Comparison of Respiratory Muscle Electromyography between Adolescent Idiopathic Scoliosis and Healthy Subjects

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ABSTRACT

Purpose: Scoliosis is one of the most common spinal deformities that affect chest wall mechanics. Scoliosis results in ventilator disorders and respiratory muscle weakness. However, the mechanism of these disorders is still unknown. The main objective of this study was to identify the intensity of respiratory muscles activity in patients with idiopathic scoliosis compare with healthy individuals and determine the relationship between scoliosis degree and respiratory dysfunctions. In this study, 20 female patients with adult idiopathic scoliosis (mild, moderate) as well as 10 healthy matched individuals with characteristics of the patients were selected.

Methods: Electromyography values were recorded through rest phase. In addition, the electromyography values of external intercostal muscles and diaphragm were recorded bilaterally.

Results: The RMS of concave and convex external intercostal muscles and concave diaphragm in patients with idiopathic scoliosis were reduced significantly relative to healthy individuals in rest ($P<0.001$, $P<0.001$, $P=0.023$). .There was a correlation between scoliosis degree and decrease in concave and convex intercostal muscle performances ($P=0.001$) but there was no correlation in diaphragm muscle.

Conclusion: Respiratory muscle performance is drastically decreased in patients with adult idiopathic scoliosis. There was a relationship between scoliosis degree and respiratory dysfunction. This reduction has more observed in concave side and resulted in reduced physical capacity.

Key Words:

Adolescent
Idiopathic Scoliosis,
Electromyography.
Respiratory Muscles.

1. Introduction

Scoliosis is a three-dimensional deformity [1] and the most common spinal disorder, which directly affects the chest wall [2]. Scoliosis classified either as congenital or [3] adolescent idiopathic scoliosis, results in lateral and rotational curvature of the spine [1]. The onset of this disease occurs during adolescence in healthy individuals [4].

The prevalence of idiopathic scoliosis is 1 to 3% among adults [1], in the thoracic spine [5,6]. Factors contributing to the development of respiratory disorders are not clearly known but analyses of the relationship between respiratory disorders and scoliosis angle reveal that increase in the scoliosis angle leads to the increase of respiratory disorders as well [7].

Even in asymptomatic mild scoliosis with no signs of respiratory dysfunction during rest and exercise, incorrect ventilatory patterns can be seen [8]. Respiratory muscles (intercostals, abdominal muscles, and diaphragm) are the most affected muscles [9].

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Barrios et al. (2005) assessed the ventilatory functione of patients with adult idiopathic scoliosis with mild and moderate curvature. Although patients with mild and moderate scoliosis do not show any cardiopulmonary limitations in static mode, they are less tolerant to maximum exercise tolerance tests. The reasons of decrease in tolerance of these patients are respiratory failure with low ventilatory capacity and reduced levels of maximum oxygen volume (VO2) [10].

Llorens et al. (2010) analyzed the relationship of ventilatory dysfunction and weakness of respiratory muscles with exercise limitations. There was apparently a relationship among the respiratory capacity of patients, the strength of their inspiratory, expiratory muscles and lower extremities muscles. These relationships were the main causes of diminished exercise capacity in these patients [11].

In spite of the importance of respiratory muscles in the respiratory, cardiovascular, and positional complications of scoliosis, no study has been conducted on the changes of the activity of respiratory muscles in scoliosis cases. The strength of respiratory muscles and their activity patterns in patients with scoliosis is very important.

The purpose of the present study was to identify the intensity of the respiratory muscles activity in patients with idiopathic scoliosis in comparison with healthy individuals through surface electromyography (SEMG) and finding the relationship between the degree of curvature and the severity of respiratory disorders.

2. Methods

Twenty women with adult idiopathic scoliosis were studied in this research. Patients were assigned to two groups: mild scoliosis (n = 10; Cobb angle 20.60 ±4.88 degree in the frontal plane and 34.40 ± 3.5 in the sagittal plane), and moderate (n = 10; Cobb angle 34.70 ± 2.90 in the frontal plane and 38.15 ± 2.85) groups. The subjects were matched by their body mass index (BMI) and sex. The population also included 10 healthy individuals. A number of samples had been obtained by G power software. The average age, height, weight and BMI of these individuals are shown in Table 1.

The inclusion criteria for the patient groups comprised: subjects with idiopathic, structural scoliosis with thoracic Cobb angle 10 – 50 degree, age between 10 to 30; In the present study, the severity of scoliosis was measured by Cobb method (Cobb, 1948) [12]; accordingly, patients were divided into two groups (mild scoliosis < 30 degrees, moderate scoliosis 30-50 degrees). The exclusion criteria for this group included: any cardiovascular, respiratory, and systemic diseases; severe deformity resulting in lack of recording electrical activities of muscles; participation in any professional sport activities; any corrective surgeries; using spinal braces for the past year; presence of kyphosis curves more than 55 degrees [13]. The study was approved by the Ethics Committee of Tehran University of Medical Sciences.

The experiments were performed after receiving the written permission of all participants. They were thoroughly familiarized with the tests steps. In order to record the activity of the respiratory muscles, surface electromyography (Biometrics Data log, 8-channel, England) was employed. After shaving and cleaning the underlying skins with alcohol, 4 pairs of silver-silver chloride surface electrodes were applied on intercostal muscles and diaphragm, respectively, on the second and eighth intercostal space parallel to the midclavicular line bilaterally [16]. The electrodes were attached to the skin firmly by adhesive tapes. A ground electrode was used unilaterally on the right wrist of the subjects. In order to omit heart signal, the analysis was performed between QRS segments [16].

Table 1. Mean age, height, weight and BMI of the participants in groups [Values are presented as mean ± standard deviation (SD)].

Value	Healthy 10	Mild Scoliosis 10	Moderate Scoliosis 10
Age	1.17±24.40	3.27 ± 23.50	4.03 ±24.40
Height	2.78±167.00	2.91±167.40	3.04±167.80
Weight	3.39 ± 60.00	5.40 ± 60.50	3.55 ± 59.80
BMI[1]	0.98±21.51	1.04 ±21.94	0.92± 21.39

1.BMI (body mass index)

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All EMG signals were amplified and band – pass filtered between 20 Hz – 500 Hz and digitized at a sampling rate of 1KHz. EMG data were analyzed off- line.

The test was performed in a relaxed and sitting position with the arm resting in 90 degrees of elbow flexion. Each record contained one set of three repetitions with duration of 10 second. The root mean square (RMS: indicator of intensity of muscles activity) and the median frequency (indicator of respiratory muscle fatigue) were derived from the recorded signals. The SPSS software version 17 was used to perform a statistical analysis. Before analyzes of the statistical tests, the data distribution method was assessed by using the Kolmogorov-Smirnov test. Since all data had a normal theoretical distribution, parametric methods were employed in subsequent analyses. The ANOVA method was used for analyzing the amplitude of muscles activity and fatigue indicators, and in order to draw a paired comparison between the variables. Also, correlation tests were used to analyze the relationship between degree of scoliosis and RMS and Median frequency of respiratory muscles. A simple non-probabilistic sampling was also performed.

The significant level for the variables was assumed to be $P<0.05$.

3. Results

The values of mean and standard deviation of RMS and median frequency during fatigue are presented in Table 2. The RMS of external intercostal and diaphragm on the concave sides and diaphragm on the concave side were significantly reduced in patients with idiopathic scoliosis than the healthy subjects during rest. However, there was no significant difference in diaphragm of the convex sides (Table 3). There were significant differences between external intercostal of convex and concave side and concave diaphragm (Sig 0.0001, 0.0001 and 0.023) in ANOVA tests between mild and moderate scoliosis and healthy subjects. But there was no difference in convex diaphragm between scoliosis groups and healthy subjects (0.0686). There was a relationship between reduced RMS in scoliotic patients with the increase in the Cobb angle in all muscles group except diaphragm (Table 4).

Table 2. Mean of RMS (root mean square) of respiratory in the three study groups [Values are presented as mean ± standard deviation (SD)].

Groups	Muscles	N	Min	Max	Mean	SD
Mild Scoliosis	Convex EI[1]	10	9.00	13.50	10.61	1.65
	Concave EI	10	7.00	10.00	8.58	0.91
	Convex Di[2]	10	7.83	16.20	10.89	2.47
	Concave Di	10	6.20	9.40	8.34	0.99
Moderate Scoliosis	Convex EI	10	5.33	11.00	7.57	1.72
	Concave EI	10	4.85	9.66	6.37	1.30
	Convex Di	10	8.75	11.50	10.00	0.88
	Concave Di	10	4,33	11.50	7.49	2.10
Healthy	Convex EI	10	11.00	16.50	13.00	2.24
	Concave EI	10	6.42	12.50	10.30	2.00
	Convex Di	10	5.90	16.66	10.72	3.28
	Concave Di	10	6.00	12.60	9.91	2.25

1.. EI: external intercostal
2.. DI: diaphragm

Table 3. Results of one way ANOVA test of RMS (root mean square) respiratory muscle between groups.

	Muscles	Sum of Means	Df	Sum of Squares	F	Sig
Convex EI[1]	Between	148.18	2	74.09	29.65	0.0001
	In	96.83	27	3.58		
	Total	245.02	29			
Concave EI	Between	77.94	2	38.97	17.87	0.0001
	In	58.85	27	2.18		
	Total	136.80	29			
Convex DI[2]	Between	4.501	2	2.25	0.38	0.686
	In	159.17	27	5.89		
	Total	163.67	29			
Concave DI	Between	30.33	2	15.16	4.32	0.023
	In	94.67	27	3.50		
	Total	125.01	29			

1. EI : external intercostal
2. DI:diaphragm

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4. Discussion

There was a significant difference in the intensity of respiratory muscles between patients with scoliosis (especially moderate) and healthy subjects in the rest. But it was not significant difference among mild patients, so they were asymptomatic in the rest. This dysfunction results in reduced chest expansion and lung volumes. The most affected muscles in these patients are external intercostals. Also, diaphragm was deconditioned because of over stretching or inability to stretch. Leech (1985) concluded that there was no change in mild group because of younger subjects [5]. Lorens revealed that there was a respiratory dysfunction with reduced maximum inspiratory and expiratory pressure in adolescent idiopathic scoliosis. Deconditioning of the respiratory muscles results in muscles weakness, and it is directly dependent on chest wall and thorax biomechanics. There were structural and functional muscle dysfunctions [14]. In spite of previous studies, mild and moderate scoliosis patients show respiratory muscle dysfunctions at rest.

The other limiting factor is changes in chest wall orientation that results in deconditioning of the respiratory muscle. As the convex costotransvere joints are in the frontal positions and in the concave side are in the sagital plane [8]. There was no significant difference in moderate groups because there was the same dysfunction on the both sides especially in the external intercostals [2]. Diaphragm was more complicated in the concave side because of the over pressure on the ribs.

This study suggests that increase in the severity of scoliosis results in the respiratory muscles dysfunction because of increased mechanical load on chest wall and disadvantages of these muscles. Moreover, the muscles dysfunction on the concave side (especially intercostals muscles) was shown to be disturbed more than that of the convex side. It can be ascribed to the higher level of compression on the concave side [15] and the reduced movement of ribcage. In idiopathic scoliosis, the spinal deformity exposes respiratory and ventilatory defects to increased pressure and mechanical load. In addition, the alteration of the length-tension relationship is one of the factors that limit the activity of respiratory muscles. It represents a significant relationship between the severity of scoliosis and respiratory complications. Such relationship is caused by an increase in ribcage rotation, lateral bending and muscle deconditioning due to compression and inability to expand the chest wall [1]. Also, increase

Table 4. One tailed Correlation between muscles (root mean square) and Median Frequency and scoliosis degree (Correlation is significant at the 0.01 level (1-tailed)).

Muscles		Degree
Convex EI[1]	Pearson	-0.68
	Sig	0.001
	N	20
Concave EI	Pearson	-0.072
	Sig	0.0001
	N	20
Convex DI[2]	Pearson	-0.245
	Sig	0.297
	N	20
Concave DI	Pearson	-0.262
	Sig	0.264
	N	20

1. EI : external intercostal
2. DI: diaphragm

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in chest wall compliance is another factor that contributes in decreasing the respiratory muscle activity and strength due to increasing the scoliosis severity [8].

One of the limitations of this research was lack of pulmonary functional tests that made it difficult to interpret EMG data of isolated muscles. Surface EMG data are not sufficient to show respiratory dysfunction and it is better to be completed with other respiratory and pulmonary tests.

In order to prove the aforementioned hypotheses, it is recommended to study the effect of endurance and aerobic exercises on the strength and fatigue of respiratory muscles in the future studies. This can be done by recording the electromyogram of muscle activities and comparing the conditions of muscles before and after exercise.

5. Conclusion

Scoliosis causes respiratory muscle weakness compared to healthy subjects and these dysfunctions are directly related to the severity of curvature. Jones expressed that in the convex side of thorax cannot remain in end- expiratory positions, and the concave side is not able to have end-inspiratory position.

Rehabilitation of respiratory muscles has the main role in improving the patients with scoliosis performances.

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