	102	133 (43.5)	169 (41.9)
Years quit <3	3 (3.1)	34	15 (4.9)	18 (4.5)
Years quit ≥3	33 (34.0)	68	118 (38.6)	151 (37.5)
Never smoker	33 (34.0)	55	116 (37.9)	149 (37.0)
Lifetime pack years smoked (for ever smokers) ^b	25.2 [21.9]		28.5 [25.5]	27.6 [24.6]
COPD	14 (14.4)	88	21 (6.7)	35 (8.7)
Asthma	13 (13.4)	52	27 (8.8)	40 (9.9)
Obstructive lung disease	22 (22.7)	103	42 (13.7)	64 (15.9)
Heart disease	10 (10.3)	60	32 (10.5)	42 (10.4)
Pneumonia/bronchitis since SCI	40 (41.2)	146	71 (23.2)	111 (27.5)
Hypertension	26 (26.8)	74	91 (29.7)	117 (29.0)
Chronic cough	21 (21.7)	82	49 (16.0)	70 (17.4)
Chronic phlegm	24 (24.7)	89	60 (19.6)	84 (20.8)
Any wheeze	61 (62.9)	185	140 (45.8)	201 (49.9)
FEV ₁ ^b (L)	2.74 [0.91]		2.95 [0.86]	2.90 [0.87]
FVC ^b (L)	3.48 [1.17]		3.75 [1.02]	3.69 [1.06]
FEV ₁ /FVC ^b (%)	79.3 [11.0]		78.6 [8.9]	78.8 [9.5]
Percent-predicted FEV ₁ ^b	71.3 [19.5]		78.9 [18.8]	77.1 [19.2]
Percent-predicted FVC ^b	70.8 [19.5]		78.1 [17.9]	76.4 [18.6]

Characteristics	Persons With Chest Illnesses (<i>N</i> = 97)	Number of Illnesses	Persons Without Chest Illness (<i>N</i> = 306)	Total Persons (<i>N</i> = 403)
Pulmonary medication	9 (9.3)	45	25 (8.2)	34 (8.4)

Values are expressed as *N* (%) unless indicated.

AIS, American Spinal Injury Association Impairment Scale; SCI, spinal cord injury; COPD, chronic obstructive pulmonary disease; FEV₁, forced expiratory volume in 1 sec; FVC, forced vital capacity.

^a Others include Native American, Hispanic/Latino, and Asian/Pacific Islander.

^b Expressed as mean [SD].

TABLE 2

Unadjusted predictors of chest illness

Covariate	Coefficient (β)	Relative Risk	95% Confidence Limits
Age	-0.026	0.974	0.958, 0.992
Injury duration	-0.011	0.989	0.971, 1.008
Percent-predicted FEV ₁	-0.014	0.986	0.973, 0.999
Percent-predicted FVC	-0.011	0.989	0.976, 1.001
FEV ₁ /FVC < 0.70	0.42	1.52	0.78, 2.95
Body mass index (continuous)	0.03	1.03	1.00, 1.06
Obese	0.50	1.65	0.94, 2.90
Others	Reference	Reference	
COPD	1.79	5.97	3.02, 11.78
Obstructive lung disease	1.39	4.02	2.27, 7.11
Asthma	1.15	3.16	1.51, 6.60
Heart disease	1.34	3.80	1.89, 7.65
Hypertension	0.35	1.42	0.82, 2.43
Chronic cough	0.96	2.61	1.44, 4.73
Chronic phlegm	0.89	2.43	1.38, 4.27
Any wheeze	1.36	3.88	2.40, 6.27
Pneumonia/bronchitis since SCI	1.45	4.25	2.63, 6.87
MIP, cm H ₂ O (<i>n</i> = 380)	-0.005	0.995	0.987, 1.002
MEP, cm H ₂ O (<i>n</i> = 288)	-0.003	0.997	0.991, 1.003
Pulmonary medication	1.21	3.34	1.52, 7.33
Level of Injury			
Cervical motor complete and cervical AIS C	-0.18	0.83	0.45, 1.53
Thoracic and lower motor complete and AIS C	-0.94	0.39	0.22, 0.70
AIS D	Reference	Reference	
Packs smoked per day (among current smokers) ^a	0.68	1.97	1.08, 3.60
Former smokers: years quit <3 ^a	0.94	2.57	1.52, 4.32
Former smoker: years quit ≥3 ^a	-0.003	1.00	0.97, 1.02

AIS, American Spinal Injury Association Impairment Scale; SCI, spinal cord injury; COPD, chronic obstructive pulmonary disease; FEV₁, forced expiratory volume in 1 sec; FVC, forced vital capacity; MIP, maximum inspiratory pressure; MEP, maximum expiratory pressure.

^aCompared with never smokers.

TABLE 3

Predictors of chest illness adjusted for age and cigarette smoking

Covariate	Coefficient (β)	Relative Risk	95% Confidence Limits
Percent-predicted FEV ₁	-0.017	0.984	0.971, 0.996
Percent-predicted FVC	-0.016	0.984	0.971, 0.996
Level of injury			
Cervical motor complete and cervical AIS C	0.11	1.11	0.60, 2.09
Thoracic/lower motor complete and AIS C	-0.62	0.54	0.29, 0.99
AIS D	Reference	Reference	
Body mass index			
Obese	0.23	1.25	0.72, 2.20
Others	Reference	Reference	
COPD	1.53	4.63	2.36, 9.09
Obstructive lung disease	1.15	3.17	1.82, 5.52
Asthma	0.73	2.08	0.98, 4.40
Heart disease	1.08	2.95	1.45, 6.00
Chronic cough	0.50	1.65	0.88, 3.09
Chronic phlegm	0.55	1.73	0.96, 3.12
Any wheeze	1.09	2.97	1.83, 4.80
Pneumonia/bronchitis since SCI	1.31	3.71	2.35, 5.85
Pulmonary medication	0.91	2.47	1.08, 5.68

AIS, American Spinal Injury Association Impairment Scale; SCI, spinal cord injury; COPD, chronic obstructive pulmonary disease; FEV₁, forced expiratory volume in 1 sec; FVC, forced vital capacity.

TABLE 4

Multivariate predictors of chest illness

Covariate	Coefficient (β)	Relative Risk	95% Confidence Limits
Percent-predicted FEV ₁	-0.013	0.988	0.977, 0.999
Age	-0.018	0.982	0.966, 0.998
Packs smoked per day (among current smokers)	0.29	1.33	0.81, 2.20
Ex-smoker: years quit < 3	0.53	1.69	1.07, 2.68
Ex-smoker: years quit $\geq$ 3	0.01	1.01	0.99, 1.04
Any wheeze	0.65	1.92	1.20, 3.08
COPD	0.78	2.17	1.08, 4.36
Pneumonia/bronchitis since SCI	0.83	2.29	1.40, 3.75

COPD, chronic obstructive pulmonary disease; FEV₁, Forced expiratory volume in 1 sec; SCI, spinal cord injury.