International Journal of Research in Medical Sciences
Thorat KD et al. Int J Res Med Sci. 2024 Jul;12(7):2390-2397
www.msjonline.org
pISSN 2320-6071 | eISSN 2320-6012

DOI: https://dx.doi.org/10.18203/2320-6012.ijrms20241888

Original Research Article

Effectiveness of respiratory proprioceptive neuromuscular facilitation technique on pulmonary function in spinal cord injury patients: a randomized controlled trial

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Received: 25 April 2024
Accepted: 05 June 2024

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ABSTRACT

Background: Spinal cord injury (SCI) often leads to respiratory complications due to impaired neuromuscular control. Proprioceptive neuromuscular facilitation (PNF) techniques have shown promise in improving respiratory function in various populations, but their effectiveness in SCI patients remains underexplored. This study aimed to investigate the effectiveness of respiratory PNF techniques on pulmonary function in individuals with SCI.
Methods: A randomized controlled trial was conducted involving SCI patients with respiratory impairment. A total of 43 participants were included in this study. The study duration was 4 years with an intervention period of 4 weeks and the outcome measures were pulmonary functions and chest expansion using inch tape.
Results: There was a significant improvement in pulmonary functions in the control group and a highly significant improvement in pulmonary functions in the experimental group after 4 weeks of interventions and chest expansion was significantly improved in the experimental group.
Conclusions: The respiratory PNF techniques demonstrated a clinically meaningful enhancement in pulmonary function and chest mobility among SCI patients. Respiratory PNF techniques represent a valuable adjunct therapy for improving pulmonary function and chest mobility in individuals with SCI.

Keywords: Forced expiratory volume, Forced vital capacity, Peak expiratory flow rate, Respiratory proprioceptive neuromuscular facilitation technique, Spinal cord injury

INTRODUCTION

Spinal cord injury (SCI) is a life threatening condition that carries a high risk of morbidity and mortality The causes of TSCI in the world are traffic accidents, gunshot injuries, knife injuries, falls and sports injuries.[1]

The incidence of SCI varies from 9.2 to 56.1 per million, which is influenced not only by research methodology but also by social, economic, geographical, demographic and political characteristics of the region. In the Indian setup, as in most developing countries, very little is known about the exact incidence of SCI. Approximate 20,000 new cases of SCI are added every year.[2]

The most obvious consequence of SCI is paralysis. People with SCI are at increased risk of chronic respiratory symptoms, added disability, and early death from respiratory complications where respiratory function following a SCI is primarily determined by the extent and level of neurological injury, due to the partial or complete paralysis of respiratory muscles innervated below the neurological level of injury.[6]

Respiratory muscle paralysis both restricts maximum inflation of the lungs and impairs the ability to cough, leading to increased risk of atelectasis and retained mucus secretions. Obstructive pulmonary dysfunction is also of concern, not only because airways may collapse or be clogged by mucus, but also because they may be especially susceptible to constriction. Injury to the cervical and upper thoracic spinal cord disrupts function of inspiratory and expiratory muscles, as reflected by reduction in spirometric and lung volume parameters and static mouth pressures. In association, subjects with tetraplegia have decreased chest wall and lung compliance, increased abdominal wall compliance, and rib cage stiffness with paradoxical chest wall movements, all of which contribute to an increase in the work of breathing. Expiratory muscle function is more compromised than inspiratory muscle function among subjects with tetraplegia and high paraplegia, which can result in ineffective cough and propensity to mucus retention and atelectasis. Subjects with tetraplegia also demonstrate heightened vagal activity with reduction in baseline airway caliber, findings attributed to loss of sympathetic innervation to the lungs.[7,8]

Alterations in respiratory function following SCI include: Reduction in lung capacity, Impaired ability to cough, Altered breathing pattern, Imbalance in Autonomic Nervous System following a SCI above the level of T6, with relative bronchoconstriction (airway narrowing) and increased secretion production and chronic secondary changes including reduction in lung and chest wall compliance (flexibility).[8]

There is a high incidence of respiratory complications following SCI, which are one of the leading causes of hospital readmission and mortality. Common respiratory complications include atelectasis (segmental lung collapse), pneumonia and respiratory failure. Respiratory muscle strength and endurance can be improved by various breathing exercises such as respiratory muscle training, pursed lip breathing and diaphragmatic breathing.[8-10]

The management of an individual with SCI is complex and lifelong requiring a multidisciplinary approach.[11] Proprioceptive neuromuscular facilitation techniques (PNF) consist of intercostal stretch, vertebral pressure to thoracic spine, anterior stretch and posterior basal lift and abdominal co-contraction. This Proprioceptive and tactile stimuli produce remarkably consistant reflexive responses in ventilatory muscles.[12]

Inspiratory expansion of ribs, increased diaphragmatic excursion visibly increased and palpably tone in abdominal muscles facilitation of contraction of intercostal muscles facilitation and activation diaphragm and change in respiratory rate are the responses observed. Few authors also conclude that it improves the chest wall mobility, chest expansion and breathing pattern in neurological patients through the stretch reflex mechanism. Majority of these responses to these stimuli are mediated by muscle stretch receptors via. dorsal roots and inter segmental reflexes.[13]

A study conducted by Dietz indicated that muscle strength can be improved using three-dimensional spiral large scale resistive exercises using PNF. Respiratory muscles have mechanoreceptors which have function of central control of breathing. The muscle spindle endings and tendon organs are considered to be the primary receptors.[13] Most of the studies that have been conducted on the effect of Respiratory PNF on pulmonary function include stroke patients. Few studies have shown that respiratory PNF prevents pulmonary complications after any neurological damage involving respiratory functions.

Hence the purpose of the study was to find the effect of respiratory proprioceptive neuromuscular facilitation technique on pulmonary function and chest expansion in spinal cord injury patients. Objectives of the study were to see the effect of respiratory PNF on pulmonary functions (FVC,FEV1 and PEFR) and chest expansion in patients with spinal cord injury.

METHODS

Patient data was collected from the inpatient ward of Smt. Sindhutai E. Vikhe Patil Spinal Cord Injury Rehab Centre of Pravara Rural Hospital, Loni, Maharashtra. The study design was a randomized controlled trial with a sample size of 43 which was calculated from open EPI software. Patients with a clinical diagnosis of SCI were included in this study and study duration of this study was from Jan 2020 to Dec 2023 for 4 years.

Inclusion criteria

Patients with cervical and thoracic level SCI aged between 20 to 60 years were included in this study.

Exclusion criteria

Non-traumatic SCI, patients who are hemodynamically unstable, K/C/O respiratory disease, associated neurological condition chest trauma and rib fracture were excluded from this study.

Equipment used for this study was a pulmonary function test machine (Spirometer-Helios 401) and inch tape to check chest expansion.

Outcome measures

The pulmonary function test was used to measure forced vital capacity (FVC), forced expiratory volume in one second (FEV1), and peak expiratory flow rate. The inch tape was used to assess the chest expansion.

Study groups

Group A total of 43 patients in the study were randomized into 2 groups: Group A (Control group) consisted of 21 patients treated with conventional respiratory physiotherapy management (glossopharyngeal breathing, diaphragmatic breathing, balloon blowing exercises, inspiratory muscle training, chest mobility exercises strengthening exercises, balance training, gait training).

Group B (Experimental group) consists of 22 patients treated with the same conventional respiratory physiotherapy along with respiratory PNF techniques.

Interventions

Respiratory PNF technique protocol (intercostal stretch, posterior basal lift, abdominal co-contraction) 10-12 repetitions of each technique in 1 set (1 min rest after 5-6 repetitions) 5 sets in one session, 1 sessions in a day, 6 days/week for 4 weeks.

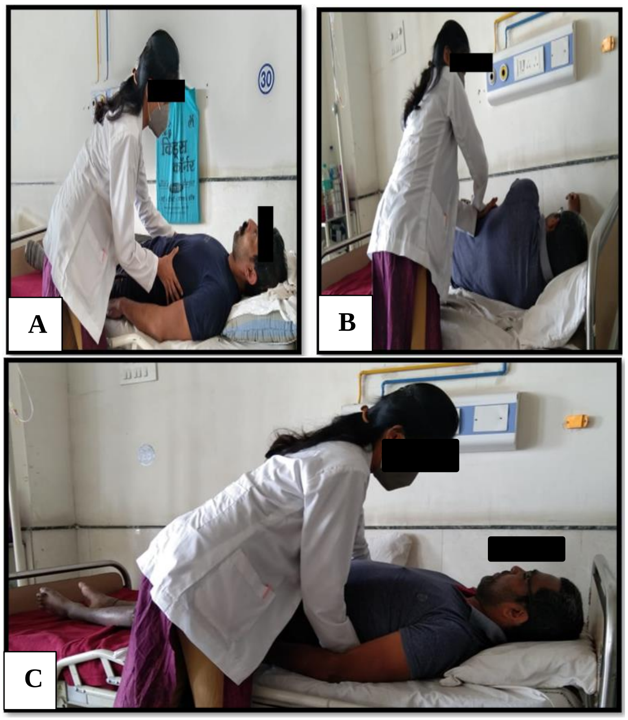

Figure 1: Patient receiving respiratory proprioceptive neuromuscular facilitation techniques. (A) Respiratory PNF technique (Intercostal Stretch); (B) Abdominal co-contraction; (C) Posterior basal lift.

Data analysis

Statistical analysis was carried out utilizing the software version of SPSS 27.0 and Graph Pad Prism 7.0 and $p<0.05$ is considered as level of significance. Statistical measures such as mean, standard deviation (SD) was calculated and Student's Paired 't' test and unpaired 't' test was applied to analyse the data. The results were concluded to be statistically significant with $p<0.05$.

RESULTS

In the present study, 43 (39 male and 4 female) participants were included after fulfilling the inclusion and exclusion criteria. Participants were randomly assigned into two groups. Twenty-one participants were included in control group, in which 18 were male (86%) and 3 were female (14%). Twenty-two participants were included in experimental group, in which 21 were male (95%) and 1 female (5%). All the 43 patients completed 4 weeks of intervention. There were no statistical differences in terms of physical characteristics, anthropometrics and physiological data between participants.

Baseline comparisons

All the participants completed both pre and post-test measurements. There was borderline significant difference between the groups before the starting of the intervention in terms of pulmonary functions and chest expansion between the groups.

Table 1: Age and gender wise distribution of patients of both groups.

Groups age	Group A (n=21)	Group B (n=22)	t-value	p-value
Mean	37.94	36.36	0.53	0.59, p>0.05 not significant
SD	9.23	10.24		

Pulmonary functions

Forced expiratory volume in one second (FEV_1)

The pre intervention mean value of FEV_1 in participants of control group was 1.44±0.34 Liters and 55.47±12.17of percentage of predicted and after 4 weeks mean value of FEV_1 was 1.54±0.37 Liters and 59.33±11.01 of % predicted. The difference between the pre and post values of FEV1in control group was 0.10 Liters and 3.85±4.12 of % predicted which shows statistically significant difference after 4 weeks of treatment in control group.

Before the intervention of the mean value of FEV_1 in participants of experimental group was 1.25±0.27 Liters and 47.63±9.40 of percentage of predicted and after 4 weeks of intervention mean value of FEV_1 was 1.54±0.30 Liters and 58.50±9.10 of % predicted. The difference between the pre and post values of FEV_1 in experimental group was 0.28 Liters and 10.86 of % predicted which shows statistically highly significant difference after 4 weeks of treatment in experimental group (Table 3).

Forced vital capacity (FVC)

The pre intervention mean value of FVC in participants of control group was 1.44±0.34 Liters and 45.76±9.86 of percentage of predicted and after 4 weeks mean value of FVC was 1.54±0.37Liters and 49.14±9.31of % predicted. The difference between the pre and post values of FVC in control group was 0.10 Liters and 3.38 of % predicted which shows statistically significant difference after 4 weeks of treatment in control group.

Before the intervention of the mean value of FVC in participants of experimental group was 1.27±0.26 Liters and 39.90±7.93 of % predicted and after 4 weeks of intervention mean value of FVC was 1.57±0.28Liters and 49.18±8.69of % predicted. The difference between the pre and post values of FVC in experimental group was 0.30 Liters and 9.27 of % predicted which shows statistically highly significant difference after 4 weeks of treatment in experimental group.

Peak Expiratory Flow Rate: (PEFR)

The pre intervention mean value of PEFR in participants of control group was 3.69±1.25 Liters and 43.95±13.97of percentage of predicted and after 4 weeks mean value of PEFR was 4.25±1.51 Liters and 50.42±16.26 of % predicted. The difference between the pre and post values of PEFR in control group was 0.56 Liters and 6.47of % predicted which shows statistically significant difference after 4 weeks of treatment in control group.

Before the intervention of the mean value of PEFR in participants of experimental group was 3.19±1.12 Liters and 37.59±11.07 of percentage of predicted and after 4 weeks of intervention mean value of PEFR was 4.27±1.06 Liters and 48.77±9.96 of % predicted. The difference between the pre and post values of PEFR in experimental group was 1.07 l and 11.18 of % predicted which shows statistically highly significant difference after 4 weeks of treatment in experimental group.

Table 2: Baseline comparison of pulmonary functions and chest expansion of both the groups.

Group parameters		Group A (n=21) Mean±SD	Group B (n=22) Mean±SD	T value	P value	
FEV1	Liters	1.44±0.34	1.25±0.27	1.98	0.05	significant
	Pred %	55.47±12.17	47.63±9.40	2.37	0.023	significant
FVC	Liters	1.44±0.34	1.27±0.26	1.81	0.077	not significant
	Pred %	45.76±9.86	39.90±7.93	2.14	0.034	significant
PEFR	Liters	3.69±1.25	3.19±1.12	1.36	0.18	not significant
	Pred %	43.95±13.97	37.59±11.07	1.65	0.10	not significant
Chest expansion (SN)		1.10±0.15	1.32±0.18	4.12	0.0001	significant
(XP)		1.10±0.15	1.33±0.19	4.18	0.0001	significant
(T8 level)		1.56±0.09	1.59±0.16	0.60	0.54	not significant

Table 3: Pre-post comparison of pulmonary functions and chest expansion of group A.

Group parameters		Pre-test, Mean±SD	Post test, Mean±SD	Mean difference	T value	P value, p<0.05 significant
FEV1	**Liters**	1.44±0.34	1.54±0.37	0.10±0.11	3.87	0.01,p<0.05 significant
	Pred %	55.47±12.17	59.33±11.01	3.85±4.12	4.28	0.01,p<0.05 significant
FVC	**Liters**	1.44±0.34	1.54±0.37	0.10±0.11	3.87	0.01,p<0.05 significant
	Pred %	45.76±9.86	49.14±9.31	3.38±3.33	4.64	0.01,p<0.05 significant
PEFR	**Liters**	3.69±1.25	4.25±1.51	0.56±0.66	3.88	0.01,p<0.05 significant
	Pred %	43.95±13.97	50.42±16.26	6.47±7.54	3.93	0.01,p<0.05 significant
Chest expansion (SN)		1.10±0.15	1.31±0.23	0.20±0.10	8.80	0.01,p<0.05 significant
(XP)		1.10±0.15	1.31±0.23	0.20±0.10	8.80	0.01,p<0.05 significant
(T8 level)		1.56±0.09	1.86±0.12	0.30±0.04	30.74	0.01,p<0.05 significant

Chest expansion measurement

a) At Sternal Notch: The pre intervention mean value of chest expansion at sternal notch (SN) in participants of control group was 1.10±0.15 cms and after 4 weeks mean value of chest expansion at SN was 1.31±0.23 cm. The difference between the pre and post values of chest expansion at SN in control group was 0.20 cm which shows statistically significant difference after 4 weeks of treatment in control group.

Before the intervention mean value of chest expansion at sternal notch (SN)in participants of experimental group was 1.32±0.18 cms and after 4 weeks mean value of chest expansion at SN was 1.93±0.11 cms. The difference between the pre and post values of chest expansion at SN in experimental group was 0.60 cms which shows statistically highly significant difference after 4 weeks of treatment in experimental group.

b) At Xiphoid Process: The pre intervention mean value of chest expansion at Xiphoid process (XP) in participants of control group was 1.10±0.15 cms and after 4 weeks mean value of chest expansion at XP was 1.31±0.23 cms. The difference between the pre and post values of chest expansion at XP in control group was 0.20 cms which shows statistically significant difference after 4 weeks of treatment in control group.

Before the intervention mean value of chest expansion at Xiphoid process (XP) in participants of experimental group was 1.33±0.19 cms and after 4 weeks mean value of chest expansion at XP was 1.93±0.11 cms. The difference between the pre and post values of chest expansion at XP in experimental group was 0.60 cms which shows statistically highly significant difference after 4 weeks of treatment in experimental group.

c) At T8 Vertebral level: The pre intervention mean value of chest expansion at T8 vertebral level (T8) in participants of control group was 1.56±0.09 cms and after 4 weeks mean value of chest expansion at T8 was 1.86±0.12 cms. The difference between the pre and post values of chest expansion at T8 in control group was 0.30 cms which shows statistically significant difference after 4 weeks of treatment in control group.

Before the intervention mean value of chest expansion at T8 vertebral level (T8) in participants of experimental group was 1.59±0.16 cms and after 4 weeks mean value of chest expansion at T8 was 2.06±0.08 cms. The difference between the pre and post values of chest expansion at T8 in experimental group was 0.47 cms which shows statistically highly significant difference after 4 weeks of treatment in experimental group.

Student's unpaired 't' test was used to compare the control group and the experimental group revealing that there was a statistically highly significant difference (p=0.0001) in FEV1, FVC and the PEFR in liters and percentages predicted and in the chest expansion between two groups. Results of this study indicated that pulmonary functions and chest expansion were more improved in Group B compared to Group A.

Table 4: Pre-post comparison of pulmonary functions and chest expansion of group B.

Group parameters		Pre-test, Mean±SD	Post test, Mean±SD	Mean difference	T value	P value, p<0.05 significant
FEV1	**Liters**	1.25±0.27	1.54±0.30	0.28±0.10	12.95	0.0001, p<0.05 highly significant
	Pred %	47.63±9.40	58.50±9.10	10.86±3.80	13.37	0.0001, p<0.05 highly significant
FVC	**Liters**	1.27±0.26	1.57±0.28	0.30±0.10	13.10	0.0001, p<0.05 highly significant
	Pred %	39.90±7.93	49.18±8.69	9.27±2.89	15	0.0001, p<0.05 highly significant
PEFR	**Liters**	3.19±1.12	4.27±1.06	1.07±0.31	16.21	0.0001, p<0.05 highly significant
	Pred %	37.59±11.07	48.77±9.96	11.18±3.30	15.87	0.0001, p<0.05 highly significant
Chest expansion (SN)		1.32±0.18	1.93±0.11	0.60±0.17	15.89	0.0001, p<0.05 highly significant
(XP)		1.33±0.19	1.93±0.11	0.60±0.18	15.64	0.0001, p<0.05 highly significant
(T8 level)		1.59±0.16	2.06±0.08	0.47±0.17	12.64	0.0001, p<0.05 highly significant

Table 5: Mean difference (between group) comparison of pulmonary functions and chest expansion of both group.

Group parameters		Group A, mean difference	Group B, mean difference	T value	P value, pp<0.05 Significant
FEV1	**Liters**	0.10±0.11	0.28±0.10	5.49	0.0001, p<0.05 highly significant
	Pred %	3.85±4.12	10.86±3.80	5.79	0.0001, p<0.05 highly significant
FVC	**Liters**	0.10±0.11	0.30±0.10	5.90	0.0001, p<0.05 highly significant
	Pred %	3.38±3.33	9.27±2.89	9.18	0.0001, p<0.05 highly significant
PEFR	**Liters**	0.56±0.66	1.07±0.31	3.28	0.002, p<0.05 highly significant
	Pred %	6.47±7.54	11.18±3.30	2.67	0.011, p<0.05 significant
Chest expansion (SN)		0.20±0.10	0.60±0.17	8.76	0.0001, p<0.05 highly significant
(XP)		0.20±0.10	0.60±0.18	8.60	0.0001, p<0.05 highly significant
(T8 level)		0.30±0.04	0.47±0.17	4.45	0.0001, p<0.05 highly significant

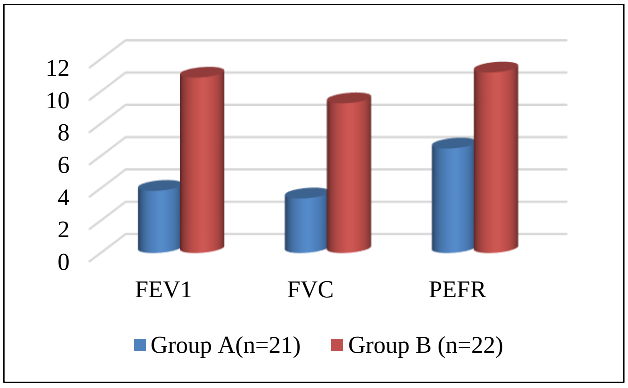

Figure 2: Mean difference comparison of pulmonary functions (% pred) of both groups.

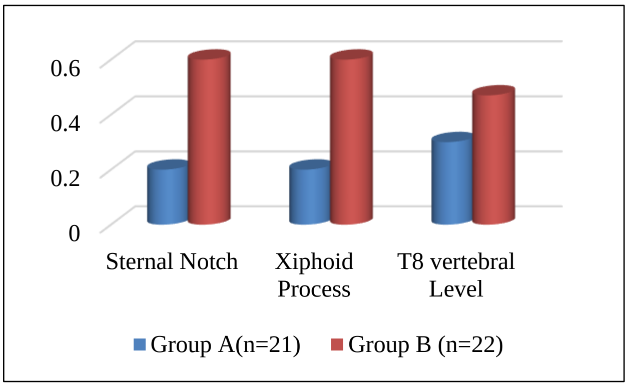

Figure 3: Mean difference comparison of chest expansion of both the groups.

DISCUSSION

The present study was conducted to find the effect of Respiratory proprioceptive neuromuscular facilitation technique on pulmonary function in patients with spinal cord injury. Results of this study showed that pulmonary functions (FEV1, FVC, PEFR) were more improved in the experimental group than in the control group. Chest expansion was also significantly increased in the experimental group. This study indicates that Respiratory proprioceptive neuromuscular facilitation technique is effective in improving pulmonary functions when it is given in spinal cord injury patients along with conventional respiratory management and it is also effective in improving chest expansion in spinal cord injury patients.

The respiratory complications remain the most common cause of mortality following SCI.[14] Patients are most vulnerable to respiratory illness in the first year after injury but continue to suffer from respiratory complications throughout life.[15]

Injury to the cervical and upper thoracic spinal cord disrupts function of inspiratory and expiratory muscles, as reflected by reduction in spirometric and lung volume parameters and static mouth pressures. In association, subjects with tetraplegia have decreased chest wall and lung compliance, increased abdominal wall compliance, and rib cage stiffness with paradoxical chest wall movements, all of which contribute to an increase in the work of breathing. Expiratory muscle function is more compromised than inspiratory muscle function among subjects with tetraplegia and high paraplegia, which can result in ineffective cough and propensity to mucus retention and atelectasis.[16]

The present study showed that the application of respiratory PNF stimulates the main respiratory muscles (diaphragm and intercostal), as well as other accessory muscles (neck muscles, chest wall, and upper limbs). The first mechanism behind this was application of respiratory PNF the chest wall muscles are being maximally stretched the intercostal muscle and diaphragm contains sensory muscle spindles that respond to elongation. A signal is sent to spinal cord and anterior horn cells. These neurons signal make more muscle fibers to contract (recruitment) and thus increase the strength. Stretching the ribs and diaphragm activate the stretch reflex and help the patients to take a deep breath which helps in improving the quality of breathing.[17]

In similar study conducted by Vikram M and Kamaria K, on effect of intercostal stretch on pulmonary function Parameters and they stated that the use of manual stretching procedures has become more prevalent in cardiorespiratory physiotherapy to improve pulmonary functions. In the experimental group, subjects underwent intercostal stretch for ten breaths on the inspiratory phase of the respiratory cycle with breathing control exercises in semi recumbent position, while in the control group, breathing control exercises alone were performed in the semi recumbent position. The results of the study showed, FEV1 and FVC in the experimental group significantly improved than the control group, which means intercostal stretch increased lung volume and lead to improved lung function. This study suggested the intercostal stretching with breathing control may be more effective in improving dynamic lung parameters.[18]

A similar study supporting the present study was conducted by Gautam et al conducted study on effect of Upper limb proprioceptive Neuromuscular Facilitation with Resistance Training on Respiratory Muscle Strength in Quadriplegics in this study 26 participants with C5-C8 level injury were divided into two groups group A received upper extremity PNF combined with resistance training and Group B received respiratory training with triflow type incentive spirometer for 4 weeks both the group participants were evaluated for maximum inspiratory pressure (MIP), maximum expiratory pressure (MEP) and modified Borg Scale (MBS). The result of this study showed significant improvement in between group comparisons. This study concluded that upper limb PNF combined with resistance training is more effective in improving respiratory muscle strength.[19]

Research by Saha et al, efficacy of chest PNF on pulmonary function in patients with Parkinson's diseases found similar result like our study. The result of this study was no significant difference between pre and post intervention in both groups for FVC and chest wall expansion (axilla, xiphi sternum) whereas between-group analysis revealed that PFT parameters were not significantly improved whilst chest expansion at the two measured levels were significantly improved.[20]

The possible explanation for this may be the chest PNF provides proprioceptive stimulus to the primary respiratory muscles, which leads to improving their function and increases chest wall mobility. It also increases the activity of the diaphragm and abdominal muscles. The rigid chest wall muscles may get inhibited through autogenic inhibition and promotes mobility to the chest wall. PNF also increases stress relaxation to the chest wall muscles which promotes chest wall mobility.[21]

Hence, respiratory proprioceptive neuromuscular facilitation technique is given along with conventional physiotherapy to get its combined effect on improving the pulmonary functions and chest expansion in spinal cord injury patients.

CONCLUSION

Our research findings suggest that the respiratory proprioceptive neuromuscular facilitation technique holds an effective intervention for improving pulmonary functions in spinal cord injury patients. Through our study, we observed significant improvement in various pulmonary functions and chest expansion parameters following the implementation of PNF techniques. These findings indicate the potential of PNF to enhance respiratory muscle strength, mobility of the chest wall and overall pulmonary functions in individuals with spinal cord injury.

ACKNOWLEDGEMENTS

Authors would like to thank the management of the Pravara Institute of Medical Sciences for permitting to conduct of this study.

Funding: No funding sources
Conflict of interest: None declared
Ethical approval: The study was approved by the Institutional Ethics Committee

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Cite this article as: Thorat KD, Tungikar S, Lofvenmark I. Effectiveness of respiratory proprioceptive neuromuscular facilitation technique on pulmonary function in spinal cord injury patients: a randomized controlled trial. Int J Res Med Sci 2024;12:2390-7.