

# The Effect of Position on Measured Lung Capacity of Patients with Spinal Cord Injury

MYOUNG-KWON KIM, PT, PhD<sup>1)</sup>, GAK HWANGBO, PT, PhD<sup>2)</sup>

<sup>1)</sup> Department of Physical Therapy, Youngsan University: Joonam-dong, Yangsan, Kyeongsangnam-do, San 150, Republic of Korea.

TEL: +82 55-380-9367, FAX: +82 55-380-9305, E-mail: skybird-98@hanmail.net

<sup>2)</sup> Department of Physical Therapy, Daegu University

**Abstract.** [Purpose] To determine whether position affects measured lung capacity of spinal cord injury patients. [Subjects] The study subjects were 45 patients with spinal cord injury (cervical level 15, thoracic level 15, lumbar level 15). Subjects were provided with a full explanation of the experimental procedures and all provided written consent signifying their voluntary participation. [Methods] We used a spirometer (Spirometer, Micromedical Ltd, UK) to measure pulmonary function in the supine and sitting positions (straightened upper body at an angle of 90°). Forced vital capacity (FVC), forced expiratory volume during the first second (FEV1), tidal volume (TV), and maximum insufflation capacity (MIC) were also measured. [Results] FVC, FEV1, TV, MIC (%) were greater in the supine than in the sitting position for those with injury at the cervical or thoracic injury level. On the other hand, FVC, FEV1, TV, MIC (%) were lower in the supine position for those with an injury at the lumbar level. [Conclusion] More attention should be paid to the effect of injury level on measured lung capacity.

**Key words:** Spinal cord injury, Position, Lung capacity

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## INTRODUCTION

It has been suggested that spinal cord injury is perhaps the worst of all survivable traumas<sup>1)</sup>, and of the complications that arise from spinal cord injury, respiratory difficulties are regarded to be the most common cause of mortality and morbidity<sup>2)</sup>. Injury to the spinal cord disrupts the diaphragm, intercostal muscles, accessory respiratory muscles, and abdominal muscles, thereby reducing spirometric and lung volume parameters and static mouth pressures. As a result, patients may have ineffective cough and difficulty clearing secretions, which in turn predisposes to mucus retention, atelectasis, and pulmonary infections, and ultimately significantly increasing the risks of morbidity and mortality<sup>3)</sup>. Mortalities caused by respiratory complications in patients with neuromuscular diseases, especially patients with spinal cord injuries, have reduced, because of recent developments in respiratory care and treatment modalities<sup>4)</sup>. However, although mortality caused by respiratory complications has reduced, time after injury and degree of respiratory muscle weakness are key prognostic factors for patients with spinal cord injury. Therefore, the understanding and assessment of respiratory functional impairment is of the utmost importance during treatment decision making<sup>5)</sup>.

Lechtzin and Wiener<sup>6)</sup> reported that measurements of lung capacity in amyotrophic lateral sclerosis patients in the supine position are a more sensitive indicator of diaphragm function than measurements taken in the sitting position, and Varrato et al.<sup>7)</sup> showed differences in lung capacity rates

measured in the sitting and supine positions provide more sensitive indicator of diaphragm function.

Most studies of spinal cord injury patients have addressed functional improvements achieved through pulmonary rehabilitation, such as electrical stimulation and exercise<sup>8–10)</sup>, but relatively few studies have examined the effect of position on pulmonary measurements of spinal cord injury patients. In the present study, we studied whether position affects measured lung capacity of spinal cord injury patients.

## SUBJECTS AND METHODS

The subjects of this study were 45 patients with spinal cord injury (Table 1). Subjects were provided with a full explanation of the experimental procedure and all provided their written consent signifying voluntary participation. We measured of pulmonary function in the supine and sitting positions (straight upper body at an angle of 90°) using a Bobath table (AKRON Mat Table, AKRON, UK) which is foldable. Measurements were made in triplicate and the maximum values were used in the analysis.

Pulmonary function was measured using a spirometer (Spirometer, Micromedical Ltd, UK). Forced vital capacity (FVC), forced expiratory volume during the first second (FEV1), tidal volume (TV), and maximum insufflation capacity (MIC) were measured. Vital capacity was measured when patients inhaled as deeply as possible and exhaled as slowly as possible, whereas tidal volume was measured during normal breathing. FEV1 was defined as

**Table 1.** Clinical characteristics of subjects

	Cervical	Thoracic	Lumbar
Age (years)	43.2 ± 1.3	49.8 ± 4.9	52.2 ± 4.4
Sex M/F (n)	11/4	10/3	13/4
Height (cm)	174.1 ± 3.3	175.8 ± 2.1	171.2 ± 1.8
Weight (kg)	68.2 ± 3.2	64.3 ± 1.2	65.9 ± 0.9
BMI (score)	22.46 ± 2.2	20.9 ± 1.2	22.23 ± 1.3
Neurological level	C6 (n=7)	T8 (n=4)	L1 (n=2)
	C7 (n=8)	T9 (n=7)	L2 (n=7)
		T12 (n=4)	L5 (n=6)

Cervical : cervical nerve injury between C1~8, Thoracic : Thoracic nerve injury between T1~12, Lumbar : Lumbar nerve injury between L1~5

forced expiratory volume during the first second. Maximum insufflation capacity was measured in the sitting position by adding as much air as possible in a manual resuscitator bag to the air that subjects could inhale by themselves, and measuring the exhalation volume with a spirometer.

Data were analyzed using one-way ANOVA and SPSS Ver. 12.0 for Windows. We used Tukey's measure as a post hoc test. Statistical significance was accepted for p values of <0.05.

## RESULTS

For patients with cervical level injury, mean FVC(%) was 5.13±3.10% higher in the supine position than in the sitting position. For patients with thoracic level injury, mean FVC(%) was 4.20±3.23% higher in the supine position, and for patients with lumbar level injury, FVC(%) was -1.93±1.62% lower in the supine position. Post hoc testing revealed significant differences between the mean FVC(%) values of patients with cervical and lumbar injuries and those with thoracic and lumbar injuries.

For patients with injury at the cervical level, mean FEV1(%) was 5.70±2.44% higher in the supine position than in the sitting position, for patients with a thoracic level injury, mean FEV1(%) was 4.39±2.39% higher in the supine position, and for those with lumbar level injury, mean FEV1(%) was -1.30±1.20% lower in the supine position.

Post hoc testing revealed significant differences between the mean FEV1(%) values of patients with cervical and lumbar injuries and those with thoracic and lumbar injuries.

For patients with cervical level injury, TV(%) was 2.85±1.47% higher in the supine position than in the sitting position, for those with thoracic level injury, mean TV(%) was 3.61±1.90% higher in the supine position, and for those with lumbar level injury, mean TV(%) was -1.64±1.24% lower in the supine position.

Post hoc testing revealed a significant differences between the mean TV(%) values of patients with cervical and lumbar injuries and those with thoracic and lumbar injuries.

For patients with cervical level injury, mean MIC(%) was 4.73±2.00% higher in the supine position, for patients with thoracic level injury, mean MIC(%) was 3.57±1.62% higher in the supine position, and for patients with lumbar level injury, mean MIC(%) was -0.28±0.54% lower in the

supine position.

Post-hoc testing revealed a significant differences between the mean MIC(%) values of patients with cervical and lumbar injuries and a thoracic and lumbar injuries (Table 2).

## DISCUSSION

The aim of this study was to determine the effect of position (supine or sitting position) on pulmonary function test results of spinal cord injury patients. Our results indicate significant differences related to measurement position in the FVC, FEV1, TV, and MIC values of spinal cord injury patients regardless of the location of injury. Specifically, for patients with an injury at the lumbar level, FVC, FEV1, TV, and MIC were all higher in the supine position than in the sitting position, but without statistical significance. During inspiration, with contraction of the diaphragm, the ribs are distended laterally, the upper ribs are distended upwardly, and the chest is raised, whereas during forced inspiration, abdominal muscles, muscles around the spine, and accessory breathing muscles in the cervical and thoracic regions contract. During expiration, which is essentially a passive process, the diaphragm and intercostalis muscles are relaxed, and during forced expiration abdominal muscles play the predominant role. The up-and-down motion of the diaphragm is influenced by changes in position, degree of stomach expansion, and abdominal obesity. The reason why there is a difference between the measured lung capacities of spinal cord injury patients in different patient positions is that when patients with a thoracic level injury exhale lung capacity measured in the sitting position is less than in the supine position, because the dilated lung and thorax shrink passively by recoil, and because the effect of gravity on abdominal contents reduces diaphragm excursion<sup>11, 12).</sup>

In the supine position, internal organs in the abdomen aid motion of the diaphragm, and the lung capacity of normal people is 5% lower than in the sitting position. For normal people in the sitting position, gravity is counteracted by strong abdominal muscles and diaphragmatic contraction increases the activities of the intercostalis; thus, lung capacity is mainly maintained by intercostal motion via contraction of the intercostal inspiratory muscles, the diaphragm, and accessory abdominal muscles. Because the contents of

**Table 2.** Comparison of lung capacities at the three different spinal cord injury levels

	Cervical	Thoracic	Lumbar
FVCsupine (ml)	1676.3 ± 316.5	2026.5 ± 178.7	3104.4 ± 118.6
FVCsitting (ml)	1598.93 ± 320.69	1976.8 ± 209.7	3165.6 ± 108.9
FVC (%)*	5.13 ± 3.10 <sup>a</sup>	4.20 ± 3.23 <sup>a</sup>	-1.93 ± 1.62 <sup>b</sup>
FEV1supine (ml)	1531.0 ± 298.7	1835.0 ± 167.8	2951.8 ± 97.6
FEV1sitting (ml)	1450.8 ± 293.2	1782.4 ± 193.9	2990.5 ± 81.9
FEV1 (%)*	5.70 ± 2.44 <sup>a</sup>	4.39 ± 2.39 <sup>a</sup>	-1.30 ± 1.20 <sup>b</sup>
TVsupine (ml)	562.0 ± 71.4	651.8 ± 134.5	558.4 ± 24.0
TVsitting (ml)	546.8 ± 72.2	628.2 ± 126.5	567.7 ± 22.3
TV (%)*	2.85 ± 1.47 <sup>a</sup>	3.61 ± 1.90 <sup>a</sup>	-1.64 ± 1.24 <sup>b</sup>
MICsupine (ml)	1799.0 ± 296.7	2145.4 ± 186.8	3331.8 ± 307.6
MICsitting (ml)	1720.6 ± 295.2	2088.2 ± 201.6	3340.3 ± 295.7
MIC (%)*	4.73 ± 2.00 <sup>a</sup>	3.57 ± 1.62 <sup>a</sup>	-0.28 ± 0.54 <sup>b</sup>

Cervical: cervical nerve injury between C1~8, Thoracic : Thoracic nerve injury between T1~12, Lumbar: Lumbar nerve injury between L1~5, FVC (%): (forced vital capacity in the supine position – forced vital capacity in the sitting position)/ forced vital capacity in the sitting position \*100, FEV1 (%): (forced expiratory volume in 1 second in the supine position - forced expiratory volume in 1 second in the sitting position) / forced expiratory volume in 1 second in the sitting position \*100, TV (%): (tidal volume in the supine position – tidal volume in the sitting position)/ tidal volume in the sitting position \*100, MIC (%): (maximum insufflation capacity in the supine position - maximum insufflation capacity in sitting position) / maximum insufflation capacity in the sitting position \*100

NOTE. Each value represents the mean ± SE. The values with different superscripts in the same column are different significantly (p<0.05) by Tukey's measure

the abdomen press against the diaphragm in the supine position, lung capacity in the supine position is reduced<sup>13)</sup>. Furthermore, the lung capacities of lumbar spinal cord injury patients in the sitting position has also been reported to be non-significantly higher than those in the supine position<sup>13)</sup>. Respiratory function starts to fall when spinal cord injury is higher than the T12 level, and paralysis of the abdominal and intercostalis muscle increases and respiratory function decreases with extent of injury. All intercostalis and abdominal muscles are paralyzed when the injury level is higher than the C8 level. However, in lumbar spinal cord injury patients, several muscles involved in respiration are not damaged directly, and our subjects didn't have a significant differences in lung capacity, even though lung capacity in the sitting position was higher than that in the supine position. This result is in agreement with that of Allen et al.<sup>14)</sup>, who reported that the lung capacity of normal people in the sitting position is 7.5±5.7% higher than that in the supine position. Our findings indicate that more attention should be paid to the effect of injury level on the measured lung capacity of patients with spinal cord injury.

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