Effects of Inspiratory Muscle Training using Incentive Spirometer on Aerobic Capacity, Functional Performance, and Quality of Life of Individuals with Chronic Paraplegia from Spinal Cord Injury: A Pilot Study

Nita Theresia Reyne[1], Farida Arisanti[1], Vitriana Biben[1], Indriati M. S. Tobing[2], Rosiana Pradanasari[2]

[1] Departement of Physical Medicine and Rehabilitation, Dr. Hasan Sadikin General Hospital, University of Padjadjaran, Bandung, Indonesia

[2]Departement of Physical Medicine and Rehabilitation, Fatmawati General Hospital, University of Indonesia, Jakarta, Indonesia

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Abstract: In spinal cord injury (SCI), partially or fully denervated inspiratory or expiratory muscles have impaired contractility and exhibit diminished exercise ventilation and ventilatory reserve. Inspiratory muscle training (IMT) using an incentive spirometer (IS) improve lung functions in individuals with chronic SCI. This study aimed to investigate the effects of IMT-using-IS on the aerobic capacity, the functional performance, and QoL individuals with chronic paraplegia. The quasi-experimental with the pre-post design conducted at Sasana Bina Daksa Budi Bhakti Pondok Bambu Jakarta in January-February 2019. The outcomes were the aerobic capacity measured with the 6-Minutes Push Test (6MPT), the functional activities daily living (ADL) performance with the Spinal Cord Independence Measure III (SCIM III), and QoL with International SCI Data Sets-Quality of Life Basic Data Set. There were 11 individuals with chronic paraplegia recruited. After the IMT-using-IS 5 times per weeks for 4 weeks, there were significant increases in the 6MPT (p=0.002), and the QoL score (p=0.004), however the SCIM scores were not significantly different (p=0.271). Individuals with chronic paraplegia, the IMT-using-IS significantly improved aerobic capacity and QoL. There was no effect on functional performance in ADL as individuals with chronic paraplegia had already reached their highest level in performing ADL.

1 INTRODUCTION

Respiratory dysfunction frequently occurs in individuals with spinal cord injury (SCI) due to the loss of autonomic and somatic nerve control resulting in complete or partial paralysis of the respiratory muscles. Respiratory dysfunction resulting from SCI remains a major cause of morbidity, mortality, and economic burden (Kumar, 2016; Schilero et al, 2009; Sheel et al, 2008; Sisto and Evan, 2014).

Respiratory muscle dysfunction in SCI leads to mechanical alterations in inspiration which results in decreased compliance of the lungs and chest wall. This is due to the disruption of muscle strength of the primary inspiratory muscles, the diaphragm, and external intercostal muscle. The decreased abdominal muscle function disrupts mechanical respiration as well. Abdominal muscles play an important role during inspiration through their tonic activity, directly facilitating diaphragm muscle contraction by preventing excessive contraction during inspiration. In addition, the increased intraabdominal pressure yielded by the abdominal muscle contraction during expiration prepares the respiratory system for the next inspiration by optimizing the diaphragm muscle length-tension (Berlowitz and Tamplin, 2013; Galeiras, 2013; Schilero et al, 2009; Sheel et al, 2018).

Individuals with chronic SCI frequently experience an alteration in ventilation, becoming restrictive. The weak abdominal muscles and the

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inability of deep inhalation cause increased abdominal compliance and chest cavity stiffness which results in the formation of a restrictive respiratory pattern. This respiratory pattern will reduce the ability to produce maximum minute ventilation, then inhibit maximum oxygen uptake (VO2 max), and ultimately limit physical activity performance (Battikha et al, 2014). In addition, SCI causes a loading shift from lower extremity to upper extremity during exertion. Muscles in the upper extremity are not weight-bearing muscles and can only bear 60% of the workload compared to lower extremity muscles, thus, causing early fatigue in SCI patients. Inspiratory muscle dysfunction decreases aerobic capacity, level of physical activity, and moreover, leads to physical deconditioning and decreased the independence and performance in activities daily living (ADL) among individuals with SCI (Berlowitz and Tamplin, 2013; Sisto and Evan, 2014). Physical exercise represents an important therapeutic part of successful mobility advancement and contributes greatly to a rehabilitation process aiming at self-determination and autonomy. Therefore, it also has a great impact on quality of life (QoL) (Anneken et al, 2010)

Respiratory muscle training is specific training inspiratory, expiratory, or both muscles to increase both muscles strength and endurance. There were numbers of respiratory muscle training using in SCI management, one of them was resistive inspiratory muscle training (IMT). Various systematical reviews showed improvement in lung function and respiratory muscle strength in individuals with SCI after training using resistive IMT technique. The problem is that determining the intensity of resistive IMT requires maximum inspiratory pressure (MIP) measurement using a respiratory pressure meter (RPM), in which the availability in Indonesia is scarce and the price is quite expensive. Other respiratory training methods were using an incentive spirometer (IS). It is a device used in inspiratory training which provides feedback when a patient inhales a predetermined flow or volume and maintains inhalation for at least five seconds. This device is inexpensive, easy to apply and superior in providing a visual feedback during training compared to the resistive IMT. However, there are no specific methods, frequency, and duration of training recommended for pulmonary rehabilitation in SCI, and thus, further studies are required. Prior studies investigating IMT-using-IS with a frequency of 5 times/week and duration of 8 weeks in chronic paraplegia and tetraplegia SCI phase had shown improvement in lung functions; however, its effect to functional performance remains unknown (Berlowitz and Tamplin, 2013; Kim et al, 2017; Paiva et al, 2015).

This study was conducted to investigate the effects of IMT-using-IS on aerobic capacity, performance in ADL, and QoL of individuals with chronic paraplegia from SCI.

2 METHODS

The quasi-experimental with the pre-post design was conducted at Sasana Bina Daksa Budi Bhakti Pondok Bambu Jakarta in January-February 2019. Inclusion criteria for the participants were: individuals with paraplegia from SCI more than six months, age around 18 to 59 years, a stable spine, being able to sit for 30 minutes and performing voluntary ventilation; having the MMSE score more than 24, the Hamilton Depression score less than 19, no history of pulmonary disease or respiratory symptoms, no any recent or active pulmonary infection, and not receiving medication known to alter airway tone. They were excluded if they could not perform deep breathing due to pain or taking an opiate, having a vital capacity of less than 10 mL/kg. They will be dropped out from the study if they did not perform the exercise in 72 hours, wanted to quit from the study, and had unstable medical conditions (Kim et al, 2017). All participants gave written informed consent. The protocol was approved by the Research Ethics Committee of Universitas Padjadjaran, Bandung, Indonesia with registration number 0318050788.

The primary outcomes measured were aerobic capacity, performance in ADL, and QoL. The secondary outcomes were lung function and inspiratory muscle strength. Measurements were administered before and after the intervention period.

The aerobic capacity was determined with 6MPT based on the American Thoracic Society guidelines (Cowan, Callahan and Nash, 2012). The participants were tested in their wheelchair. The ability to do ADL and the QoL were assessed with

Figure 1: Inspiratory muscle training with incentive spirometer.

questionnaires, the SCIM III and the International SCI Data Sets-QoL Basic Data Set, respectively. (Catz et al, 2007; Charlifue et al, 2012). Lung function was measured with a spirometer MicroLab ML3500 M5 (Amplivox, Birmingham, USA) by a skilled nurse. Three repeated flow volume curves were performed. Outcomes that analyzed was the score of the trial with the highest value of three close test readings (Miller et al, 2005). Respiratory muscle strength was determined with MIP by using a Micro RPM (CareFusion, Yorba Linda CA, USA). The highest value of three maneuvers that varied less than 5% from the next value was recorded and used for analysis (Postma et al, 2014).

In this study, an incentive spirometer (Voldyne® 5000 volumetric exerciser, Hudson RCI, Temecula CA, USA), was used for IMT. All measurements and exercise, except lung function, were conducted by a physician. The participants were instructed to hold the spirometer in an upright position, exhaled normally, and then placed the lips tightly around the mouthpiece. The next step was a slow inhalation to raise the piston/plate (volume-oriented) in the chamber to the set target (Figure 1). At maximum inhalation, the mouthpiece is removed, followed by a breath-hold and normal exhalation (Restrepo et al, 2011). All subjects completed 20 supervised training sessions, 5 times a week for 4 consecutive weeks. A total of five sets of 10 repetitions made up one session. After each set, a one-minute rest was allowed. If participants complained of fatigue or dizziness during the If participants complained of fatigue or dizziness during the respiratory exercise, they took a short rest and then proceeded with the exercise. If these symptoms became severe, they were asked to stop the exercise (Kim et al, 2017).

Data were analyzed using SPSS 24.0 for Windows (SPSS Inc., Chicago, IL, USA). The paired T-test and the Wilcoxon signed rank test were used for statistical analysis.

3 RESULTS

Thirteen paraplegics (12 males, 1 female) participated in the study, however, only 11 completed the study. Two participants were excluded because they did not want to continue the study due to personal reason. No complication was reported. Demographic data and characteristics of the participans were shown in Table 1.

The demographic characteristics of this study subjects were dominated by the male (90.9%), underweight (63.6%), and had the same average and median age (44 years). Other factors affecting respiratory function assessment are cigarette smoking, level of injury, and comorbid respiratory system diseases, such as post-tuberculosis obstruction syndrome, pneumonia, chronic obstructive pulmonary disease, and asthma. About 81.8% of research subjects were smokers with filtered cigarettes, about 4–8 cigarettes per day, for 20 years on average. Based on the Brinkmann Index, they were classified into mild active smokers and they did not show signs and symptoms of respiratory obstruction at the time of the study. Their clinical conditions were consistent with the results of spirometry without bronchodilators: mild-moderate or normal restrictive, averagely. Based on history and physical examination, neither the history nor the presence of active respiratory system diseases were found, including subjects who had the etiology of SCI i.e. spondylitis tuberculosis.

From table 2, the distance of 6MPT (p=0.002) and the QoL score increased (p=0.008) are improving, however, the SCIM III score did not show any significant improvement (p=0.271), although the participants mentioned that performing ADL and work was easier, lighter and/or faster after the study ended. There were significant improvement on lung function, FVC (p=0.005) and FEV1 (p=0.007), as well as the MIP (p=0.0001). It proved that respiratory training using IS not only improves the lung function but also able to increase the inspiratory muscle strength.

Table 1: Characteristics of subjects.

Variables	n=11
Age (year-old)	44.27±7.69
Gender (male/female)	10(90.9%)/1(9.1%)
Bodyweight (kilogram)	51.09±6.64
Body height (centimeter)	165.09±5.90
BMI	18.72±2.17
Underweight	7(63.6%)
Normal	3(27.3%)
Overweight	1(9.1%)
Vocational	
Craftsman	10(90.9%)
Mechanic	1(9.1%)
Smoking status	9(81.8%)
Duration of SCI (months)	259.63±104.37
AIS classification (Com/Inc)	10(90.9%)/1(9.1%)
Lesion Level	
T2-T11	8(72.7%)
T12-L3	3(27.3%)
Respiratory Comorbid	0(0.0%)
MMSE>24	11(100%)
Severe depression	0(0%)

Categoric data are expressed as number/frequency and percentage, numerical data as mean ± standard deviation. BMI, body mass index; AIS, *American Spinal Injury Association Impairment Scale*; T, thoracic; L, lumbar.

4 DISCUSSIONS

The demographic data is consistent with the existing epidemiology data in Indonesia that reported the majority of SCI patients were young adult males of productive age (Departemen Rehabilitasi Medik RSUP Fatmawati, 2015). The National Spinal Cord Injury Statistical Center Data in Birmingham reported that men and women ratio was 4:1, with average age of 27 years and highest occurrence at the age of 19 years (National Spinal Cord Injury Statistical Center, 2016). The results of respiratory function are influenced by several variables such as age, height, and sex, thus, they could become the confounding factors in this study (Kim et al, 2017). However, these confounding factors had been minimized in this study. SCI lesions in this study were dominantly complete lesions (according to the American Spinal Injury Association Impairment Scale criteria), most injuries were in the level of T2-T11, and the highest is T5; or they could be classified as high paraplegia where the nervous system disorders affected the respiratory muscles, both inspiratory (especially the muscles of chest wall), and expiratory muscles (McConell, 2013).

The most frequently used method for assessing physical activity is self-report by questionnaire. However, the existing questionnaire is not sensitive to the SCI population because it does not calculate ambulation using a wheelchair as in most individuals with SCI. The existing self-reports in the disabled population do not assess an important part of physical activity as well, i.e. intensity. The PARA-SCI, a specific self-report of the SCI population, is still developed (Ginis et al, 2005). The level of activity of all research subjects tended to be similar, i.e. ADL and working. Most of the study subjects were craftsmen and spent their leisure time by browsing online and singing. MMSE results showed all the subjects could follow the instruction of the exercise. Hamilton Depression results showed no depression that could interfere the exercise compliance.

Respiratory muscle dysfunction in SCI, especially in those with tetraplegic, leads to mechanical alteration in the inspiratory process which results in decreased breathing efficiency, reduced maximum static respiratory pressure, the inability of inhalation and reduced lung volume. These can be measured by FVC, FEV_1, and MIP. The FVC, FEV_1 and MIP values in tetraplegia and paraplegia (both high and low paraplegia) were proven to be lower than the predicted value of able-bodied population (Berlowitz and Tamplin, 2013; Schilero et al, 2009; Sheel et al, 2008).

Table 2: Comparison of lung function, inspiratory muscle strength, aerobic capacity, independence in ADL, and QoL pre- and post-intervention.

Variables	Pre- (n=11)	Post- (n=11)	p value
Lung function			
FVC (liter)	2.32±0.55	2.59±0.62	0.005**
FEV_1 (liter)	2.16±0.59	2.40±0.65	0.007**
MIP (cm H_20)	43.81±2.48	52.72±5.78	0.0001**
6MPT (meter)	390.63±57.59	477.72±76.60	0.002**
SCIM III scores			
Self-care	20.00	20.00	1.000
Respiration and sphincter management	33.54±4.52	34.00±4.44	0.138
Mobility	17.72±1.55	17.72±1.61	1.000
Total	71.27±4.00	71.72±3.90	0.271
QoL			
General QoL (overall well-being)	5.54±1.507	6.54±1.368	0.008**
Rating of physical health	5.27±0.786	6.63±1.026	0.004**
Satisfaction with psychological health	5.36±0.924	6.81±0.981	0.004**

Mean ± SD **p value<0,05: statistically significant different. SD: Standard Deviation; FVC: Forced Vital Capacity; FEV_1: Forced Expiratory Volume in 1 minute; MIP: Maximal Inspiratory Pressure; 6MPT: 6-Minutes Push Test; SCIM III: Spinal Cord Independence Measure III; QoL: Quality of life 2013;

Similar results appeared in this study with an average predictive value of 67% when compared to able-bodied population. These lung function results were following the average pre-intervention MIP. Based on the calculation of the predictive respiratory muscle strength in able-bodied population by Evans and Whitelaw (2009), the predicted MIP in individuals with SCI was shown below normal (68.6–101.96 cmH_2O). These could be influenced by the severity (complete/incomplete) and lesion level, duration of injury, and relatively lower (than able-bodied individuals) physical activities. The value of lung function and muscle strength are related to one another. The pressure yielded during inspiration and expiration is resulted from the activities of respiratory, diaphragm, intercostal and abdominal muscles. An increase in transpulmonary pressure of 1 cm H_2O will increase lung volume by 200 ml (Guyton and Hall, 2006). The increased lung volume results from the increase in respiratory muscle strength. This principle applies to the IMT-using-IS. This was evidenced by the statistically significant increase in post-intervention FVC, FEV_1 and MIP. Although the current study had a shorter duration, the results were consistent with the study conducted by Kim et al. (2017), which reported an increase in FVC and FEV_1 after administration of IMT-using-IS and abdominal drawing-in for 8 weeks. May be the difference is the gain of improvement of lung function. The increased skeletal muscle strength due to physical exercise occurs, especially, within the first 2 weeks of exercise, precedes an increase in muscle mass (Johnson, Sharpe and Brown, 2007).

Previous study has shown that paraplegic and tetraplegic subjects have more restricted pulmonary and cardiovascular responses to exercise and significantly lower peak oxygen consumption and minute ventilation than uninjured controls. It has also been suggested that the loss of function of the abdominal muscles, especially in individuals with an injury level above T7, can limit the ability to meet increasing expiratory requirements that occur in moderate to intense activities. It might be the reason that inspiratory and expiratory pulmonary deficits consequent to SCI impair ventilation during exercise and contribute to the lower peak oxygen consumption; however, it could be improved by training (Battikha et al, 2014). Assessing the wheeling distance for 6MPT is an easy, validated way to measure aerobic capacity in individuals with SCI (Cowan, Callahan and Nash, 2012). This study showed a statistically significant increase in 6MPT before the intervention (390.63±57.59 meters) and after the intervention (477.72 ±76.60 meters).

The effect of IMT on exercise tolerance and/or performance in SCI is less clear. In able-bodied individuals, IMT may reduce the severity of respiratory and/or locomotor muscle fatigue by attenuating or delaying the respiratory muscle metaboreflex. In SCI, it is unclear if exercise imposes sufficient stress to induce a respiratory muscle metaboreflex. Although the mechanisms underlying the increase in VO_2 peak remain elusive, some researchers speculate that increased aerobic capacity may be caused by an increase in diaphragm strength and/or a change in rib-cage configuration.

Conceivably, both changes may result in a greater circulatory pump action of the diaphragm and/or prevention of the transition to a predominant rib-cage contribution to inspiration during the latter stages of exercise, which may have the net effect of increasing venous return, stroke volume, and O_2 delivery. It is equally possible, however, that any improvements in aerobic performance may occur by way of relieving the sensation of respiratory discomfort (Taylor, 2016).

The functional ability and performance in SCI depends on several factors, such as level of injury, muscle strength, aerobic capacity, and motivation. The administration of IMT is expected to increase aerobic capacity, and ultimately improve functional performance in individuals with SCI. The SCIM III questionnaire is a tool for evaluating the level of independence in ADL comprehensively in individuals with SCI. The pre-intervention self-care subscale of SCIM III in this study had reached the maximum score (100%), indicating that all study subjects had fully rehabilitated, and were able to perform self-care independently. Respiration and sphincter management subscale scored had reached its maximum value, indicating that the study subjects were breathing independently and had fully rehabilitated for bowel bladder management. However, the extent to which lung function, will affect aerobic capacity in individuals with SCI is below the normal range of able-bodied individuals. This is primarily influenced by the severity and level of SCI lesion, as well as relatively lower (than able-bodied individuals) physical activities which worsens respiratory capacity and ultimately affects the aerobic capacity in individuals with SCI (Anneken et al, 2010; Taylor, 2016). The mobility subscale had reached the maximum score, while others could still be improved by IMT intervention, as seen in this study, although the improvements were not statistically significant. The statistically not significant difference in the results of SCIM III was due to the high score of pre-intervention results, called the ceiling effect. We propose International Spinal Cord Injury Data Sets-Activities and Participation Basic Data Set, which has a performance ratings provide insight in the actual functioning of persons with SCI in the rehabilitation setting or in the community and the point of view of perceived difficulty or satisfaction with performance; or, Comprehensive ICF Core Set for Spinal Cord Injury-chronic situation, which has a qualifier.

Although the results of SCIM III in this study were statistically not significant, some subjects reported improvement after the intervention. Most of them found it easier, lighter and/or faster when doing ADL, thus, they were more motivated to do ADL. Two subjects who previously complained neuropathic pain associated with SCI reported that the pain was reduced by the third week of training. A study conducted by Hicks et al. (2003) reported that training could improve the psychological well-being of populations with SCI, such as reducing pain and depression. This was evidenced by the statistically significant increase in the value of The International SCI data sets for QoL, which consisted of general QoL (overall well-being), rating of physical health, and satisfaction with psychological health. QoL is an important aspect of a complete outcome evaluation to document the effects of rehabilitation for persons with disabilities, including those with SCI. SCI event is unexpected and dramatically alters the course of an individual's life. It causes sudden, often devastating damage to the central nervous system, with potential adverse effects in multiple body systems. Individuals with SCI must relearn basic skills such as eating, bathing, dressing, and driving. Living with SCI may also require the use of adaptive technologies such as manual or power wheelchairs, all of which greatly affect QoL. Individuals with SCI also often have to cope with altered social roles and psychiatric comorbidities including reactive depression and anxiety disorders. These issues represent major challenges to living with SCI. Therefore, anything we can do for the QoL of an individual with SCI is worth it (Tulsky et al, 2015). As well as the experience in this study, although they were chronic cases that could cope with SCI, they should be persuaded for the exercise.

The limitation of this study was that the detailed physical activity of subjects, as a potential confounding factor, was not recorded and assessed due to the lack of a questionnaire that could accommodate the activities of individuals with SCI. We suggest future studies with a large sample and/or different research designs (randomized controlled clinical trials). We also suggest future studies focusing on subacute phase SCI to assess the effect of IMT on improving the functional training performance, shortening the length of stay, and reducing treatment cost.

5 CONCLUSIONS

Individuals with chronic paraplegia from SCI often survived with a lot of functional disabilities including respiratory that can lead to physical inactivity and deconditioning that affect the QoL. Our study shows that the inspiratory muscle training with an incentive spirometer 5 sets of 10 repetitions per day, 5 days per week for 4 consecutive weeks, could improve lung function, inspiratory muscle strength, increase aerobic capacity and quality of life, but not functional of individuals with chronic paraplegia from SCI that had fully rehabilitated. Therefore, it is encouraged to add IMT-using-IS in the management of chronic SCI to improve aerobic capacity and QoL.

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