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Respiratory motor function in seated and supine positions in individuals with chronic spinal cord injury

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ABSTRACT

This case-controlled clinical study was undertaken to investigate to what extent pulmonary function in individuals with chronic spinal cord injury (SCI) is affected by posture. Forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), maximal inspiratory pressure (PI_{max}) and maximal expiratory pressure (PE_{max}) were obtained from 27 individuals with chronic motor-complete ($n = 13$, complete group) and motor-incomplete ($n = 14$, incomplete group) C_2–T_{12} SCI in both seated and supine positions. Seated-to-supine changes in spirometrical (FVC and FEV_1) and airway pressure (PI_{max} and PE_{max}) outcome measures had different dynamics when compared in complete and incomplete groups. Patients with motor-complete SCI had tendency to increase spirometrical outcomes in supine position showing significant increase in FVC ($p = .007$), whereas patients in incomplete group exhibited decrease in these values with significant decreases in FEV_1 ($p = .002$). At the same time, the airway pressure values were decreased in supine position in both groups with significant decrease in PE_{max} ($p = .031$) in complete group and significant decrease in PI_{max} ($p = .042$) in incomplete group. In addition, seated-to-supine percent change of PI_{max} was strongly correlated with neurological level of motor-complete SCI ($\rho = -.77$, $p = .002$). These results indicate that postural effects on respiratory performance in patients with SCI can depend on severity and neurological level of SCI, and that these effects differ depending on respiratory tasks. Further studies with adequate sample size are needed to investigate these effects in clinically specific groups and to study the mechanisms of such effects on specific respiratory outcome measures.

1. Introduction

Respiratory dysfunction is a major cause of morbidity and mortality in patients with SCI (Center, 2013; Garshick et al., 2005). Individuals with SCI are also at increased risk of sleep disordered breathing (Burns et al., 2000). Major causes of such dysfunction are respiratory motor control deficits associated with paresis, paralysis and spasticity of trunk and respiratory muscles (Gracies, 2005; Ovechkin et al., 2010; Schilero et al., 2009; Terson de Paleville et al., 2011). In general clinical practice and research the pulmonary function test (PFT) is used to evaluate respiratory motor function. In people with SCI, this test includes spirometrical and maximum airway pressure measures acquired with the test subject in the seated position (American Thoracic Society/European Respiratory Society, 2002; Brusasco et al., 2005; Jain et al., 2006; Miller et al., 2005; Stolzmann et al., 2008). While normative values are corrected for age, height, gender and race, they may also vary depending on body position (Manning et al., 1999; Segizbaeva et al., 2013) and functional capacity of the respiratory muscles (Rehder, 1998). It has been shown that healthy individuals exhibit significantly lower spirometrical and airway pressure outcomes in supine compared to seated position (Badr et al., 2002; Meysman and Vincken, 1998; Navajas et al., 1988; Vilke et al., 2000). It is not clear how postural changes affect respiratory function in individuals with SCI. In contrast to healthy controls, individuals with chronic SCI showed higher FVC and FEV_1 outcomes in supine compared to seated position (Chen et al., 1990; Estenne and De Troyer, 1987; Maeda et al., 1990). However, it has been shown that paraplegic patients with

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Table 1
Characteristics of participants.

Groups		Subjects ($n = 27$)	Sex	Age (yrs)	Height (in.)	Weight (lb)	Smoking	BMI	Level of SCI	AIS category	Time after SCI (mos)
Complete	Cervical	A33	M	51	74	232	–	29.8	C2	AIS-A	36
		A38	F	37	69	113	–	16.7	C4	AIS-A	256
		A41	M	19	72	150	–	20.3	C4	AIS-A	30
		B18	M	46	72	155	–	21.0	C3	AIS-B	241
		B17	M	42	75	217	–	27.1	C5	AIS-B	16
		B12	M	23	75	180	–	22.5	C5	AIS-B	33
		B11	M	23	68	185	–	28.1	C5	AIS-B	75
	Thoracic	A37	M	25	74	115	–	14.8	T3	AIS-A	23
		A35	M	34	73	200	–	26.4	T3	AIS-A	396
		A43	M	30	74	210	†	27.0	T4	AIS-A	11
		A39	M	35	70	175	–	25.1	T5	AIS-A	184
		A46	F	44	62	192	–	35.1	T6	AIS-A	44
		B07	M	22	72	181	–	24.6	T2	AIS-B	35
Incomplete	Cervical	C19	F	59	62	130	–	23.8	C4	AIS-C	38
		C27	M	57	70	190	–	27.3	C4	AIS-C	36
		C26	M	33	72	165	†	22.4	C6	AIS-C	7
		D33	F	60	62	200	–	36.6	C2	AIS-D	26
		D16	M	45	61	200	–	37.8	C3	AIS-D	109
		C23	M	64	71	182	–	25.4	C3	AIS-D	32
		D21	F	22	62	125	–	22.9	C5	AIS-D	72
		D34	M	67	74	212	–	27.2	C6	AIS-D	130
	Thoracic	C16	M	35	72	185	–	25.1	T1	AIS-C	75
		C15	M	53	72	175	–	23.7	T5	AIS-C	262
		C25	M	36	70	195	–	28.0	T11	AIS-C	32
		C24	F	40	68	128	–	19.5	T12	AIS-C	113
		C11	M	30	67	170	–	26.6	T12	AIS-C	15
		D22	M	44	68	130	–	19.8	T4	AIS-D	145
Mean ± SD			N/A	40 ± 14	70 ± 4	174 ± 33	N/A	25.3 ± 5.4	N/A	N/A	92 ± 98

† indicates active smoking.

thoracic SCI can reach higher spirometrical values in seated position (Baydur et al., 2001). The dynamics of the maximum airway pressure measures in response to the seated-to-supine postural change in SCI population are less known. Compared to supine position, individuals with acute tetraplegic injury exhibited higher PE_{max} and PI_{max} outcomes in the semirecumbent position (Alvisi et al., 2012). At the same time, significant seated-to-supine decrease in PE_{max} has been found in the group of patients with motor-complete and incomplete cervical SCI (Sankari et al., 2014). Therefore, since postural factors may have differential impacts in healthy individuals and persons with SCI, it suggests that neurological level and severity of SCI may have complex effects on postural variations in spirometrical and maximum airway pressure measures. This study was undertaken to investigate the impact of postural changes on spirometrical and maximum airway pressure measures in patients with motor-complete and motor-incomplete chronic SCI.

2. Materials and methods

2.1. Neurological assessment

The study was approved by the University of Louisville Institutional Review Board in compliance with all the institutional and federal regulations concerning the ethical use of human volunteers for research studies. Neurological level and clinical severity of the spinal cord lesion were determined using the American Spinal Cord Injury Association Impairment Scale (AIS) according to the International Standards for the Neurological Classification of Spinal Cord Injury (ISNCSCI) (Kirshblum et al., 2011). The ISNCSCI categories were based on the clinical estimation of voluntary contraction strengths from upper-limb (C_5 to T_1) and lower-limb (L_2 to S_1) muscles. Those with AIS-A or AIS-B were classified as motor-complete SCI subjects (complete group) and participants with AIS-C or AIS-D were classified as motor-incomplete SCI subjects (incomplete group). A sensory level of injury was determined by light touch and pin prick for C_2 through S_5 dermatomes (Marino et al., 2003).

2.2. Demographic and Clinical Characteristics

Twenty seven individuals, 40 ± 14 (mean ± SD) years of age, 21 males and 6 females, 92 ± 98 months after SCI participated in this study. Thirteen participants were classified as motor-complete and fourteen were diagnosed as motor-incomplete with cervical ($n = 15$; 7 with motor-complete and 8 with motor-incomplete SCI) or thoracic ($n = 12$; 6 with motor-complete and 6 with motor-incomplete SCI) neurological levels of SCI ranging from C_2 to T_{12} (Table 1).

2.3. Pulmonary function test (PFT)

The participants have been tested in the afternoon when their morning routines were restricted to exclude the consumption of caffeine and alcohol and withholding from smoking. Participants have been asked to empty their bladder before testing. Standard spirometrical and maximum airway pressure measurements were taken in the seated and supine positions during every recording session. First, spirometry and airway pressure assessments have been performed in the seated position and then, after 30-min period, had been repeated in the supine position. FVC and FEV_1 were obtained from the best of three acceptable attempts and were expressed as the percent of a predicted value (American Thoracic Society/European Respiratory Society, 2002; Hankinson et al., 1999; Hart et al., 2005). PE_{max} and PI_{max} were assessed using MP45-36-871-350 differential pressure transducer (Validyne Engineering, Northridge, CA) with graphical representation visible during recording. The PI_{max} was measured during maximal inspiratory effort beginning at residual volume and PE_{max} was measured during maximal expiratory effort starting from total lung capacity (American Thoracic Society/European Respiratory Society, 2002)