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Effectiveness of Respiratory Muscle Training Interventions in Patients with Spinal Cord Injury; A Literature Review

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Abstract

Spinal Cord Injury (SCI) level tinggi dapat menyebabkan gangguan pada pernapasan yang dapat mengancam nyawa pasien. One of the interventions that can be given to individuals with SCI in reducing complications of respiratory problems is Respiratory Muscle Training (RMT). Respiratory Muscle Training (RMT) is a technique that aims to improve the function of the respiratory muscles through specific exercises. This study determined the effectiveness of respiratory muscle training in spinal cord injury patients with respiratory problems. This literature review used several databases such as Google Scholar, Pubmed, Ebsco, Sciencedirect, CINAHL, and SAGE with inclusion criteria Articles published less than five years (2018-2022), English, Full text, Systematic review/meta-analysis/RCT. The results indicate that this RMT intervention's effectiveness on respiratory muscles and lung function depends on the characteristics of SCI patients. There were six articles used for the review of this paper. The results show that this respiratory muscle training intervention's effectiveness impacts respiratory muscles and lung function depending on the characteristics of the spinal cord injury patient himself. Furthermore, the results suggest that this RMT intervention's efficacy on respiratory muscle and lung function depends on the features of the SCI patient.

Keywords: Respiratory Function Disorder, Spinal Cord Injury, Respiratory Muscle Training or exercise, Pulmonary Function.

Introduction

Spinal cord injury (SCI) or spinal cord injury refers to damage to the spinal cord as a result of trauma (e.g. car accidents) or from disease or degeneration (e.g. cancer) (WHO, 2013). SCI is a severe medical condition and often results in morbidity and permanent disability. This condition is related to nerve axon damage in the spine which can lead to loss of motor and sensory function below the level of injury (Eckert & Martin, 2017). Symptoms of SCI depend on the severity of the injury and its location in the spine (WHO, 2013). SCI patients may experience symptoms related to partial or complete loss of sensory function or motor control of the arms, legs or body.

Other symptoms can include disorders of the system that regulates bowel or bladder control, breathing, heart rate and blood pressure. SCI can cause significant functional impairment for the rest of the patient's life and puts the individual at risk of various complications that lead to increased morbidity and mortality (Alizadeh, 2019).

The prevalence of SCI is estimated at 40 to 80 cases per million, with the most common cause being trauma (WHO, 2013). The worldwide incidence of SCI is 10 to 83 per million people. The prevalence of cervical SCI (CSCI) is 55%, and lower spinal cord injury is 45%. A study by Devivo et al. suggests that high-grade cervical injuries have increased over the past decade. Respiratory complications are the most common cause of mortality and morbidity in SCI patients (Nygren-Bonnier et al., 2018).

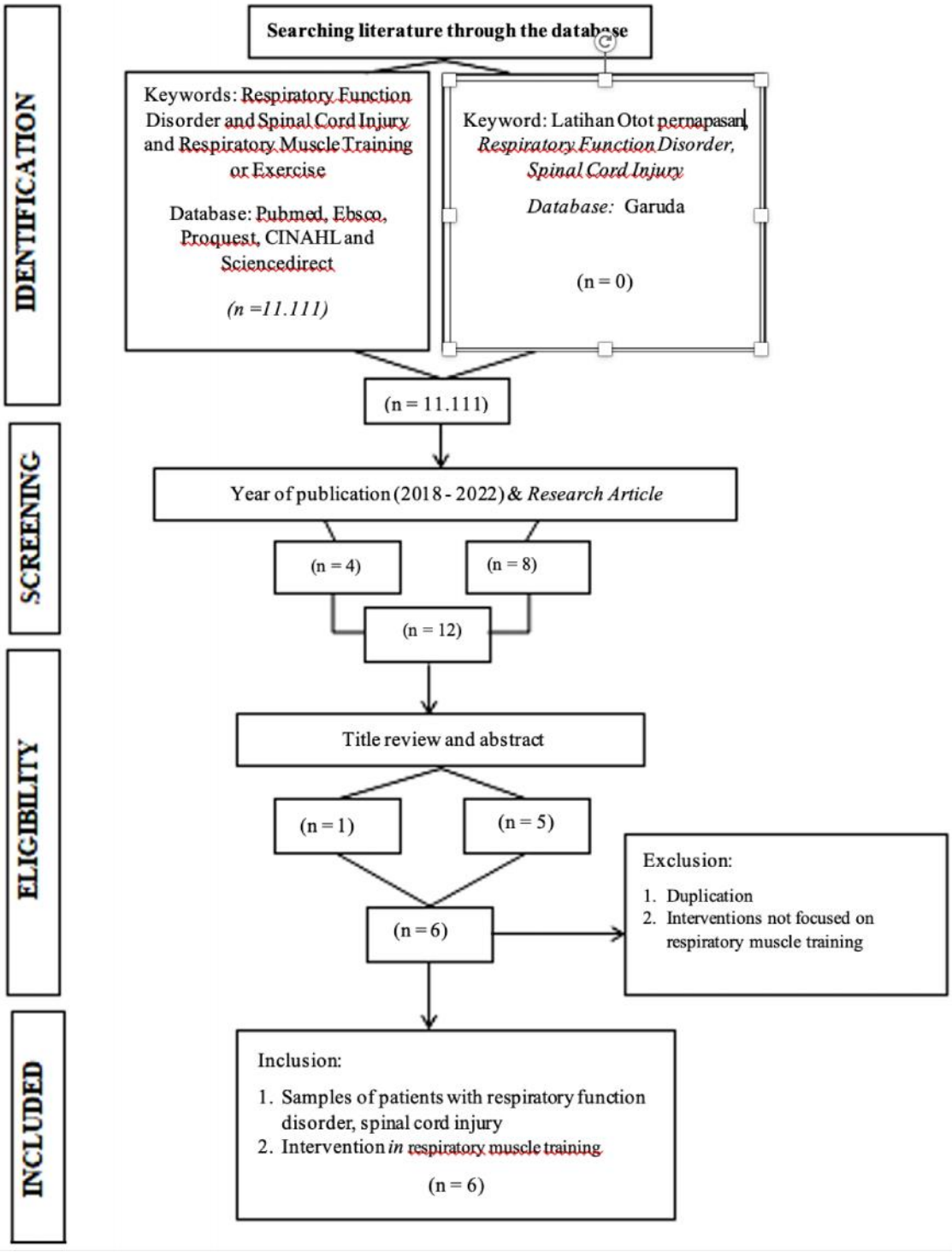
Neurological disorders experienced by high-level (cervical) SCI patients can cause a decrease in vital lung capacity (VC) and total lung capacity (TLC) due to respiratory muscle dysfunction. Cervical SCI patients may experience respiratory muscle weakness, resulting in lower intrathoracic and expiratory pressures than healthy individuals. These conditions can cause a decrease in the ability to cough effectively, which can lead to impaired airway clearance in SCI patients. If secretions in the patient's airway are not corrected, it can lead to atelectasis, retention of secretions, infection, and impaired gas exchange (Nygren-Bonnier et al., 2018).

One of the interventions that can be given to SCI patients to reduce complications of respiratory problems is Respiratory Muscle Training (RMT). Respiratory Muscle Training (RMT) can be defined as a breathing exercise technique that aims to improve the function of the respiratory muscles through specific exercises. RMT focuses on increasing the energy-generating capacity of the inspiratory and expiratory muscles (Sapienza et al., 2011). However, the literature regarding the effectiveness of RMT in SCI patients is still limited. Therefore, this study was conducted to identify the effectiveness of Respiratory Muscle Training in Spinal Cord Injury patients with respiratory problems.

Research Methodology

The method used in the search for articles is based on the period 2018-2022 through searches from databases such as Pubmed, Proquest, Ebsco, Sciencedirect, and CINAHL. The search was conducted using the keywords: Respiratory Disorder, Spinal Cord Injury, Respiratory Muscle Training or exercise, and Pulmonary Function. With inclusion criteria Articles published for less than five years (2018-2022), in English, Full text, Systematic review/meta-analysis / RCT. Exclusion criteria included articles that did not follow the purpose of writing EBP and articles that did not use respiratory muscle training to intervene in patients with spinal cord injuries. The keywords used in the search for articles in this study were "((Respiratory Disorder) AND (Spinal Cord Injury) AND (Respiratory Muscle Training OR Respiratory Muscle Exercises) AND (Pulmonary Function))". This literature review aims to determine the effectiveness of respiratory muscle training interventions in patients with spinal cord injuries. The final result of the article search is six articles analyzed in this paper. The flow of the search for the article can be seen in Figure 1 below.

Figure 1. PRISMA Flow Chart



Results And Discussion

The search results in this study found six articles that met the criteria and were under the research topic. The search was conducted by identifying the author and year of publication, research title, design, respondents, RMT technique used, and result. The search results can be seen in

table 1.

Table 1. Results of the literature review

No.	Author & Year	Respondents	Design	Intervention (RMT Technique Used)	Result
1.	(Gee et al., 2019)	athletes with a history of spinal cord injury	Experiment	Athletes completed two sessions of 30 repetitions of the RMT threshold pressure five days a week for six weeks.	After six weeks, the intervention significantly improved the ability to generate inspiratory and expiratory mouth pressures, as well as PEF. The initial inspiratory mouth pressure threshold was set at 43±6 cmH2O and progressively increased to 64±9 cmH2O. Similarly, the expiratory mouth pressure threshold was set at 35±6 cmH2O and increased to 43±12 cmH2O. RMT also prevents dynamic hyperinflation during submaximal incremental exercise and increases peak work rates. Collectively, these findings suggest that RMT has the potential to increase aerobic exercise capacity in athletes with cervical SCI.
2.	(Legg Ditterline et al., 2018)	People with chronic SCI ranging from C2 to T11 participated in RT (n=24), and untrained chronic SCI controls ranging from C2 to T9 (n=20).	A case-controlled clinical study.	A total of 21 ± 2 RMT sessions were performed five days a week over four weeks using a combination of pressure threshold inspiratory and expiratory devices.	In contrast to the untrained controls, individuals in the RT group experienced significantly increased FVC and FEV1 ($p < 0.01$) concerning improvements in sleep, cough, and speech quality. Sympathetic (phase II) and parasympathetic (phase IV) mediated baroreflex sensitivity were both significantly ($p < .05$) increased during 5s of MEP. During the orthostatic stress test, increased autonomic control over HR was associated with a significant increase in sympathetic and parasympathetic modulation (low and high-frequency changes, $p < 0.01$ and $p < 0.05$, respectively)
3.	(Raab et al., 2019)	Spinal cord injury patients with C4-T12 lesion grade and AIS A to D, male and female patients 18 years of age, with traumatic SCI or Non-traumatic.	Retrospective cohort study	Inspiratory muscle training was performed with the Threshold IMT, a small handheld device with a mouthpiece and spring valve. The valve will provide a constant inspiratory pressure training load, and the participant must generate negative pressure large enough to open the inspiratory valve and inhale air. The valve is calibrated and can be adjusted (9–41 cmH2O) according to the participant's maximum PI.	Overall results, 67 people were analyzed. The variation in maximal PI is explained by maximal PI at baseline and training intensity. This adjusted effect size suggested a 7% increase (95% CI 2.8 to 11.6%) in maximal PI per 10 units of increase in exercise intensity. Controlling for variation in maximal baseline PE, the effect of exercise intensity on maximal PE was dependent on the AIS ($p < 0.021$). At the same time, individuals with complete motor lesions increased PE. by 6.8% (95% CI 2.1 to 11.7%). Maximum per 10 unit increase in exercise intensity, the adjusted effect size in those with incomplete motor lesions was 0.1% (95% CI 4.3 up to 4.5%). Conclusion Inspiratory muscle exercise intensity is more relevant than exercise volume for increasing respiratory muscle strength in individuals with SCI.
4.	(Sonali	Samples of	Randomize	Group 1 BMI	Of the 30 participants, 27 completed the study. The

No.	Author & Year	Respondents	Design	Intervention (RMT Technique Used)	Result
	Soumyashree & Jaskirat Kaur, 2018)	30 people with paraplegia (T1-T12), time of injury >3 months, age 18 years and over, complete/incomplete injury, and able to push a manual wheelchair	d Controlled Trial	(Inspiratory Muscle Training) received inspiratory muscle training for 15 minutes 5 times a week for four weeks while group 2 control was given breathing exercises.	results showed that after four weeks of BMI training, there was a significant increase in the mean change score of the BMI group compared to the control group. Participants in the BMI group performed better at 12MWAT (P = 0.001), MSFT (P = 0.001) and 6MPT (P = 0.001). Improvements in MIP scores (P = 0.001), MEP scores (P = 0.001) and MBS scores (P = 0.004) were also seen in the BMI group.
5.	(Xi et al., 2019)	Eighteen patients with spinal cord injury >24 months post-injury and without regular respiratory muscle training before the study were prospectively included.	Pilot Short-Term Randomized Controlled Trial	Patients in the normocapnic hyperpnea group did 15-20 minutes of training daily, five times a week, for four weeks. The patient is hyperventilated through partial re-breathing of ventilated air. The control group did not receive respiratory muscle training. Other rehabilitative programs were carried out identically in both groups. Test Lung function was performed before and after the study in a sitting position.	There was a significant difference in the ratio of improvement in lung function between the NH group and the control group for all investigated parameters, except total lung capacity (TLC) and lung diffusion capacity for carbon monoxide (DLCO). In addition, significant differences in FVC and Borg scores were found between high and low-grade lesions, both before and after the study (high vs low FVC 53.6 ± 10.8 vs 68.6 ± 16.9 (before, $p<0.05$), 44.8 ± 17.8 vs 68.6 ± 21.3 (post, $p<0.01$), Borg score in high vs low levels 5.0±0.8 vs 3.0±1.8 (pre, $p<0.01$), 5.0 ±2.0 vs 3.0±1.0 (post, $p<0.01$)). However, the repair ratio did not depend on the extent of the lesion.
6	(Shin et al., 2019)	The sample of this study was 104 Spinal Cord Injury patients who were admitted to Yonsei University Hospital for short-term (4-8 weeks) treatment.	Retrospective study	Respiratory muscle training and care consisted of glossopharyngeal breathing exercises performed ten times a day more than five days a week, inspiratory muscle strengthening using incentive spirometry	FVC results increased in all subgroups after the respiratory muscle exercise intervention. Thus, these results suggest that various components of respiratory muscle training can contribute to producing varying degrees of therapeutic effect on lung function. However, the effect of respiratory muscle training on lung function can depend on the characteristics of the spinal cord injury patient. Although respiratory muscle training showed relatively better results in the subacute phase of SCI, patients with chronic SCI could still benefit substantially from the intervention and should therefore consider administering respiratory muscle training.

No.	Author & Year	Respondents	Design	Intervention (RMT Technique Used)	Result
				performed daily or more than five times a week, and air stacking exercises with resuscitation bags performed more than five times a week.	

Spinal cord injury (SCI) or spinal cord injury patients may experience loss of motor and sensory function below the level of the injury, an injury that can be traumatic or nontraumatic. SCI patients can experience disturbances in the digestive, urinary, respiratory, heart rate, and blood pressure systems, resulting in morbidity and permanent disability due to spinal cord damage due to trauma. Cervical spinal cord injury (SCI) will result in respiratory dysfunction due to loss of motor control over the main respiratory muscles (Brown et al., 2006). The primary muscle of inspiration, the diaphragm, is supplied by the phrenic nerve (spine segments C3-C5), whereas the primary muscle of active expiration, the abdominal muscles, is supplied by the spinal segments T4-T11.

Respiratory problems in SCI patients can lead to death, so they need special treatment. One of the interventions that can be given to individuals with SCI to reduce complications of respiratory problems is Respiratory Muscle Training (RMT). The purpose of Respiratory Muscle Training (RMT) in individuals with SCI is to increase the strength and endurance of the respiratory muscles by using methods such as impedance loads and threshold pressure loads because the main problem for individuals with SCI is respiratory complications due to weak respiratory muscles, which often results in respiratory muscle weakness. Lower intrathoracic and expiratory pressures.

Based on the results of the search for articles, all respondents experienced or had a history of cervical or thoracic spinal cord injuries. People who experience cervical SCI show dynamic hyperinflation, where the increase in exercise intensity is accompanied by an increase in the final expiratory lung volume above the resting value. They were increasing inspiratory and expiratory pressure ability after cervical SCI by pumping the respiratory muscles and decreasing lung volume to increase venous return to increase oxygen and train the respiratory muscles.

RMT is done with various techniques by doing inspiration and expiration exercises. Exercise is done 10-15 minutes, five days a week, for 4-6 weeks. Exercises are carried out using various devices such as a spirotiger. All devices used can help exercise the respiratory muscles to increase muscle endurance. In addition, maximum expiratory and inspiratory pressure exercises can improve lung function (Xi, et al., 2019).

Based on the search results in this study, it was found that RMT was proven effective in inspiratory and expiratory pressure, aerobic exercise cavity, FVC and FEV 1, and lung function. RMT can prevent dynamic hyperinflation during exercise and

increase peak work rates. Aerobic capacity in SCI patients depends on several factors, including the level of injury, body mass index, age, and activity level. Studies have shown that the aerobic capacity of people with paraplegia is lower than that of non-disabled people. Collectively, these findings suggest that RMT has the potential to increase aerobic exercise capacity. This result is in line with El-Kader's study in 2018 that there was a significant increase in arterial partial pressure of oxygen (PaO2), partial pressure of arterial carbon dioxide (PaCO2), and PH after six weeks of a resistive respiratory muscle exercise program ($p<0.05$).

RMT can influence and improve breathing and cardiac autonomic function, which improves cardiovascular stress response in people with chronic SCI and thus improves pulmonary function outcomes (Legg Ditterline et al., 2018). In addition, respiratory muscle training can produce a degree of therapeutic effect on lung function.

Conclusions

Respiratory disorders in SCI patients are one of the conditions that can endanger the patient's life, so it requires appropriate intervention. RMT is one of the interventions that aim to improve the ability of inspiration and expiration to improve the ability of lung function. RMT can be done by breathing exercises for 10-15 minutes in 5 days/week for 4-6 weeks using various devices such as a spirotiger. RMT effectively increases inspiratory and expiratory pressure, aerobic exercise cavity, FVC and FEV1, and lung capacity.

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