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# Respiratory Dysfunction and Spinal Cord Injury

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**Abstract**

There are an estimated 270,000 individuals in the United States living with spinal cord injury (SCI), with approximately 12,000 new cases occurring yearly. Respiratory dysfunction is the most common cause of death for those with SCI and affects patients' overall quality of life. This article explores various respiratory complications, their prevalence, and treatment options for those with SCI.

Keywords: respiratory dysfunction, spinal cord injury, rehabilitation, respiratory complication

## Respiratory Dysfunction and Spinal Cord Injury

There are an estimated 270,000 individuals in the United States living with spinal cord injury (SCI), with approximately 12,000 new cases occurring yearly (National Spinal Cord Injury Statistical Center [NSCISC], 2012). Advances in medicine and assistive technology have significantly lowered mortality rates and improved quality of life for those with SCI since after World War II (DeVivo, 2012; Brown, DiMarco, Hoit, & Garshick, 2006). Despite technological advances, respiratory dysfunction has emerged as the most common cause of death for those with SCI (particularly those with tetraplegia) and can affect one's overall quality of life (National Spinal Cord Injury Association, 2013; Brown, DiMarco, Hoit, & Garshick, 2006). This article discusses various respiratory complications that may occur with spinal cord injury and explores common treatment options available.

**The Respiratory System.** The respiratory system's function is to regulate breathing, allowing the body to inhale and fuel the blood with oxygen and exhale carbon dioxide. The respiratory system is divided into two parts, the upper and lower tracts. Comprising the upper respiratory tract is the nose, pharynx, larynx, and trachea, while the lower respiratory tract is made up of the bronchi, bronchioles, and the lungs (McLafferty, Johnstone, Hendry, & Farley, 2013).

To inhale, the body depends upon the diaphragm, a muscle between the chest cavity and abdomen. The diaphragm muscle also assists with coughing, which serves to expel the lungs of excess fluid. The spinal cord, which serves as a conduit for nerves that send signals from the brain to the rest of the body, controls the respiratory muscles. Damage or disruption to any of these areas can cause respiratory dysfunction.

**Respiratory Dysfunction.** Respiratory dysfunction has been documented as early as 1881, presented as pneumonia (Driver, 2012), and remains a major health concern worldwide (World Health Organization [WHO], 2013c). Although pneumonia continues to be a leading cause of death in the United States, other respiratory diseases are beginning to rise in numbers. These include asthma, chronic obstructive pulmonary disease (COPD), pulmonary hypertension, and acute respiratory distress syndrome (ARDS) (WHO, 2013b; Bernard, 2005). According to the World Health Organization (WHO, 2013c), there are over 1 billion estimated cases of chronic respiratory diseases worldwide. A few common respiratory diseases are described below.

**Pneumonia**. The first recorded case of pneumonia was observed and documented by American physician Sir William Osler in the late 19th century (Driver, 2012). Despite advances in medicine, pneumonia is ranked among the top ten causes of death in the United States, killing over 55,000 people annually (American Lung Association [ALA], 2013a). Typically co-occurring as a complication from other conditions such as influenza or bronchitis, pneumonia is an inflammation of the lungs resulting from a bacterial or viral infection. Those at greatest risk for the development of pneumonia are those with weakened or compromised immune systems, children under the age of five, and adults over the age of 65 (ALA, 2013a; Driver, 2013).

**Chronic obstructive pulmonary disease.** Chronic obstructive pulmonary disease (COPD) is a life threatening lung disease characterized by difficulty breathing due to a blockage of airflow through the lungs (WHO, 2013a). Emphysema and chronic bronchitis are two diseases now classified under COPD. Affecting roughly 64 million people worldwide and the cause of death for an estimated 3 million annually, COPD has no known cure. However, available treatments may slow the progression of the disease, thus improving the quality of life for those affected. According to WHO (2013a), both women and men age 40 and older are at risk of developing COPD.

**Acute respiratory distress syndrome.** Formerly referred to as wet lung and shock lung, acute respiratory distress syndrome (ARDS) is the severe fluid buildup in the lungs leading to sudden respiratory failure (ALA, 2013b). In ARDS, the small blood vessels that line the walls of the air sacs within the lungs leak excessive fluid into the air sacs, preventing sufficient oxygen from being transmitted into the bloodstream. Common causes of ARDS include blunt trauma, sepsis, smoking, overdose of tricyclic antidepressants, and pneumonia. It is estimated that ARDS affects 190,000 people in the United States each year, and is fatal in approximately 30% of these cases (ALA, 2013b).

### The Spinal Cord and Respiratory Function

Nerves comprising the spinal cord, including those that control the respiratory muscles, are housed within the spinal column, which is the bony structure that serves to protect the spinal cord. The spinal cord consists of four sections, each separated into numbered segments (Sarhan, Saif, & Saif, 2013). These are the cervical (C1-C7), thoracic (T1-T12), lumbar (L1-L5), and sacral (S1-S5) segments. The segments each contain a pair of spinal nerves that exit the vertebrae. Injury to the spinal cord results in damaged or lost neurons, causing paralysis at and below the injury level. Tetraplegia results from injuries to one of eight cervical segments, and paraplegia occurs with lesions to the thoracic, lumbar, or sacral regions (Brown, et al., 2006). Lesions are described as either complete (no nerve function) or incomplete (at least one nerve fiber functioning). The phrenic nerve is especially important to respiratory function as it sends signals from the brain to the diaphragm. Damage to the C4 segment where the phrenic nerve is located is thus significant. The C4-C6 section of the spinal cord is highly susceptible to traumatic spinal cord injury (Sarhan, Saif, & Saif, 2013), and any damage to the cervical segments of C1-C5, or neck region, will likely damage the phrenic nerve, and hence reduce respiratory functioning. Traumatic spinal cord injury can also negatively affect the functioning of the intercostal muscles around the ribcage, which in turn impacts respiration. Injury to the spinal cord also reduces chest wall compliance and lung capacity; however, spontaneous partial recovery of chest wall compliance may occur up to one year after injury (Brown, et al., 2006). With higher level cervical injury, mechanical ventilation or phrenic-nerve stimulation may be required due to the nearly complete paralysis of muscles needed for inhalation and exhalation. There is a greater chance of independent breathing for patients with lower level spinal cord injuries, however. Complete injuries are associated with respiratory difficulties that are more severe and occur more frequently (Lemons & Wagner, 1994).

**Respiratory Complications and Prevalence Among Those with Spinal Cord Injury**

The National Spinal Cord Association (NSCA, 2013) reports that individuals with spinal cord injury are at greater risk for respiratory dysfunction than non-injured individuals and can be life threatening. This is due to the loss of control of the respiratory muscles, which in turn reduces lung capacity and increases congestion. Those with tetraplegia are especially at risk for respiratory complications, as over 80 percent of individuals with traumatic cervical injury report dysfunction with respiration in the acute phase (Berney, Bragge, Granger, Opdam, & Denehy, 2011; Jackson & Groomes, 1994). Because loss of muscle and nerve control occur at and below the level of injury, the respiratory system is increasingly affected the higher the level of injury. The first three to five days following injury are especially critical, as patients are more prone to experience respiratory failure during this time period (Berlly & Shem, 2007). Regardless of level or length of injury, pneumonia is the number one cause of death (NSCA, 2013, Montgomerie, 1997) and is contracted by up to 20 percent of all patients with spinal cord injury during the acute phase of injury (Montgomerie, 1997). Pulmonary embolism, a blockage in the blood vessels within the lungs, is the second highest cause of death within the first year of injury. Other possible complications for all levels of spinal cord injury include sleep apnea (characterized by the temporary cessation of breathing during sleep, snoring, daytime sleepiness, and irregular breathing) and atelectasis (partial collapse of the lungs due to inadequate air supply). These complications are exacerbated by smoking as well as the reduced ability to excrete secretions with cough (Berlly & Shem, 2007; Brown, et al., 2006).

Lifestyle risks to respiratory health, both before and after spinal cord injury, include tobacco use and alcohol consumption. Davies and McColl (2005) examined the interaction of tobacco and alcohol use in relation to body mass index for 97 adults with spinal cord injuries. Independent of smoking, alcohol consumption has been linked to lower lung functioning. Utilizing the American Thoracic Society – Division of Lung Diseases (ATS-DLD) questionnaire to explore chronic pulmonary morbidity, the researchers found that over half of respondents reported respiratory morbidity. The level of lesion played a factor in morbidity, coupled with the amount of cigarettes smoked per day. Those with tetraplegia were nearly 70 percent more likely to have respiratory morbidity than those with paraplegia, which is believed due to the more impaired ability to excrete mucus from the respiratory tract with higher level injuries. Although alcohol consumption was not found to be a significant predictor of respiratory morbidity, its interaction with smoking tobacco was discovered to increase risk among respondents. Given this, assistance in smoking cessation and alcohol reduction would be beneficial to reduce the risk for respiratory complication.

Those with spinal cord injuries are also at an increased risk for frequent hospitalizations as well as for hospital-acquired infections (HAI) (Evans, et al., 2008). Frequent illnesses and subsequent treatments raise the risk for those with spinal cord injury to contract infections that are resistant to antibiotics, and in turn increasing mortality rate. Evans et al., (2008) studied 226 veterans with spinal cord injury and their risk for contracting an infection during hospitalization. The study focused on 113 patients with tetraplegia and 103 patients with paraplegia. For the 549 hospitalizations recorded over a two-year period, 657 HAIs were contracted by patients. There were on average six HAIs per patient. Over half of all the patients in the study contracted at least one HAI during the study period. Respiratory tract infections accounted for nearly seven percent of all HAIs recorded. Antibiotic-resistant respiratory infections have been a concern for those with spinal cord injury, who are more susceptible to life-threatening respiratory complications than the general population.

In a related study of veterans with spinal cord injury, Evans, Smith, Parada, Kurichi, and Weaver (2005) found the majority of the respiratory infections were treated with antibiotics, despite its use not being indicated. The overuse of antibiotics has long been cited as a reason for drug-resistant strains of infections. Because respiratory infections are a large cause for concern among those with spinal cord injury, predicting who may be at greater risk for developing one is beneficial. Postma, et al., (2009) studied 140 individuals with spinal cord injury in an attempt to assess that risk. Of their sample, 36.7% had tetraplegia, 63.3% had paraplegia, and 45.3% were smokers. Postma and her colleagues reported that 10% of participants developed at least one respiratory infection within one year after being discharged from an inpatient rehabilitation facility. There was no significant difference in number of infections based on lesion in this study. However, Postma et al. reported that pulmonary function indicated risk level. Those with lower pulmonary functioning were more likely to develop respiratory infection within one year than those with higher pulmonary functioning.

Waddimba et al., (2009) investigated the risk veterans with spinal cord injury have for hospitalization for pulmonary and circulatory diseases. Investigating hospital records and personal information for 309 veterans with spinal cord injury, the researchers reported that the level and completeness of injury could not be used as a predictor for hospital admission for cardiopulmonary disease in their study. The risk factors that were uncovered were a history of contracting pneumonia after injury, chronic respiratory problems, and reduced lung functioning. As well, the risk for hospitalization grew three percent for every year older the sample aged. Of the 1,478 hospital admissions that were recorded, 22.4 percent of them were for respiratory illness.

Among those with less severe thoracic spinal cord injuries, the mortality risk increased significantly when respiratory complications developed (Cotton et al., 2005). Cotton et al., (2005) studied the medical records of 10,484 patients with a diagnosis of thoracic or lumbar spine fractures without spinal cord injury and 596 patients with thoracic spinal cord injury. The researchers discovered that the risks for intubation, pneumonia, and death were significantly higher for those with T1-T6 spinal cord injuries than for the other patients in the study. Of the patients studied, those with spinal cord injury were 26.7 times more likely to die of complications from respiratory dysfunction.

Watt, Wiredu, Silva, and Meehan (2011) also studied survival rates for those with spinal cord injury, comparing those who had been on ventilation for short versus long term. Short-term was defined as being weaned off of mechanical ventilation prior to discharge from the hospital. The researchers found that patients who were weaned off of the use of either mechanical ventilation or diaphragm pacing had a better survival rate than those who were indefinitely dependent on ventilatory support. This rate was significantly better for those who were between 31 to 45 years of age. Overall, however, 57.1 percent of those tracked over the study period, died of respiratory failure.

Garshick et al., (2005) similarly studied a sample of 361 individuals with SCI for at least one year and assessed the mortality risk for respiratory disease. Study participants completed a questionnaire about their respiratory health, participated in pulmonary function testing, and underwent a neurological examination. Respiratory dysfunction accounted for nearly one-fourth of the underlying or contributing causes of death, and 5.4 percent of the deaths noted respiratory disease as the primary cause of death. The authors of the study suggest that smoking cessation would help increase survival rates of individuals with spinal cord injuries, as this was a contributing factor in many of the deaths.

Linn, Adkins, Gong, and Waters (2000) also assert that smoking cessation should be a focus for those with spinal cord injuries since it facilitates pulmonary function loss over time. Linn and colleagues surveyed 222 individuals with spinal cord injury who were not dependent on mechanical ventilation to examine risk factors for respiratory morbidity. Ninety-eight of the participants had tetraplegia, 62 of whom had complete motor lesions and 26 had incomplete lesions. Of the 124 participants with paraplegia, 87 had complete motor lesions and 37 had incomplete lesions. According to the researchers, completeness of lesion among those who had paraplegia did not have a significant effect on loss of pulmonary function. Completeness of lesion was, however, associated with loss of pulmonary function with tetraplegia. They also found that the longer duration since the onset of injury, the greater the loss of pulmonary function. Study authors concluded that repeated respiratory infections contribute to irreversible loss in pulmonary function, the loss of pulmonary function following respiratory infections are significant, and those patients who are more recently injured will benefit from advances in acute care medical treatment.

**Exercise and Testing**

Dysphagia is a swallowing disorder that may lead to pneumonia and difficulties with eating and communication. Wolf and Meiners (2003) studied dysphagia among 51 patients with spinal cord injury and found that all those with C4 and lower injuries who were treated early utilizing the fiberoptic endoscopic examination of swallowing (FEES) instrument avoided pulmonary complications and were able to successfully terminate the use of artificial respiration. Seventy-five percent of those with sub-C2 injuries were able to cease artificial respiration after treatment. A later study conducted by Chaw, Shem, Castillo, Wong, and Chang (2012) buttressed Wolf and Meiner's argument for early detection of dysphagia. Chaw et al., (2012) examined 68 individuals with tetraplegia and found nearly 31 percent of the sample had dysphagia. Significant risk factors were having a tracheostomy, the use of a ventilator, and having a nasogastric tube. Results yielded no significant difference based on injury level or completeness of injury. Pneumonia was also demonstrated to occur at a higher rate among those with dysphagia than those without. As well, those with dysphagia tended to be admitted to the hospital for a longer length of time than those without dysphagia. Early detection and treatment of dysphagia has thus been shown to be crucial for those with spinal cord injury.

Exercise is recommended for the general population as a means toward good health and is also highly recommended for those with spinal cord injuries. Furusawa, Tajima, Okawa, Takahashi, and Ogata (2007) examined the incidence of upper respiratory tract infection among a small sample of wheelchair marathon racers (N=21) with spinal cord injuries. Upper respiratory tract infections are extremely common among athletes without spinal cord injuries and often occur within the first two weeks after a marathon race. The researchers found that the incidence rate for developing an upper respiratory tract infection within the first two weeks after a marathon for those with spinal cord injury was significantly greater if the athlete trained in excess of 40.4 miles per week. Furusawa et al., recommended that marathon athletes with spinal cord injuries consider the risk that strenuous physical training places on respiratory health, and although beneficial in moderate, may be more damaging if too rigorous.

Higuchi et al., (2006) also examined exercise and its effects on respiratory health among those with spinal cord injury. The researchers compared cardiorespiratory responses during passive walking exercise with those with tetraplegia and non-injured individuals. Seven participants had tetraplegia with complete lesions at the C6-C7 levels. Six individuals comprised the non-injured control group. The authors reported that heart rate and oxygen consumption were similar for those with tetraplegia and those without. However, there was a significantly higher respiratory rate during exercise for those with tetraplegia than the control group, suggesting a greater strain on the respiratory system for those with tetraplegia. Cardiovascular benefits were noted by the authors.

Berlowitz, Brown, Campbell, and Pierce (2005) studied the prevalence of sleep disordered breathing in a small sample (N=13) of individuals with tetraplegia within the first year of injury. The authors followed participants for 52 weeks post-injury. Berlowitz et al., found that sleep disordered breathing began to manifest after two weeks of the cervical injury (60% incidence rate) and at three months post-injury the prevalence rose to 83 percent. The researchers noted that when patients were no longer prescribed sedatives that performed antispasmodically, symptoms of sleep disordered breathing improved. Improvements in symptoms for many participants were noted after six months. Biering-Sørensen, Jennum, and Laub (2009) similarly found in their extensive review of the literature on sleep disordered breathing and spinal cord injury, that sedative use had a negative impact on nocturnal breathing, and this was correlated with level of spinal cord lesion and age (the greater the age, the greater the likelihood of respiratory problems).

Breathlessness was reported to be significantly correlated to level of lesion for those with spinal cord injury by Spungen, Grimm, Lesser, Bauman, and Almenoff (1997). Surveying 180 individuals with spinal cord injury, Spungen and colleagues found that among those with high cervical SCI (C1-C5), 73 percent reported experiencing breathlessness. These numbers fell consistently by level of lesion; 58 percent of those with a C6-C8 injury, 43 percent of those with T1-T7 injury, and 29 percent of those with a T8-L3 injury. Those with high tetraplegia often reported breathlessness when exposed to smoke or hot air and while resting. Spungen et al., also considered whether respondents were current or former smokers, or non-smokers. They found that phlegm and wheezing were more frequently reported among current smokers with paraplegia than their non-smoking counterparts. Among those with tetraplegia, smoking did not appear to significantly impact respiratory complaints in this study.

Respiration control during resting breathing for those with tetraplegia was studied by Spungen, Bauman, Lesser, and McCool (2009). Eighteen individuals of similar characteristics comprised the population sample, ten with tetraplegia and eight with no injury. Those with tetraplegia possessed significantly less inspiratory and expiratory strength, forced expiratory volume, and forced vital capacity than the control group during rest. This is significant in that the results demonstrated that difficulty with respiration occurred for those with tetraplegia at all times, whether at rest or being active.

The reduced ability to ventilate by those with tetraplegia was also demonstrated in a study by Hopman, van der Woude, Dallmeijer, Snoek, and Folgering (1997). Utilizing 15 participants with tetraplegia and 15 individuals with no injury as controls, all participants were similar in age, weight, and physical characteristics. The authors reported static inspiratory and expiratory mouth pressure, inspiratory endurance capacity, and rest oxygen uptake were significantly lower for those with tetraplegia. Hopman, et al. also found that those with tetraplegia were not fully utilizing their capacity to generate inspiratory pressure and attributed this to respiratory dysfunction and greater muscle fatigue. The authors recommended that regular cardiovascular exercise should help those with tetraplegia to increase respiratory muscle strength and endurance.

**Treatment Options**

For those with higher level tetraplegia involving impairment to the phrenic nerve, ventilator dependency and earlier mortality is predominant (Nantwi, 2009). The latest medical advances such as phrenic nerve pacing may relieve some patients from the use of full-time assisted ventilation. Hirschfeld, Exner, Luukkaala, and Baer (2008) reported that the use of phrenic nerve stimulation was associated with lower occurrence of respiratory infection and better quality of speech than mechanical ventilation. The authors studied 64 patients with respiratory complications due to spinal cord injury, 32 who were on mechanical ventilation and 32 using phrenic nerve pacing. They found that although the initial costs of phrenic nerve stimulation is higher than that of mechanical ventilation, pacing's use is recommended as a lower cost option in the long term due to the reduced number of respiratory infections and lower upkeep for the cost of equipment. For those patients who may not be candidates for phrenic nerve pacing alone due to complications with other inspiratory muscles, DiMarco, Takaoka, and Kowalski (2005) found that assistance could be successfully provided by combining phrenic nerve pacing with the stimulation of the intercostal muscles.

Phrenic nerve pacing may also be combined with abdominal binding. Abdominal binding helps support the abdominal wall and organs, which can increase total lung capacity in those with spinal cord injury (Brown et al., 2006). Combining abdominal binding with phrenic nerve pacing was studied by Hoit, Banzett, and Brown (2002). They found that the use of the two in combination increased speech quality and an increase in tidal volume.

Respiratory muscle training for both strength and endurance is another treatment modality for respiratory dysfunction of spinal cord injury. Brown et al., (2006) reported that no training program to date was evaluated to be superior to others. Ehrlich, Manns, and Poulin (1999) assert that respiratory muscle training is not only effective in increasing pulmonary function and respiratory muscle ability, but reduces the number of respiratory infections and financial costs for care.

Advances in treatment options for individuals who are ventilator dependent can also be assisted with a tracheal stoma stent instead of a tracheostomy tube. Hall and Watt (2008) noted increases in survival rates as well as improved quality of life when patients consider the tracheal stoma stent over the tracheostomy tube. These options should be considered in the life care plan for certain patients when planning for their future care with physician recommendation. Tracheostomies are often necessary for those with a C1-C4 spinal cord injury due to inspiratory muscle weakness and rigid chest wall (Hall & Watt, 2008). However, the tubes can cause pain, narrowing of the trachea, ischemic necrosis, and psychological distress due to its appearance. Stents are smaller and have been reported by patients to be more comfortable than tubes (Hall & Watt, 2008).

Pharmacological intervention to stimulate respiration is also being utilized successfully (Nantwi, 2009). Theophylline is a commonly used medication that improves respiration and contralateral phrenic nerve activity. Nantwi (2009) discussed case studies of patients with cervical spinal cord injury for which the medication proved to be beneficial; however, further research must be conducted.

## Summary

A review of current literature revealed varying prevalence rates among studies for respiratory complications for those with cervical lesion spinal cord injuries. Although the prevalence rates are more variable, there does appear to be a number of factors which seemed to consistently facilitate the likelihood of respiratory complications. Specifically, the greater risk of complications as well as morbidity appears to be statistically significant for those who are older, have a higher lesion level and are ventilator dependent , smokers, excessive alcohol users, lack of exercise, history of pneumonia, and low pulmonary and respiratory functioning. Respiratory illnesses also often occurred in tandem with other complications to increase morbidity risk. Possible respiratory complications include respiratory infection, sleep disordered breathing, and breathlessness. Recognizing secondary complications early in treatment has been shown to decrease morbidity and improve clinical outcomes. As well, medical advances are improving quality of life while reducing the rate of respiratory dysfunction. Knowledge and consideration of all available treatment options for acute and chronic spinal cord injury is necessary for those working with this population.

Life care planners in consultation with pulmonary specialists should explore the various treatment options and what may be best regarding future care costs. Various options that may have to be considered in certain cases could include smoking cessation programs, substance use disorder programs, exercise programs and relevant exercise home equipment, regular diagnostic tests on respiratory function, and for those who qualify, phrenic nerve pacing surgery. It appears antibiotics for respiratory infections will have an initial positive impact for some time; however, they lose their effectiveness for treating infections long term due to increased resistance.

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Table 1

*Summary of Respiratory Disease Prevalence Study Results for Persons with SCI*

| Author | Year | n=x | Level of Injury/Lesion | Findings |
|---|---|---|---|---|
| **Chaw et al.** | 2012 | n=68 | 49 high tetraplegia<br>19 low tetraplegia<br>28 complete injury<br>40 incomplete injury | 30.9% of subjects had dysphagia<br>Risk factors: tracheostomy, ventilator, nasogastric tube<br>56% with dysphagia developed pneumonia<br>16.7% without dysphagia developed pneumonia<br>47.9% ± 20.8 days in hospital with dysphagia<br>38.7% ± 17 days in hospital without dysphagia |
| **Watt et al.** | 2011 | n=194 | 44 C1-C2 (9 weaned, 35 ventilated)<br>60 C3-C4 (44 weaned, 16 ventilated)<br>68 C5-C8 (66 weaned, 2 ventilated)<br>22 T1-S5 (20 weaned, 2 ventilated) | Patients weaned off respiratory assistance had on average better survival rate than those using mechanical ventilation or diaphragm pacing<br>Survival rate significantly better for those aged 31-45 weaned off ventilatory support<br>57.1% of cause of death was respiratory illness |
| **Postma et al.** | 2009 | n=140 | 52 tetraplegia<br>88 paraplegia<br>94 complete lesion<br>63 current smokers | 10% had respiratory infection within first year after discharge from hospital<br>Significantly lower pulmonary function in those who had respiratory infection |
| **Spungen et al.** | 2009 | n=18 | 10 tetraplegia<br>8 no injury | Significantly less inspiratory and expiratory strength, forced expiratory volume, and forced vital capacity during resting breathing for those with tetraplegia |
| **Waddimba et al.** | 2009 | n=309 | 87 tetraplegia (complete, grade C)<br>133 paraplegia (complete, grade C) | 22.4% hospital admissions were for respiratory illness<br>Risk factors for hospital admission: higher age, pneumonia after injury, lower BMI, chronic respiratory problems, reduced lung functioning |

| | | | | |
|---|---|---|---|---|
| | | | 89 others, grade D<br>Veterans with injuries ≥1 year old | Reduced risk: higher forced expiratory volume in 1 second<br>Injury level and completeness not statistically significant |
| **Evans et al.** | 2008 | n=226 | 113 tetraplegia<br>103 paraplegia<br>10 unknown<br>Veterans | 6.5% of hospital-acquired infections were respiratory |
| **Furusawa et al.** | 2007 | n=21 | Wheelchair marathon athletes | Significantly higher risk to develop respiratory infection within 2 weeks of marathon if trained over 40.4 miles per week |
| **Berlowitz et al.** | 2005 | n=13 | tetraplegia | After 2 weeks, 60% develop sleep disordered breathing (SDB)<br>After 3 months, 83% develop SDB<br>Removal of sedative medication improved symptoms |
| **Higuchi et al.** | 2006 | n=13 | 7 tetraplegia (complete)<br>6 no injury | No difference in oxygen consumption and heart rate between study and control group during passive walking exercise<br>Significantly higher respiratory rate for those with tetraplegia |
| **Cotton et al.** | 2005 | n=11,080 | 10,484 thoracic or lumbar fracture<br>596 thoracic SCI | Significantly higher risk of intubation, pneumonia, and death for T1—T6 SCI<br>Thoracic SCI 26.7% more likely to die from respiratory complications |
| **Garshick et al.** | 2005 | n=361 | Injured at least one year prior | Respiratory disease at least contributing cause of death in 24% cases<br>Primary cause of death in 5.4% of cases |
| **Wolf & Meiners** | 2003 | n=51 | tetraplegia | Early fiberoptic endoscopic examination of swallowing (FEES) treatment avoided pulmonary complications in C4-lower patients<br>FEES treatment correlated with successful termination of artificial respiration in C4-lower patients<br>FEES treatment accounted for termination of artificial respiration in 75% sub-C2 injuries |
| **Davies & McColl** | 2002 | n=97 | 41 tetraplegia<br>55 paraplegia<br>1 unknown | Over half subjects reported respiratory morbidity<br>70% more likely to have respiratory morbidity if have tetraplegia<br>Alcohol and smoking interaction increases morbidity risk |
| **Linn et al.** | 2000 | n=222 | 98 tetraplegia<br>(62 complete lesion, 26 incomplete)<br>124 paraplegia<br>(87 complete lesion, | Tetraplegia, completeness of lesion associated with pulmonary function loss<br>Paraplegia, pulmonary function loss not associated with completeness of lesion<br>Pulmonary dysfunction correlated with length of injury |

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*Table 1 cont. from pg. 75*

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|---|---|---|---|---|
| | | | 37 incomplete)<br>None dependent on mechanical ventilation | |
| **Hopman et al.** | 1997 | n=30 | 15 tetraplegia<br>15 no injury | Static inspiratory and expiratory mouth pressure, inspiratory endurance capacity, and rest oxygen uptake significantly lower with tetraplegia<br>Those with tetraplegia were not fully utilizing capacity to generate inspiratory pressure<br>Greater muscle weakness and fatigue for those with tetraplegia |
| **Spungen et al.** | 1997 | n=180 | 30 C1-C5 SCI (9 complete lesion, 21 incomplete)<br>57 C6-C8 SCI (11 complete lesion, 46 incomplete)<br>35 T1-T7 SCI (22 complete lesion, 13 incomplete)<br>58 T8-L3 SCI (26 complete lesion, 32 incomplete)<br>60 current smokers | Lesion level correlated with prevalence of breathlessness<br>C1-C5 SCI, 73% report breathlessness<br>C6-C8 SCI, 58% report breathlessness<br>T1-T7 SCI, 43% report breathlessness<br>T8-L3 SCI, 29% report breathlessness<br>Smoking not significant on symptoms among cervical SCI<br>Smoking associated with more phlegm and wheezing for paraplegia |