The Effects of Breathing Exercise with Intermittent Positive Pressure Ventilator on Pulmonary Function in Patients with Cervical Spinal Cord Injury

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Purpose The purpose of this study was to examine the effect of pulmonary function through intermittent positive pressure ventilator(IPPV) exercises in the patients with spinal cord injury. ***Methods*** In order to demonstrate the effect of the study that IPPV group(n=13) and pursed lips breathing(PLB) group(n =11) and general physical therapy(GPT) group(n=9) were randomly assigned to proceed with the study. Measurements of pulmonary function were used CadioTouch3000S(BIONET). The participants were assessed before and after the intervention conducted for 8-weeks. ***Results*** The results of this study were as follows. In the forced vital capacity(FVC), forced expiratory volume 1 second(FEV_1), FEV_1/FVC, peak expiratory flow(PEF), IPPV group showed a significant difference pre- and post-training($p<.05$). In the FVC, FEV_1, FEV_1/FVC, PEF, PLB group showed a did not significant difference pre and post-training($p>.05$). In the PEF, GPT group showed a significant difference($p<.05$), but in the FVC, FEV_1, FEV_1/FVC showed a did not significant difference pre- and post-training($p>.05$). ***Conclusion*** In conclusion of this study, cervical spinal cord injury patients who performed breathing exercise through IPPV showed effective results to improve pulmonary functions.

Key words SCI, IPPV, Breathing Exercise, Pursed Lips Breathing

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Received date 31. December 2015
Revised date 29. January 2016
Accepted date 20. February 2016

I. Introduction

Spinal cord injury (SCI) takes place commonly as a result of trauma. Not only do patients with this type of injury present with paralysis and sensory loss below the level of injury but may have disability from a limited and/or irreversible recovery.[1)] According to the literature, two-third of patients with SCI experience respiratory complications during the first year following the trauma.[2)] In particular, in cervical lesions, there were both also a lack of lung expansion and pulmonary dysfunction due to the weakness of respiratory muscles and reduced pulmonary compliance.[3)] Therefore, these problems are considered to cause a higher incidence of respiratory complications[4)], which causes morbidity or mortality following a SCI.[5)] In addition, the paralysis of respiratory muscles, such as the intercostalis and abdominalis, affects complete coughing, resulting in incomplete expulsion of secretions, causing adysfunction of lung expansion and, potentially, pneumonia. Because most respiratory complications can be a result of the inability to expel secretions and the lack of lung expansion, one might consider to additional ventilation to assist in clearing secretions during the respiratory rehabilitation, in order to prevent or minimize complications and to reduce the possibility of fatal consequences.[6)] Dyspnea has been defined as a subjective difficulty or distress in breathing.[7)] Respiratory rehabilitation has been used to relieve symptoms, increasing quality of life, and the maintenance of independence of the activity of daily living through promoting exercise tolerance.[8)] Respiratory physiotherapy has been used in patients with neuromuscular disease, particularly SCI with an upper level and the ankylosing spondylitis, as well as chronic obstructive pulmonary disease, a disease of the lung itself and accompanying the respiratory problems.[9)] Although there has been a lot of research and many interventions utilizing respiratory rehabilitation, little has been discussed about respiratory rehabilitation in cases of SCI. The intermittent positive pressure ventilation (IPPV), one of many methods in respiratory rehabilitation, is an assistive breathing machine which contributes in clearing secretions. This produces lung inflation by generating and applying positive pressure to the airways, then rapidly shifts to a negative pressure. This rapid shifts of the pressure produce a high expiratory flow to the lungs, simulating a cough, and thus preventing dysfunction of lung expansion, minimizing complications, increasing functional residual capacity, and resulting in the intercostals' muscular integrity by performing ongoing periodic lung expansion.[10)] The respiratory exercise using the IPPV has been found to increase a maximal expiratory capacity and help secretions.[11)] However, little has been studied regarding the extent to which exercise using the IPPV might affect pulmonary functions in patients with cervical SCI. Pursed-lip breathing (PLB) is a breathing exercise to reduce a functional residual capacity and increase a breath efficiency with longer periods of expiration than inspiration. The physiologic changes induced by PLB cause an increased intrabronchial pressure during expiration and, as a consequence, may increase the bronchial diameter and therefore improve the inspiratory and expiratory flow. For research by Visser et al.[12)], PLB was founded to improve an inspiratory capacity in patients with COPD (Chronic obstructive pulmonary disease). Also, Relatively little is known about the effect of PLB on respiratory function in patients with SCI. The aims of this study were to compare the effect of the IPPV of an air cumulative training with abdominal compression and PLB on a pulmonary function in patients with SCI on cervical and to recommend an effective strategy of the breathing exercise.

II. Materials and Methods

1. Participants

33patients at the Yeeun Hospital enrolled in this study. The inclusion criteria were:1) having a cervical SCI Association Impairment Scale (AIS), 2) having the ability to understand instructions, 3) having a normal glottis function, and 4) having the ability to perform training for 15-minutes or more(13, 14). The exclusion criteria were: 1) being on a medication or intervention for pulmonary functions, 2) already using ventilator support and tracheostomy, and 3) in respiratory diseases. Our study followed the principles of the Declaration of Helsinki and all the recruits provided their informed consent.

2. Study design

This study was a prospective, randomized controlled trial, with 13 participants assigned to the IPPV exercise group, 11 participants assigned to the PLB group, and 9 participants assigned to the general exercise group. The participants were assessed before and after the intervention conducted for 8-weeks .The Baseline and the post-test data were collected by an evaluator who was blind to the group assignments.

3. Measurements

1) Pulmonary function test

We performed a pulmonary function test using the CardioTouch3000S(BIONET), in the sitting position. Patients were instructed fully about the experimental procedure prior to data collection. Pulmonary function tests in this study included forced vital capacity, forced expiratory volume in 1 second which is the ratio of forced expiratory volume in 1 second to forced vital capacity, and peak expiratory flow. Each test was measured three times and the mean of the tests was recorded.

2) Forced vital capacity (FVC)

Forced vital capacity is the maximum amount of the air a person can expel from the lungs after a maximum inhalation and is used as an indicator of restrictive lung disease. The value above 80 %is regarded as normal with respect to age, height, and weight. Lower values indicate lung disease.

3) Forced expiratory volume in 1 second (FEV1)

FEV_1 is defined as the greatest volume of the air that can be breathed out in the first second of a breath. In general, the value of more than 80 % is regarded as normal, and this is related to the severity and prognosis of respiratory disease

4) Forced expiratory volume in 1 second / Forced vital capacity (FEV_1/FVC)

is used in the diagnosis of obstructive and restrictive lung disease. It represents the proportion of a person's vital capacity that they are able to expire in the first second of forced expiration. The diagnosis of restrictive lung disease is made when the score is more than 75% of the normal value.

5) Peak expiratory flow (PEF)

expiratory flow (PEF) is the value for measuring a person's maximum speed of expiration and airway resistance. The lower value indicates weakness of expiratory muscle and high airway resistance.

4. Exercise groups

1) IPPV group

We performed with the device CoughAssist(CA-3000, Emerson). The positive insufflations and negative exsufflation pressures, duration, and inspiratory flow rate were preset. One treatment consists of 3-5 cycles of in- and exsufflation (with abdominal compression during exsufflation) followed by about 30 seconds of rest(11, 15). In-exsuflation was delivered via a mask, and a therapist applied pressure on the diaphragm area with both arms while simulating a cough. This was repeated for 15-minute in a semirecumbent position at 45 degrees.

2) PLB group

Patients were instructed to sit straight and relax their necks and shoulders. And then they leaned their arms against the arm rests of a chair and breathed quietly in through the nose and out by means of pursed lips breathing. During the inspiration the mouth was closed. The expiration was about 2 times longer duration than the inspiration(12).In the beginning, the time of the inspiration and expiration were 3 seconds and 6 seconds, respectively, and then gradually increased to 5 seconds and 10 seconds, and until 7 seconds and 14 seconds, respectively. This process was repeated 10 times.

3) GPT group

General Physical Therapy is intervention group receiving regular exercise routine time in the Rehabilitation Hospital.

5. Data analysis

The data was analyzed using spss 18.0. Descriptive statistics were performed for all variables measured. The Kolmorogov-Smirnov test was used to test the normality of the data. The paired t-test was used to check the difference between pre- and post-treatment in each group. In order to compare the differences for the types of therapy among the 3 groups, we used one-way analysis of variance and the Bonferroni method was used as the post hoc test. A p-value < 0.05 was considered to indicate significance.

III. Results

General characteristics and their association with each measured variable are presented in Table 1. There was no statistically significant difference between groups on any variables. Data was presented as means±SD. In the results of pulmonary function test, there were significant improvements in all dependent variables in IPPV group and the control group, which showed a positive effect only on PEF. No significant change was observed in PLB group (Table 2).

IV. Discussion

This study was conducted to compare the effectiveness of respiratory exercise using an IPPV with a PLB exercise on pulmonary functions. The results which appeared were that the respiratory exercise using the IPPV was more effective for pulmonary functions. The participants in this study were inpatients having difficulty with respiration due to the injury of the cervical

Table 1. The characterisitcs of patients recruited

		IPPV (n=13)	PLB (n=11)	GPT (n=9)
Gender	Male	11	7	7
	Female	2	4	2
Age(years)[a]		44.69±12.67	45.09±13.46	47.89±16.35
Height (cm)[a]		172.31±7.53	170.36±9.65	170.67±4.21
Weight (kg)[a]		63.00±6.67	59.91±8.79	63.00±9.75
Post-onset (months)[a]		13.31±7.42	15.73±5.75	24.56±7.13
Injury level	C3	1	0	1
	C4	0	2	1
	C5	4	3	3
	C6	2	5	2
	C7	5	0	2
	C8	1	1	0
Classification of injury	ASIA A	4	6	4
	ASIA B	4	1	2
	ASIA C	4	3	3
	ASIA D	1	1	0

Note. [a]Values are mean ± standard deviation. ASIA, American Spinal Cord Injury Association; IPPV, intermittent positive pressure ventilator; PLB, pursed lip breathing; GPT, general physical therapy

Table 2. Comparison of pulmonary functions

	IPPV plus AC			PLB			GPT		
	pre	post	*p*	pre	post	*p*	pre	post	*p*
FVC(L)	1.98±0.79	2.35±0.88	.000*	2.27±0.84	2.46±0.78	.086	2.06±0.57	2.15±0.74	.553
FEV_1(L)	1.81±0.67	1.96±0.67	.024*	2.06±0.79	2.01±0.80	.722	1.79±0.39	1.86±0.62	.498
FEV_1/FVC(%)	92.78±6.88	84.83±11.35	.015*	90.42±8.71	80.43±17.05	.070	88.59±9.09	87.71±17.02	.896
PEF(L/S)	4.27±1.37	4.66±1.59	.016*	4.92±2.15	5.22±2.01	.122	4.07±1.05	4.54±1.35	.025*

Note. mean±standard deviation. *$p<.05$
FVC, forced vital capacity; FEV_1, forced expiratory volume 1 second; PEF, peak expiratory flow; IPPV, intermittent positive pressure ventilator; PLB, pursed lip breathing; GPT, general physical therapy

spine. We performed the pulmonary function tests, which included FVC, FEV1, FEV_1/FVC, and PEF values. Those results showed an increase in FVC in the IPPV group, which indicated that restrictive problem was decreased so then vital capacity was improved in experimental groups. In addition, the increase in FVC may be due to strengthening of the expiratory muscles.[16] For FEV_1, FEV_1/FVC, and PEF values, the IPPV group also had a significant improvement in post-treatment. In particular, the improvement in PEF may indicate that patients were able to better clear secretions. Although there was greater recovery of the pulmonary functions in the IPPV group, the between-group differences did not demonstrate as compared with PLB group and general exercise group. Therefore, we could not be sure that the IPPV exercise is superior to other methods. One of the reasons may be insufficient training periods. Bach(1993) compared peak cough expiratory flows during unassisted coughing with it during assisted coughing in neuromuscular ventilator users.[17] And the study revealed that manually assisted coughing and mechanical insufflation-exsufflation were effective and safe methods for facilitating airway secretion clearance. They also concluded that expiratory flow produced with manual assistance could be more effective than those produced by the most powerful coughs from patients. The manual was similar to the method applied to the IPPV group. Furthermore, Torres-Castro et al.(2014) carried out a study to assess cough using air stacking (AS) to assist inspiratory volume with abdominal compression (AC) during expiration in 15 patients with spinal cord injury.[15] They showed that air stacking and abdominal compression improved peak cough flow and also demonstrated that the mixed method of air stacking with air compression showed a significant improvement of peak cough flow as compared with other ways. In this study, for the IPPV group a therapist applied pressure on the diaphragm area with both arms when simulating a cough in a patient by an abdominal compression. While the IPPV group had a significant improvement in pulmonary functions, it was not found in the PLB group. For pursed lip breathing, patients focused on expiration of breathing, with the inspiratory: expiratory ratio of 1:2. Our results must be interpreted with caution because of the small sample size. It is also important to note that the small number of participants and heterogeneity in SCI level may have resulted in a lack of statistical power. And we could not blind the participants and did not control fatigue during the test. These may be also a potential effects contributing toward the limitation of study. Therefore, further studies should have a larger sample and investigate respiratory muscle activity through an EMG,

V. Conclusion

Cervical spinal cord injured patients who performed the IPPV breathing exercise showed improvement in the pulmonary functions. Future studies with a larger sample-size focusing on real muscle activity, could help establish effective treatment strategies for restrictive pulmonary function.

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