Comparison of Resistance and Sham Training of Expiratory Muscles on Pulmonary Functions in Patients with Spinal Cord Injury: An Interventional Study

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Abstract— *Respiratory complications are major sources of morbidity and mortality in spinal cord injury (SCI). Improvement in expiratory muscle strength may be associated with improved cough and clearance of secretions. So that expiratory muscle training are advised in SCI cases to improve expiratory muscle strength. This study was conducted to compare the effect of Resistance and Sham training on pulmonary function test in spinal cord injury cases. It was found the mean value of all the parameters of PFT of Sham training was found to increase from baseline to 1st and 2nd follow up. This difference was found significant in all the parameters of PFT at 2nd follow up, but FEV_1 and PIFR of 1st follow up (p value < 0.05) only. Likewise, it is also observed that the mean value of all the parameters of PFT of test group was found to increase from baseline to 1st and 2nd follow up. This difference was found highly significant (p value <0.001) in all the parameters of PFT at 1st and 2nd follow up. So it can be concluded that however both the type of training improve PFTs but the improvement of high resistance training was significantly more than they were for sham training.*

Keywords: Spinal Cord Injury (SCI), Pulmonary Function Test, Resistance Training and Sham training.

I. INTRODUCTION

Respiratory complication are major sources of morbidity and mortality in both the acute and chronic phases of spinal cord injury (SCI)[1,2,3,4] with an incidence of 36% to 83%. In patients with tetraplegia, weakness of the accessory muscles of breathing along with decreased lung and chest wall compliance severely decrease respiratory efficiency. Weak inspiratory muscles impair the ability of the patient with tetraplegia to take a deep breath, causing atelectasis and a higher risk of developing pneumonia.[2] Weakness of expiratory muscles impairs the ability of the patient with tetraplegia to cough and successfully clear respiratory secretions.[2] This also predisposes patients with tetraplegia to developing atelectasis, pneumonia, and ultimately an increased risk of early mortality.[3]

The degree of respiratory dysfunction is related to the extent and level of the neurological injury in such a way that high cervical and thoracic injuries are at the highest risk. The degree of expiratory muscle weakness can be assessed by using spirometry. Recent large cross-sectional studies evaluating pulmonary function in SCI have shown that force vital capacity (FVC) and force expiratory volume in 1 sec (FEV_1), as measures of maximum inspiration, decrease linearly with higher levels of SCI, and are worst with high cervical tetraplegia.[1,5,6] Peak expiratory flow rate (PEFR), which is thought to be

indicative of cough strength, has also been shown to decrease with higher SCI levels.[7] The PEFR has been found to be more dramatically reduced at higher levels of injury than FVC or FEV_1. This may indicate that the impairment of effective cough and expiration contributes to the development of respiratory complications.[1,8]

It has been posited that improved expiratory muscle strength after expiratory muscle training may be associated with improved cough and clearance of secretions. The decreased end expiratory lung volume resulting from a stronger exhalation also increases vital capacity.[8] Given the role of ineffective cough in increasing the risk of pneumonia and early death after high SCI, it is important to find optimal means to increase the efficacy of cough. Targeted resistance training of expiratory muscles offers a relatively easy and inexpensive method to enhance cough.

So this study was planned with the aim to compare the effect of resistance and sham training on pulmonary functions in spinal cord injury cases.

II. METHODOLOGY

A hospital based randomized comparative interventional study was carried out on acute spinal cord injury (APCI) ASIA Grade A or B at or above T1 cases admitted in the department of Physical Medicine and Rehabilitation, SMS Medical College and attached Hospital, Jaipur.

ASIA Grade A or B at or above T1 18-60 year aged acute cervical spinal cord injury (SCI) cases admitted in the department of Physical Medicine and Rehabilitation were included in this study. Cases having with rib fracture, tracheostomy, head injury, cardio-respiratory, active pulmonary infections, pre-injury history of pulmonary diseases or respiratory symptoms and abdominal problems were excluded from study.

After taking written informed consent from eligible 64 cases of acute cervical spinal cord injury (SCI), the detailed medical history with desired bio-socio-demographic information consisted of comprehensive medical history including age, sex, education, employment, smoking history, etiology and level of injury was inquired from each of the eligible subject. These subjects were randomized (computer generated) into either experimental (Resistance Training) or control (Sham Training) group at the time of enrolment. Neurologic assessment and determination of the level were done according to the American Spinal Injury Association (ASIA) Impairment Scale.

(http://www.sci-info-pages.com/levels.html) Each subject underwent baseline pulmonary function testing (PFT). PFT were performed in supine position by using portable spirometer. 3 trials were performed and the maximum of the 3 attempts was recorded. Initiation of respiratory muscle training included proper instruction on the proper use of the breathing device. Resistance training group uses devices with a small aperture, which creates resistance to expiration. Sham training group use a device with an open gauge without added respiratory resistance. Each subject was assigned exercises 15 minutes per day and seven days a week. PFT using spirometer was repeated after 1 and 3 months. FVC, FEV_1, PIFR and PEFR were recorded in spirogram together while Cough Peak Expiratory Flow Rate

(CPEFR) was recorded by asking patient to cough while measuring for PEFR using same spirometer in separate spirogram. All the information gathered was collected in predesigned semi-structured schedule.

Data thus collected were entered in MS Excel worksheet 2007 as master chart. Qualitative data were expressed in proportions and percentage and quantitative data were expressed in mean ± SD. Significance of difference in proportion was inferred by Chi-square test and significance of difference in means values of both groups was inferred by Unpaired 't' Test. For significance p value less than 0.05 was considered significant.

III. RESULTS

Eighty patients with acute spinal cord injury were recruited initially from May 2015 to Nov 2016. Only sixty-four patients completed the study, out of which 32 were in Sham training group and 32 in Resistance training group.

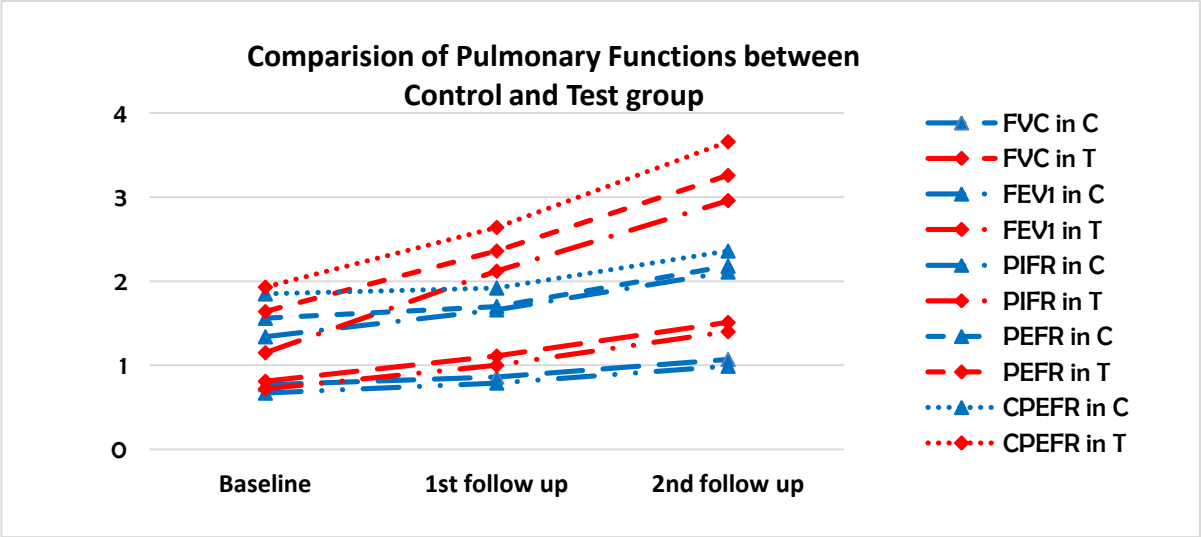
Both i.e. Resistance training (experimental) group and Sham training (Control) group were comparable in age, sex, educational status, smoking status, neurological level and spasticity. (Table 1)

Table 1
Comparison of Baseline characteristics of experimental and control group

Characteristics		Group C (N=32)	Group E (N=32)	Significance
Age (in Years) Mean ± SD		35.59 ± 11.89	34.62 ± 10.93	0.736 NS
Sex	**Male**	27 (84.4%)	27 (84.4%)	P = 0.731; NS
	Female	5 (15.6%)	5 (15.6%)	
Neurological Level	**C4**	21 (65.6%)	17 (53.1%)	P = 0.235; NS
	C5	6 (18.8%)	11 (34.4%)	
	C6	4 (12.5%)	2 (6.3%)	
	C7-T1	1 (3.1%)	2 (6.3%)	
Smoking	**Yes**	25 (56.3%)	15 (46.9%)	P = 0.617; NS
	No	7 (43.8%)	17 (53.1%)	
Education	**Literate**	20 (62.5%)	25 (78.1%)	P = 0.274; NS
	Illiterate	12 (37.5%)	7 (21.9%)	
Spasticity	**Yes**	24 (75%)	19 (59.4%)	P = 0.287; NS
	No	8 (25%)	13 (40.6%)	

It is observed from this study that the mean value of all the parameters of PFT of control group was found to increase from baseline to 1st and 2nd follow up. This difference was found significant in all the parameters of PFT at 2nd follow up, but FEV_1 and PIFR of 1st follow up (p value < 0.05) only. Likewise, it is also observed that the mean value of all the parameters of PFT of test group was found to increase from baseline to 1st and 2nd follow up. This difference was found highly significant (p value <0.001) in all the parameters of PFT at 1st and 2nd follow up. (Figure 1)

Figure 1
Comparison of Pulmonary Function Test between Experimental and Control group



It is revealed from the table no. 2 that the mean change in all the studied parameters of PFT at both follow ups were significantly more in the Experimental group than that of control group but more significant improvement in CPEFR and PEFR variable of PFT in test group in both 1st and 2nd follow up.

Table 2
Comparison of Mean Change in Pulmonary Functions between Control and Experimental group

Parameter	Change in PFT at 1st follow up			Change in PFT at 2nd follow up		
	Experimental	Control	P value*	Experimental	Control	P value*
FVC (L)	0.30 ± 0.32	0.09 ± 0.26	0.002	0.70 ± 0.33	0.30 ± 0.31	<0.001
FEV_1 (L)	0.27 ± 0.20	0.13 ± 0.29	0.014	0.68 ± 0.26	0.32 ± 0.4	<0.001
PIFR (L/S)	0.67 ± 0.52	0.32 ± 0.50	0.003	1.50 ± 0.63	0.77 ± 0.66	<0.001
PEFR (L/S)	0.72 ± 0.43	0.21 ± 0.62	<0.001	1.61 ± 0.65	0.67 ± 0.93	<0.001
CPEFR (L/S)	0.71 ± 0.48	0.13 ± 0.59	<0.001	1.73 ± 0.69	0.58 ± 0.83	<0.001

***Unpaired 't' Test**

IV. DISCUSSION

Spinal cord injury is a central neurological disorder.[9] Besides paralysis of lower and/or upper limbs, spinal cord injury may also affect respiratory function and may result in chronic respiratory insufficiency.[10] Alterations in mechanical properties of the lung and of the chest wall results in decreased ability to sigh, ineffective coughing and development of mucus hypersecretion will result in inadequate clearance of mucus. [11]

Sixty percent of persons in present study were in the age group of 21 to 40 years, almost in line observations were of Kristinsdottir EA et al.,[12] Chen Y et al.,[13] and Wang H et al.[14] suggesting spinal cord injury is common among young adult. Male to female ratio in present study were 5:1 in both the group and Yang R et al.[15] found this ratio 3.5:1. Similar result was observed by Wu Q et al.[16] and Kristinsdottir EA et al.[12] Around sixty percent of person were C4 neurological level followed by C5 level suggesting that injury is common in higher cervical region.

In present study, there was improvement in FVC value in both group at the end of 1 month and 3 month, however, the improvement was higher among resistance training group. This indicates that respiratory

resistance training has the added potential as compared to sham training, to improve the overall ventilatory function in patient with acute spinal cord injury. Derrickson,[17] Gounden P et al.[18] and Liaw et al.[19] also observed greater improvement in VC for resistance group than control. Mueller G et al.[20] observed that forced vital capacity significantly increased. However, Roth et al.[25] found FVC improved in both groups. The fact that both group showed improvement may be because the study was conducted during the acute phase of SCI, which means that some of the improvement may have resulted from the natural recovery of ventilatory muscle function.

There was improvement in FEV_1 value in both group at the end of 1 month and 3 month. However, the improvement was higher among resistance training group. Mueller G et al.[20] also observed that forced expiratory volume in one second significantly increased among intervention group. Roth et al.[21] noted FEV_1 improvement in both groups.

In present study, there was improvement in the value of PIFR in both the groups at the end of 1 month and 3 months. However, the resistance training groups have greater benefit from the intervention. Joshi M et al.[22] also found significant improvement in peak inspiratory mouth pressure (PIMP) among resistance training group.

Peak expiratory flow (PEF) is the maximal flow achieved during the maximally forced expiration initiated at full inspiration. In present study, there was significant improvement in the PEFR in the resistance training group. Joshi M et al.[22] also found significant improvement in peak expiratory mouth pressure (PEMP) among resistance training group. Derrickson,[17] noted significant improvements for both groups in PEFR. Mueller et al found significant improvement in PEFR among RT group as compared to placebo. Gounden P.[18] observed significant improvements in maximal expiratory pressure (MEP) for the intervention group only.

Cough Peak Expiratory Flow Rate (CPEFR) is a measure of cough function when peak expiratory effort is done with effort of coughing. Fujiwara T et al.[23] noticed that some accessory expiratory muscles were activated during coughing in tetraplegics. They showed that peak expiratory flow rate and maximal expiratory mouth pressure were correlated with neurological level and concluded that these muscles were activated as accessory expiratory muscles and play an important role in expiratory function in tetraplegic patients. Joshi M et al.[22] also found CPEFR as a valuable measure of cough function. They noted significant improvement in CPEFR among resistance training group which was similar to this study.

V. CONCLUSION

It can be concluded that from present study that expiratory resistance breathing exercises using a simple handheld breathing training device have the potential to improve most of the measures of ventilatory function in people with tetraplegia. Sham training, which used a substantially lower level of resistance, also resulted in some improvements in pulmonary function. However, the improvement of high resistance training was significantly more than they were for sham training. The systematic repeated use of a simple respiratory muscle training device training has the potential to increase the strength of respiratory muscle, more so in PIFR, PEFR and CPEFR of pulmonary function. This may reduce the occurrence of respiratory complications related morbidity and improve outcomes.

CONFLICT OF INTEREST

None declared till now.

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