International Journal of Research and Review
Vol.7; Issue: 5; May 2020
Website: www.ijrrjournal.com
Original Research Article *E-ISSN: 2349-9788; P-ISSN: 2454-2237*

Effect of Chest Proprioceptive Neuromuscular Facilitation Combined with Abdominal Muscle Stimulation on Respiratory Function in Tetraplegia

Apurva Chatterjee[1], Jyoti[2], Mohit Kumar Dahiya[3]

[1]Post Graduate Research Scholar, ISIC Institute of Rehabilitation Science, New Delhi
[2]Assistant Professor, Sharda University, Noida.
[3]Assistant Professor, Sharda University, Noida.

Corresponding Author: Apurva Chatterjee

ABSTRACT

Purpose: The purpose of this study was to determine whether there was an effect of chest proprioceptive neuromuscular facilitation combined with abdominal muscle stimulation on respiratory function in tetraplegia

Subjects and Methods: Twenty- seven tetraplegic subjects were randomly assigned to a PNF+ AS group (n=15) or a BRE+AS group (n=12). The PNF+ AS group received chest PNF along with abdominal muscle stimulation for 30 minutes, 4 times a week. Subjects were assessed pre-test and post- test by measurement of respiratory function (Forced vital capacity, Forced expiratory volume in 1 second and peak expiratory flow rate), respiratory muscle strength (Maximum inspiratory pressure and Maximum expiratory pressure) and dyspnoea (modified Borg Scale).

Results: After 3 weeks of intervention, pre and post intervention analysis for both groups showed a significant improvement in scores of FVC (% pred), FEV_1 (% pred), PEF (% pred), MIP, MEP and modified Borg scale. Between group analysis showed significant improvement in FVC (% pred) at (p = .01), FEV_1 (% pred) at (p = .04), PEF (% pred) at (p = .04), MIP at (p = .001), MEP at (p = .001) and modified Borg scale at (p = .001)

Conclusion: This study concludes that there was a significant improvement in respiratory function, respiratory muscle strength and dyspnoea using chest proprioceptive neuromuscular facilitation combined with abdominal muscle stimulation for tetraplegia.

Key words: Chest PNF, Abdominal muscle stimulation, breathing exercise, tetraplegia, respiratory function.

1. INTRODUCTION

Spinal cord injury (SCI) can be one of the most catastrophic experiences for the individual who sustains it. It is a life changing event that can have a profound effort on personal, social as well as economical aspect of a person's life. Injury to the cervical cord has an adverse effect to the respiratory function. As SCI results in muscle paralysis that is determined by the neurologic level and completeness of the injury, higher neurologic level and more complete injury will result in a greater degree of respiratory muscle dysfunction (P,2003).[1]

Respiratory complications are the most frequent cause of morbidity and mortality in patients with tetraplegia ((H, 2008).[2]

Tetraplegics have an alteration in their breathing mechanics because of the abnormally high extra pulmonary work of breathing.

People with tetraplegia who have a lesion at a lower level are typically able to breathe voluntarily and are mostly independent from mechanical ventilation. Their breathing capacity is still compromised due to paralysis of inspiratory and expiratory muscles. Because the paralysis also affects the abdominal wall muscles which are the main expiratory muscles, their capacity to forcefully expire air, e.g. during cough, is also reduced.

Electrical Stimulation (ES) is the application of a train of electrical pulses to a motor nerve, causing contraction of the associated muscle. ES can be used in health care for one of three purposes: to aid diagnosis, as a therapeutic tool, and/or to restore lost or damaged function. (Rushton, 1997) [3]

It has been shown that stimulation of abdominal muscles during expiration can improve respiratory function. This technique can enhanced cough since the contraction of the stimulated abdominal muscles leads directly to an increase in respiratory pressure and consequently to improved expiratory flow. It also causes a reduction of lung volume below the functional residual capacity, and the subsequent passive recoil during inspiration can result in an increase of tidal volume. Stimulation of the abdominal muscles is typically used in tetraplegic individuals with spontaneous breathing, although this technique has been applied in individuals who are unable to breathe spontaneously. The abdominal muscles are typically stimulated through surface electrodes which are easy to apply, and stimulation results in a uniform, well defined muscle response.

Proprioceptive Neuromuscular Facilitation (PNF) is a stretching technique that employs to improve muscle elasticity and has been shown to have a positive effect on active and passive range of motions. Recent research has been focused on the efficiency of the intervention on certain outcome counts, such as passive range of motion (PROM), active range of motion (AROM), peak torque and muscular strength. (Hindle, 2012) [4]

A study conducted by Dietz et al indicated that muscle strength can be improved through three dimensional spiral large scale resistive exercises using PNF. (Kim, 2015)[5] Studies have also examined the improvement of respiratory functions induced by direct respiratory muscle resistive exercises through the PNF respiration pattern.

Newer studies showed that PNF respiration exercise can increase pulmonary functions in normal adults, elderly population and stroke patients.

The purpose of this study is to evaluate the effect of chest PNF along with abdominal stimulation on pulmonary functions, cough, respiratory muscle strength and dyspnoea in tetraplegia.

2. MATERIALS & METHODS

This study was conducted in Indian Spinal Injuries centre, located in New Delhi, India. The average age of the subjects was 32 years. All of the protocols used in this study were approved by the Ethical Committee of Indian Spinal Injuries Centre, New Delhi. Before participation, the procedure, risks, and benefits were explained to all the subjects, who gave their informed consent. All the subjects were randomly allocated using an online randomiser, to the Chest PNF combined with abdominal stimulation group (PNF+AS, n = 15) or breathing exercise combined with abdominal stimulation group (BRE+AS, n = 12).

The criteria for the subject selection included complete and incomplete tetraplegics with level of injury between C5-C8; subjects between the age of 18-60 years; subjects with upper motor neuron paralysis of abdominal muscles; subjects who were medically stable and willing to participate. The exclusion criteria were any recent complication associated with SCI such as autonomic dysreflexia, orthostatic hypotension, bed sores, etc, which might interfere with the treatment; subjects with premorbid respiratory conditions such as asthma, COPD, restrictive disease of the lungs; subjects with ventilator support or tracheostomy; subjects who were current smoker i.e. those who currently smoked cigarettes, cigars, and/or pipes or those who had quit for ≤ 1 year; history of any other neurological condition (seizures, brain injury or stroke) and psychiatric conditions (dementia, Alzheimer disease), which may interfere with the treatment and any musculoskeletal conditions like rib fracture which might interfere with the treatment and any other contraindications to ES such as cardiac pacemaker, local skin infection, etc.

The instruments needed were a 4 channel stimulation unit with 8 carbon electrodes, spirometer and a manometer. Modified Borg Scale was used to measure dyspnoea.

Procedure for Group A (PNF+AS) consisted of chest PNF and abdominal stimulation. Chest PNF was administered simultaneously along with abdominal muscle stimulation. The subjects were made to lie down in supine and the entire procedure was explained. The therapist placed his hands on the lateral surface on both side of the 8th, 9th, 10th and 11th ribs of the subject. For inspiration, the subjects were instructed to "take a deep breath". As the subjects' ribs moved upward and laterally, the therapist assisted the movement of the ribs. A maximum inspiration, the subjects were instructed to hold their breath for 5 seconds. At maximum expiration the therapist applied pressure on the lower ribs diagonally in a caudal and medial direction, with both the hands. As the subjects breathed out, the therapist shook the region to discharge the remaining air from the lungs (SeoJ, 2014).[6]
Abdominal muscle stimulation was given to subjects in the supine position. Abdominal hair was shaved off and the area was cleaned with water and cotton to remove dust and oil. Four pair of electrodes were applied around the umbilicus, where two channels were used to stimulate the rectus abdominals and the other two channels were used to stimulate the internal and the external oblique on both sides of the abdomen.

Parameters for stimulation were [2]:

Frequency – 50 Hz

Intensity – constant current between 30 and 100 mA

Pulse duration – 100-400 µs

The intensity of the stimulation was increased till a visible contraction was seen in the abdominal musculature. The pulse duration was adjusted manually throughout the experiment to avoid progressive muscle fatigue. The subjects were told that they might feel a tingling sensation or a squeezing of abdominal muscles. They were asked to immediately report, in case they felt any abnormal sensation and in those cases the treatment was terminated.

Procedure for Group B (BRE+AS) consisted of breathing exercise and abdominal muscle stimulation. Breathing exercise was administered simultaneously along with abdominal muscle stimulation. The subjects were instructed to breathe in slowly and deeply through the nose, while keeping the shoulders relaxed and the upper chest quiet, allowing the abdomen to rise. At the end of inspiration, the subjects had to hold the breath for five seconds and exhales slowly through the mouth.

The spirometry was performed for FVC, FEV_1 and PEF with KoKo® Legend Portable spirometer using American Thoracic Society standards. The MIP and MEP were checked with a manometer using the Black and Hyatt model. Each subject was seated and made to wear a nose-clip. The MEP was measured near total lung capacity (TLC) after a maximal inspiration. The MIP was measured near residual volume (RV) after a maximal expiration. The pressures measured were maintained for at least 1 second. The determination was repeated three times and the average value was used in the subsequent calculations. The dyspnoea was quantified before training and at the end of 3 weeks using the Modified Borg Scale. Values of FVC, FEV_1 and PEF were recorded as percentage predicted (% pred) and the values of MIP, MEP were recorded in cm H_20.

DATA ANALYSIS

Data was analysed using SPSS version 21 for Windows (SPSS Inc., Chicago, Illinois). Out of 30 subjects there were 3 drop outs therefore analysis was done for 27 subjects who completed the study. Sample size was determined through power calculation based on previous studies for abdominal muscle stimulation in SCI with an estimated effect size of 0.08. An overall sample size of 27 participants (15 in Group A and 12 in Group B) at 0.05 level of significance was calculated. 30 subjects were recruited to allow 10% dropouts. The demographic details of Group A and Group B are given in Table 2.1.

Table2.1: Demographic details of Group A and Group B

Demographic Details	Group A (n=15)		Group B (n=12)	
	Mean	SD	Mean	SD
Age (years)	31	8.8	31.33	7.2
Time since injury (months)	9.13	8.1	8.33	3.3
Male subjects	14		12	
Female subjects	1		0	

Group A: Experimental group, Group B: Control group, n = number of subjects, SD = Standard deviation

NL	AIS Grade	Group A (n=15)		Group B (n=12)	
C5	A	9	6	9	9
C6	B	2	7	6	4
C7	C	1	1	1	0
C8	D	3	1	0	1

NL = Neurological level

The physical characteristics of the Group A and Group B were analysed by unpaired t test (table 2.2).

Table 2.2: Comparison of pre-intervention scores between Group A and Group B

Variables	Pre – intervention scores Group A (n=15)		Pre – intervention scores Group B (n=12)		T^{NS}	p
	Mean	SD	Mean	SD		
FVC (% pred)	50.93	16.41	43.17	8.60	1.48	.128
FEV_1 (% pred)	57.67	19.32	46.83	14.01	1.62	.104
PEF (% pred)	44.67	13.66	39.67	8.65	1.10	0.25
MIP	20.73	8.43	16.92	4.12	1.43	0.13
MEP	17.93	8.12	13.58	5.64	1.57	0.12
MBS	2.73	1.10	2.25	1.05	1.15	0.25

* = Significant at ≤ 0.05

NS = Non significant, Group A = Experimental Group, Group B = Control Group, n = number of subjects, SD = Standard Deviation, FVC = Forced vital capacity (% predicted), FEV_1 = Forced vital capacity in 1 second (% predicted), PEF = Peak expiratory flow rate (% predicted), MIP = Maximal inspiratory pressure (cm H_2O), MEP = Maximal expiratory pressure (cm H_2O), MBS = Modified Borgs scale for dyspnoea

The mean change scores were calculated as the difference between post and pre test scores and an independent t test was used to test the difference in the changed scores between two groups. Paired t test was used to analyse within group difference. A level of significance was set at 0.05.

3. RESULT

There were statistically significant difference between pre and post results within both groups. Mean and standard deviations are mentioned for each group in table 3.1, table 3.2, respectively. The mean change of scores of Group A and Group B revealed significant changes for FVC (p = 0.01), FEV_1 (p = 0.04), PEF (p = 0.04), MIP (p = 0.001), MEP (p = 0.001) and MBS (p = 0.001) as shown in table 3.3

Table 3.1: Comparison of pre – intervention and post – intervention scores of Group A

Variables	Pre – intervention scores Group A (n=15)		Post – intervention scores Group A (n=15)		t*	p
	Mean	SD	Mean	SD		
FVC (% pred)	50.93	16.41	58.20	16.88	-7.12	.001
FEV_1 (% pred)	57.67	19.32	66.13	19.48	-7.50	.001
PEF (% pred)	44.67	13.66	57.87	14.29	-6.65	.001
MIP	20.73	8.43	29.58	9.48	-8.18	.001
MEP	17.93	8.12	24.93	8.78	-7.48	.001
MBS	2.73	1.10	0.30	0.41	8.10	.001

* = Significant at ≤0.05

NS = Non significant, n = number of subjects, SD = Standard Deviation, FVC = Forced vital capacity (% predicted), FEV_1 = Forced vital capacity in 1 second (% predicted), PEF = Peak expiratory flow rate (% predicted), MIP = Maximal inspiratory pressure (cm H_2O), MEP = Maximal expiratory pressure (cm H_2O), MBS = Modified Borgs scale for dyspnoea,

Table3.2: Comparison of pre – intervention and post -intervention scores of Group B

Variables	Pre – intervention scores Group B (n=12)		Post – intervention scores Group B (n=12)		t*	p
	Mean	SD	Mean	SD		
FVC (% pred)	43.17	8.60	47.00	9.18	-4.24	.001
FEV_1 (% pred)	46.83	14.01	51.92	16.30	-4.69	.001
PEF (% pred)	39.67	8.65	47.50	9.51	-5.13	.001
MIP	16.92	4.12	20.17	5.60	-5.27	.001
MEP	13.58	5.64	16.67	5.99	-5.41	.001
MBS	2.25	1.05	1.29	0.75	3.83	.001

* = Significant at ≤0.05

NS = Non significant, n = number of subjects, SD = Standard Deviation, FVC = Forced vital capacity (% predicted), FEV_1 = Forced vital capacity in 1 second (% predicted), PEF = Peak expiratory flow rate (% predicted), MIP = Maximal inspiratory pressure (cm H_2O), MEP = Maximal expiratory pressure (cm H_2O), MBS = Modified Borgs scale for dyspnoea

Table3.3: Comparison of post – intervention mean change scores of Group A and Group B

Variables	Group A		Group B		Mean change Group A	Mean change Group B	t*	p
	Pre	Post	Pre	Post				
FVC	50.93	58.20	43.17	47.00	7.27±3.95	3.83±3.12	2.52	0.01
FEV_1	57.67	66.13	46.83	51.92	8.47±4.37	5.08±3.75	2.16	0.04
PEF	44.67	57.87	39.67	47.50	13.2±7.68	7.83±5.28	2.14	0.04
MIP	20.73	29.58	16.92	20.17	9.13±4.35	3.25±2.13	4.61	0.001
MEP	17.93	24.93	13.58	16.67	7±3.62	3.08±1.97	3.57	0.001
MBS	2.73	0.30	2.25	1.29	-2.43±1.22	-0.95±0.86	-3.7	0.001

* = Significant at ≤0.05

NS = Non significant, n = number of subjects, SD = Standard Deviation, FVC = Forced vital capacity (% predicted), FEV_1 = Forced vital capacity in 1 second (% predicted), PEF = Peak expiratory flow rate (% predicted), MIP = Maximal inspiratory pressure (cm H_2O), MEP = Maximal expiratory pressure (cm H_2O), MBS = Modified Borgs scale for dyspnoea

4. DISCUSSION

Respiratory dysfunction due to paresis or paralysis of respiratory muscles is common among tetraplegics. In this study, chest PNF combined with abdominal muscle stimulation was used to improve respiratory functions, respiratory muscle strength and dyspnoea.

Cervical spinal cord injury patients from neurological level C5 to C8 were recruited post 3 months after injury, to minimize changed due to spontaneous recovery in the acute phase of injury.

A total of 30 subjects consented to participate in the study. Out of these, there were 3 drop outs, 2 subjects dropped out because of illness and 1 subject could not continue the 3 week protocol.

With technical advancement and improved care, survival rates for tetraplegic patients have increased. In tetraplegics, respiratory insufficiency due to paresis or paralysis of respiratory muscles is commonly seen. Factors such as concomitant trauma of lung tissue and thorax, spasticity of the trunk muscles and the degree of preservation of expiratory muscles may play an important role. In addition, over time the inability to inspire deeply (due to weak inspiratory muscle strength) may lead to a cascade of reduced compliance of lung and thorax, lowered reserve capacity of the respiratory pump, increased susceptibility for medical complications recurrent respiratory infections and gradual deterioration of lung tissue (J., 2010).[8]

According to Mateus et al (SRM, 2007) [7], the most important pulmonary function change is a nonparenchymatous pulmonary restriction, owing to weakness or paralysis of respiratory muscles, hence the aforementioned factors of inspiratory muscle function, lung volumes and cough flow may have a complex and cumulative nature.

To maintain adequate gas exchange during quite breathing and in situations of increased respiratory demand, preserved inspiratory muscle strength is essential.

It is possible that chest PNF could had affected the chest wall compliance which is reduced in tetraplegics. Chest PNF could have worked by stimulating the proprioceptors by facilitating the neuromuscular mechanism. Kabat reported that when employing facilitating techniques with resistance, a greater motor response can be achieved. A number of factors such as application of stretch, use of particular movement patterns and use of maximal resistance in order to induce irradiation can result in facilitation.

Gellhorn and Loofbourroe showed that a muscle's response to cortical stimulation increases with resisted muscle contraction. Studies in the past explained about the neuromuscular mechanism in detail, whereby it was observed that sensory inputs from the periphery leads to stronger excitation of the cortical areas. This caused a variation in the threshold of the motor neuron activation (D,2013).[9]

Respiratory muscle strength and endurance is seen to be improved after resistive training and it could be a result of change in the individual muscle fibre's oxidative capacity of the diaphragm. The easily fatigable fibres change to more fatigue resistant fibres (A, 1998).[10] Increase in FVC, MIP and MEP are attributable to the fact that when the subject was breathing in, the activity of the diaphragm and other assistant inspiratory muscles was promoted by the therapist. Pushing both sides of the subjects' chest wall towards the head creates a spiral movement which increases the intra - abdominal pressure. This leads to resisted inspiration. When the subjects breathe out, the chest wall mobility was increased as much as possible by giving assistive movements with the medial gathering of the lower chest wall.

Resisted training causes an improvement in respiratory muscle strength which reduces dyspnoea.

Troyer et al, states that intercostal muscles have an important function in stabilizing the chest wall as these muscles prevent the inward collapse of a passive rib cage(SeoJ, 2014).[6]

Pink et al showed that unexercised muscles become active during resisted upper extremity PNF patterns in normal subjects. Loverdige et al also showed improvement in MIP after ventilator muscle endurance training.

All the findings are in accordance with the previous work done on abdominal muscle stimulation (Zupan, 1997) (Jaeger, 1993) (Linder, 1993) [2, 11-13]. They stated that there are effects of abdominal muscle stimulation on pulmonary function test results.

A possible explanation for the increases may be due to increased abdominal muscle mass and tone which has shown to be reduced in tetraplegia.

Abdominal muscles are powerful muscles for expiration which plays an important role in functions such as forced expiration and coughing. Exhalation is a passive process occurring in the absence of thoracic or abdominal muscle contraction. However, as minute ventilation increases, the abdominal muscles contract during exhalation pulling the chest caudally to facilitate thoracic emptying. Contraction of the abdominal musculature is essential in the development of the expulsive force needed for an effective cough. With their innervations arising from the thoracic and lumbar nerve roots, abdominal muscle function is absent in persons with cervical spinal cord injury. Expiratory muscle weakness impairs cough induced dynamic compression and the linear velocity of airflow through the large intrathoracic airways consequently the effectiveness of cough is severely reduced in tetraplegia.

According to Rebecca et al, clinically a significant number of individuals with complete SCI retain some connectivity across injury site; this could be represented by the non-functioning myelin.

Application with abdominal muscle stimulation could assist their contractions enabling the subjects to compromise their deficits. Moreover the ES in this study was applied at 50 Hz; pulse width: 100-400 µsec, which could theoretically improve muscle power.

Breathing exercises to prevent pulmonary complications is a popular common treatment. It can be used with added resistance during resistance during inspiration and/or expiration for general prevention. [1]

This study included a heterogeneous sample of patients with a mix of injury levels, time post injury and AIS grade leading to large inter- subject variability. Despite this complex mix, the results show that FVC, FEV_1, PEF, MIP, MEP and MBS improved in all patients.

The results have shown that both chest PNF combined with abdominal muscle stimulation and breathing exercises with abdominal muscle stimulation are effective in improving respiratory function, respiratory strength, and dyspnoea. More significant improvement was seen in MIP, MEP and dyspnoea in the group which received chest PNF combined with abdominal muscle stimulation.

REFERENCES

1. Bodin P, Kreuter M, Bake B, Olesen MF. Breathing patterns during breathing exercises in person with tetraplegia. Spinal Cord 2003; 41: 290-295
2. Gollee H, Hunt KJ, Fraser MH and McLean AN. Abdominal stimulation for respiratory support in tetraplegia: a tutorial review. Journal of Automatic Control 2008, Vol. 18(2):85-92
3. D. N. Rushton, “Functional electrical stimulation," Physiol Meas, vol. 18, pp. 241 -275, Nov 1997.
4. Kayla B. Hindle, Tyler J. Whitcomb, Wyatt O. Briggs, and Junggi Hong; Proprioceptive Neuromuscular Facilitation (PNF): Its Mechanisms and Effects on Range of Motion and Muscular Function; J Hum Kinet. 2012 Mar; 31: 105–113.
5. Chang-Beom Kim, Jin-Mo Yang, Jong Duk Choi. The effect of chest expansion resistance exercise on chest expansion and maximal respiratory pressure in elderly with inspiratory muscles weakness. J. Phys. Ther. Sci. 27:1121-1124, 2015
6. KyoChul Seo, MiSuK Cho. The Effects on the Pulmonary Function of Normal Adults Proprioceptive Neuromuscular Facilitation Respiration Pattern Exercise. J Phys Ther SCI. 2014;26:1579-1582.
7. Mateus SRM, Beraldo PSS, Horan TA. Maximum static mouth respiratory pressure in spinal cord injured patients: correlation with motor level. Spinal Cord. 2007; 45: 569-579
8. Allen J. Pulmonary complications of neuromuscular disease: a respiratory

mechanics perspective. Paediatr Respir Rev 2010; 11(1):18-23

9. Khanal D, Singaravelan RM and Khatri SM. Effectiveness of pelvic Proprioceptive Neuromuscular Facilitation Technique on Facilitation of Trunk Movement in Hemiparetic Stroke Patients. IOSR Journal of Dental and Medical Sciences Volume 3, Issue 6 (Jan. - Feb. 2013), PP 29-37
10. Rutchik A, Weissman AR, Almenoff PL, Spungen AM, Bauman WA, Grimm DR. Resistive inspiratory muscle training in subjects with chronic cervical spinal cord injury. Arch Phys Med Rehabil 1998 ;79:293-297
11. A. Zupan, R. Savrin, T. Erjavec, A. Kralj, T. Karcnik, T. Skorjanc, H. Benko, and P. Obreza, "Effects of respiratory muscle training and electrical stimulation of abdominal muscles on respiratory capabilities in tetraplegic patients.," Spinal Cord, vol. 35, pp. 540–545, Aug 1997
12. R. J. Jaeger, R. M. Turba, G. M. Yarkony, and E. J. Roth, "Cough in spinal cord injured patients: Comparison of three methods to produce cough." Arch Phys Med Rehabil, vol. 74, pp. 1358–1361, Dec 1993
13. S. H. Linder, "Functional electrical stimulation to enhance cough in quadriplegia." Chest, vol. 103, pp. 166–169, Jan 1993

How to cite this article: Chatterjee A, Jyoti, Dahiya MK. Effect of chest proprioceptive neuromuscular facilitation combined with abdominal muscle stimulation on respiratory function in tetraplegia. International Journal of Research and Review. 2020; 7(5): 332-339.

******