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MEASUREMENT AND COMPARISON OF RESPIRATORY PARAMETERS IN PATIENTS WITH SPINAL CORD INJURY AT THE CERVICAL, THORACIC AND LUMBAR REGIONS BY USING A SPIROMETER DEVICE

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ABSTRACT

Introduction and objective:Respiratory disorders, after damage to the spinal cord, are considered the most common cause of death in patients with spinal cord injury. The evaluation of the respiratory parameters by using spirometry is a convenient way to check the respiratory function. The aim of the study is to examine and compare the respiratory parameters in patients with different levels of spinal cord injury by using a spirometer.
Materials and methods :In this study, spirometry test was performed for 163 patients with spinal cord injury (76 women and 87 men) covered by a home health care team in Kahrizak charity of Tehran as well as a control group of 192 healthy subjects (81 women and 111 men). The spirometer device, BIONET SPM-300 was used and three respiratory tests, FVC, SVC and MVV were carried out by the subjects. Respiratory parameters of FEV1, FVC, FEV1 / FVC, FEF25-75%, PEF, TV and MVV were measured. Analysis of variance was used for data analysis.
Findings: Respiratory parameters in spinal cord injury patients was much lower than the control group ($P<0.05$). All indicators in all three regions of the cervical and thoracic and lumbar injury had a statistically significant difference with the control group except the indicator of TV and FEV1 / FVC in the lumbar group that respectively had $P = 0.10$ and $P = 0.49$ compared to the control group.
Conclusion: In summary, in this study it was shown that the damage to the spinal cord and its subsequent neuromuscular weakness will cause a dramatic drop in respiratory parameters among patients who suffering from this damage. The results of this study show that as the levels of damage become higher and the neurological conditions of patients become worse, all under study respiratory parameters will be significantly decreased. Instead, these changes will become smaller in lower levels of damage.

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Introduction

Damage to the spinal cord usually occurs due to the shearing, flexural and compressive forces which causes spinal dislocation or fracture. Subsequent clotting of blood or vertebral dislocation can cause spinal cord compression. In addition

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to the traumatic causes which are considered the most common causes of spinal cord injury, tumors, vascular disorders and a variety of systemic infections can also be mentioned as other causes of spinal cord injuries. Annually, about 12,000 new patients of spinal cord injury are added to the group of former patients [1]. Spinal cord injury, arisen for any reason, can cause damage, destruction of nerve structures and pathophysiological effects in uninvolved tissue. Therefore, the partial or complete lack of sensory and motor functions is the most important consequence of the damage and the majority of patients will experience secondary complications such as bowel and bladder dysfunction, chronic pain, infertility, and autonomic dysfunction.

Due to the fact that paralysis of the muscles in spinal cord injuries is determined through the imposed neurological damage, it can be surmised that as the damage occur at higher levels and more completely, respiratory muscle disorders are also more likely. Sub-breathing muscle weakness accompanied by a reduction in the compliance of the chest wall and lung volume reduction, in total, leads to severe respiratory inefficiency among patients with spinal cord injury. Inspiratory muscle weakness in people with tetraplegia reduces their ability to create deep breathing and ultimately, contributes to atelectasis and increase the risk of pulmonary pneumonia. On the other hand, expiratory muscle weakness in people with tetraplegia cause disruption in the ability to cough up and finally, the inability of the patient in removing the sputum from lungs and this condition, in turn paves the way for pneumonia, atelectasis and ultimately, premature death in these individuals.

With increasing age, the risk of pneumonia and apnea will increase among patients while they are resting. Studies have shown that those spinal cord injuries that occur in the cervical region are more able to increase the likelihood of suffering from respiratory infections that is mostly due to the patients' inability to cough up. Apnea, in turn, can also affect the quality of these individuals' sleep and can even lead to sudden death in patients with Spinal cord injury.

Breathlessness is considered the most common symptom of respiratory disorder in patients with spinal cord injury particularly in tetraplegia levels [3, 4, 5]. As the level of the damage decrease, the intensity of this signal will become lower. Studies have shown that Spinal cord injury can disrupt functions such as coughing and deep breathing because somehow, it affects the activities of their nerves. The loss of the inspiratory and expiratory muscle function among patients with Spinal cord injury leads to a sharp drop in the overall volume of their lungs and finally, can cause diseases such as pneumonia and atelectasis [6, 7, 8] that treating these secondary complications takes a great deal of medical expenses and time [9]. Therefore, it is necessary to study the parameters and respiratory disorders in patients with Spinal cord injury at broader and more precise levels and the aim of this research is to evaluate and compare indicators of respiratory diseases in patients with different levels of Spinal cord injury and healthy subjects by the spirometer.

Methods

This is a non-experimental, cross-sectional and descriptive-analytical study. The population under study consists of patients with Spinal cord injury (both women and men) in both types of incomplete and complete that is covered by home health care team in Kahrizak charity of Tehran. 163 patients of the center were selected for the Spirometry test. Codes and ethical standards were fully respected. After obtaining subjects' consent for participating in the research, the objectives of the study were fully explained to them. In order to reduce the existed problems in moving the patients and also, to reduce the costs in conducting breath test, the tester went to the patient's home with the device and the entire process of the test was done in the patients' homes.

In this study, the case control method has been used for collecting data. Spirometer device were used in this study to evaluate respiratory parameters. The device used in this study is BIONET SPM-300 model and is made in South Korea. FVC (VC), FEV1, FEF25% -75%, PEF, TV, MVV and the ratio of FEV1 / FVC are indicators that were examined in this study. For ethical and health approvals, a one-time use mouthpiece was considered for each subject (for both groups of normal and patient individuals) in this study. The test was carried out after a full explanation of the steps of the test for the patient and ensuring their normal and stable conditions. So that a unique mouthpiece was given to each person and in accordance with the instruction, they were asked to breathe three times in the mouthpiece. The mouthpiece should be placed in the mouth so that air flow couldn’t come out from the sides of the mouth. Also, the mouthpiece shouldn’t prevent the tongue from being at the proper place. All tests were done in a sitting position. Those patients who were able to control their trunks were tested in chairs without back and those patients who were not able to control their trunk (often cervical patients) were tested by bringing up a flat surface and creating a position close to sitting (of course with backrest).

The device has three options for conducting the test: Including the tests of FVC, SVC and MVV. The first test puts the indicators of FVC, FEV1, the ratio of FEV1 / FVC, FEF25-75% and the indicator of PEF at the disposal of the experimenter; So that, after the insertion of the unique mouthpiece in his mouth and putting the clamp nose, the individual will be asked to breathe in with maximum effort and without stopping in the maximum point, immediately exhale with maximum effort which will take as 6 seconds. The test is performed three times and the best values are recorded in the files related to each patient. The second test is performed to calculate the TV indicator. After putting the clamp nose and ensuring that the mouthpiece is in the right place, the individual would be asked to act according to the instructions and after three slow breaths in the mouthpiece, when the examiner said, the fourth breathe should be done with maximum effort (Either during the inhaling or during exhaling) and then, slowly resume the fifth breathe. This test is also performed three times, and the best value of TV will be recorded. The third test, as the name implies, is used to calculate the indicator of MVV. After putting the clamp nose and ensuring that the mouthpiece is in the right place, the individual would be asked to look at the monitor of the device and simultaneously, according to the instructions, with the maximum effort and as quickly as possible, do consecutive breaths in the mouthpiece.

After 12 seconds automatically, the test's time will end and it will be stopped. Obtaining the visual feedback from the ascending graph of this test from the screen is why the patient must look to the monitor device. In fact, as the patient breathe faster and harder is graph will go higher. This test will not be repeated because of the excessive fatigue of respiratory muscles and the possibility of reducing the MVV indicator in the second and third tests.

In the statistical discussion of this research, average and standard deviation statistics were used to describe the variables and analysis of variance was applied to compare the mean respiratory parameters in various groups under study. Data do not follow a normal distribution, but due to the high volume of samples under study, parametric and non-parametric statistical tests show the same output. In this study, the significance level is considered $P \leq 0.05$. SPSS version 22 software was used to analysis and conduct statistical tests.

Findings

Subjects in the spinal cord group consisted of 76 women and 87 men and the subjects in the control group included 81 women and 111 men. From a total of 163 patients with injury, 46 people suffered from cervical injury (22 women and 24 men), 71 patients had damage on the thoracic surface (33 women and 38 men) and 46 people suffered from Lumbar spinal cord damage (21 women and 25 men).

Table 1 shows that all the under research respiratory parameters between the group of spinal cord injury and control group have significant differences. ($P < 0.05$)

Table 1. Test results of comparing each of the studied variables between two groups of healthy and spinal cord injury

Variable	group		t	p-value
	Healthy	spinal cord injury		
FEV1	Mean: 2.425 Standard deviation: 0.900	Mean: 1.537 Standard deviation: 0.662	-10.678	0.000
FVC	Mean: 2.928 Standard deviation: 0.964	Mean: 1.952 Standard deviation: 0.757	-10.663	0.000
FEV1/FVC	Mean: 81.691 Standard deviation: 6.295	Mean: 77.725 Standard deviation: 7.786	-4.810	0.000
FEF25-75%	Mean: 2.905 Standard deviation: 1.044	Mean: 2.026 Standard deviation: 0.916	-8.360	0.000
PEF	Mean: 4.639 Standard deviation: 2.093	Mean: 2.802 Standard deviation: 1.335	-9.996	0.000
TV	Mean: 0.911 Standard deviation: 0.412	Mean: 0.696 Standard deviation: 0.308	-5.603	0.000
MVV	Mean: 40.825 Standard deviation: 14.177	Mean: 28.575 Standard deviation: 11.012	-9.153	0.000

The results obtained from this table show the significant difference of respiratory indicators between patients with spinal cord injury and healthy subjects. Also, the results obtained from equivalent nonparametric test (Mann-Whitney test) shows the same p-values. According to the Levven test, indicator of FEF25-75% had a stable variance in both groups, so the results indicated in this table for this indicator is also based on the stability of the variance of this variable.

Table 2 shows the comparison results of respiratory parameters in patients with spinal cord injury (separating level of injury) with the control group.

Table 2. Comparison of the studied variables between healthy people and people with spinal cord injuries by separating the level of their injury

Variable	Group	Group	The mean difference	P value
FEV1	Healthy Mean: 2.425 Standard deviation: 0.900	Cervical Mean: 0.908 Standard deviation: 0.398	1.517	0.000
		thoracic Mean: 1.641 Standard deviation: 0.540	0.784	0.000
		Lumbar Mean: 2.004 Standard deviation: 0.568	0.421	0.001
FVC	Healthy Mean: 2.928 Standard deviation: 0.964	Cervical Mean: 1.247 Standard deviation: 0.517	1.681	0.000
		thoracic Mean: 2.080 Standard deviation: 0.649	0.848	0.000
		Lumbar Mean: 2.462 Standard deviation: 0.584	0.466	0.001
FEV1/FVC	Healthy Mean: 81.691 Standard deviation: 6.295	Cervical Mean: 72.747 Standard deviation: 7.797	8.944	0.000
		thoracic Mean: 78.905 Standard deviation: 8.542	2.787	0.006
		Lumbar Mean: 80.882 Standard deviation: 8.117	0.809	0.496
FEF25-75%	Healthy Mean: 2.905 Standard deviation: 1.044	Cervical Mean: 1.232 Standard deviation: 0.520	1.674	0.000
		thoracic Mean: 2.195 Standard deviation: 0.885	0.711	0.000
		Lumbar Mean: 2.560 Standard deviation: 0.742	0.345	0.024
PEF	Healthy Mean: 4.639 Standard deviation: 2.093	Cervical Mean: 1.666 Standard deviation: 0.767	2.974	0.000
		thoracic Mean: 3.012 Standard deviation: 1.298	1.628	0.000
		Lumbar Mean: 3.615 Standard deviation: 1.071	1.025	0.000
TV	Healthy Mean: 0.911 Standard deviation: 0.412	Cervical Mean: 0.487 Standard deviation: 0.18	0.424	0.000
		thoracic Mean: 0.755 Standard deviation: 0.338	0.156	0.002
		Lumbar Mean: 0.815 Standard deviation: 0.257	0.096	0.103
MVV	Healthy Mean: 40.825 Standard deviation: 14.177	Cervical Mean: 19.947 Standard deviation: 6.942	20.878	0.000
		thoracic Mean: 30.626 Standard deviation: 11.740	10.199	0.000
		Lumbar Mean: 34.039 Standard deviation: 7.792	6.786	0.001

The result of this table shows that respiratory indicator of TV and the ratio of FEV1 / FVC had no significant difference between the Lumbar and control group. The lack of statistically significant difference between the two indicators is also evident by nonparametric tests. ($P \geq 0/05$)

Discussion

This study aimed to evaluate and compare the respiratory parameters in patients with different levels of spinal cord injury by means of spirometry device. A spirometer was used to evaluate the parameters of FEV1, FVC, FEV1 / FVC, FEF25-75%, PEF, TV and MVV in spinal cord injury and control patients.

A full respiratory function in individuals depends on the existence of a healthy and flawless neuromuscular system. Important respiratory muscles such as the diaphragm and intercostal muscles, take nerves from cervical and thoracic nerves. According to the fact that the muscle of diaphragm is known as the main respiratory muscle and this muscle takes nerve from 3, 4 and 5 cervical nerves, it is expected that the damage to the spinal cord at the cervical region put the greatest impact on the respiratory function of people. The majority of this impact is attributed to the more severe neuromuscular direct paralysis due to the damage and partly is attributed to the immobility of patients with cervical injury levels than other levels of damage. Based on our research results, respiratory parameters in patients with spinal cord injury have undergone many changes compared with healthy subjects (Table 1) also these changes are maximum in cervical injury levels (Table 2). This result is also shown in previous studies [2]. More impacts of the injury at this level on expiratory muscles than the inspiratory muscles can be known as the cause of these more changes. This situation results in the inability of patients with damage in cervical region in doing the act of coughing, because the 5, 6 and 7 cervical nerves are affected and eventually, leads to diseases such as atelectasis. Also, in these individuals, the Lung vital capacity will be affected most because of the more severe neuromuscular weakness compared to other levels of injury.

In the present study it has been shown that respiratory parameters of FEV1 and FVC and FEV1 / FVC will undergo a significant decline by the damage to the spinal cord compared with healthy subjects without injury (Table 1). Also, in this study, as the levels of damage become lower, the level of FEV1 and FVC and FEV1 / FVC indicators will increase, until it reaches the level in which despite the decline in FEV1 and FVC in the lumbar region of the injury, the ratio of these two indicators do not have a significant difference with healthy subjects (Table 2). In other words, the reduction of both indicators, FEV1 and FVC, in Lumbar patients does not affect the ratio of these two indicators. The growing reduction in FEV1 and FVC has also been shown in previous studies [3, 11, 12, 13].

The present study shows that compared to healthy subjects, the MVV indicator has undergone a significant reduction when the spinal cord has been damaged (Table 1), also, it is shown that as the level of the damage increases, this parameter will experience a greater reduction (Table 2). This is because the involved respiratory muscles are more affected and their working capacity is reduced in high levels of damage. This result has also been shown in previous studies [2, 12, 14].

The indicator of TV can indicate the amount of oxygen exchange at the end of the airways [15, 16, 17]. The reduction of this indicator cause gas exchange inefficiency in the individuals' respiratory system. Our study shows that with the damage to the spinal cord, this indicator will significantly decline, compared to the healthy subjects (except in individuals with damages in lumbar region) (Table 1 and 2). This respiratory parameter will decrease sharply in individuals who suffer from levels of cervical spine injury that this sharp reduction will eventually be the leading cause of atelectasis in patients with spinal cord injury. The results of the present study show that this respiratory indicator will be significantly decreased for high levels of injury (Table 2). More efficiency of people with lumbar spinal cord injury than other levels of injury is why there is no statistically significant difference for respiratory indicator in individuals with lumbar levels of injury compared to the control group.

The indicator of PEF is another respiratory parameter in relation to the effectiveness of expiratory muscles and the act of cough. This respiratory indicator is in relation with the action of pectoralis major and latissimus dorsi muscles. So it can be said that with regard to the nerves' action in these two muscles, this respiratory parameters will be reduced as the level of injury increase [12.18].

The present study has shown that the damages to the spinal cord will decrease this indicator dramatically and significantly in comparison with healthy people (Table 1). Also this parameter will decline more sharply in higher levels of spinal cord injury (Table 2). According to these results, the causes of cough performance inefficiency in patients with spinal cord injuries can be interpreted.

The respiratory parameter of FEF25-75% is an indicator that is associated with the diameter of the airways. This respiration parameter will decrease with a reduction in the diameter of the airways. Increasing the power and ego engine of the airways that occurs due to disruption of the sympathetic system, can be the reason of this reduction [19]. The results of this study show that when the spinal cord has been damaged, this respiratory parameter will be reduced (Table 1). Also, it is shown that the higher the level of damage, the greater the changes of respiratory indicator (Table 2).

Conclusion

In summary, our research results show that the damages to the spinal cord and the subsequent neuromuscular weakness will lead to a dramatic drop in respiratory parameters for people with this damage. The results of this study show that all under study respiratory parameters will be significantly decreased with an increase in levels of injury and worsening the neurological conditions of individuals. Instead, and with lowering the levels of damage, the changes will also be reduced, so that the results of this study show that there is no statistically significant difference between respiratory parameters of TV and the ratio of FEV1 / FVC in patients with lumbar levels of injury and the control group. It is hoped that the results of this research and similar studies, motivate the researchers to pay more attention to the function of the respiratory system of these patients in order to intensify their effort to reduce disturbances after injury and improve the life quality of patients with spinal cord injury.

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