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Review Article

The Effects of Adolescent Idiopathic Scoliosis on the Factors Affecting the Respiratory System and Its Function: A Systematic Review

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ABSTRACT

Background: Scoliosis is defined as a three-dimensional deformity of the spine associated with lateral deviation from the normal vertical direction, and mostly with rotation of the vertebras. Although some studies have been performed on the effect of scoliosis on the respiratory system, there are still some ambiguities at issue and some results are contradictory. The aim of the present systematic review study was to help clarify the effect of scoliosis on the respiratory system and the factors affecting respiration.

Methods: An electronic search was done in databases including PubMed, Web of Science, Ebsco, and Science Direct. The quality of papers was assessed using Black and Down instrument. The following keywords were used in search engines; adolescent idiopathic scoliosis, respiratory function, respiratory problem, respiratory system, ventilatory function, ventilatory problem, ventilatory system, chest wall motion, respiratory muscle, and exercise capacity. Papers in English language, subjects being over the age of 10 and suffering from adolescent idiopathic scoliosis, and no other abnormalities were among the inclusion criteria, while suffering any underlying disease was an exclusion criterion.

Results: Based on the keywords used, 76 papers were found; based on the inclusion and exclusion criteria, 7 papers were approved. Five papers had dealt with pulmonary and respiratory factors, two investigating respiratory muscles, 2 examined exercise capacity, and 2 tested the chest wall motions. The score of reporting, external validity, internal validity bias, internal validity - confounding (selection bias), and power varied within 5-7, 0-2, 2-4, 0-3, and 2-5, respectively.

Conclusion: Based on studies carried out so far, scoliosis affects respiratory function including respiratory volumes, chest wall motions, strength of respiratory muscles, respiratory patterns, and respiratory function during exercise. Although some studies show contradictory results, relying on the results of the majority of studies, it can be stated that these effects had been mentioned as negative effects on the mentioned factors. The reasons stated for the results include mechanical insufficiency and muscular disorders, which arise from developmental and systemic disorders associated with scoliosis itself. The relationships between respiratory volumes, strength of respiratory muscles, and chest wall motions are still unclear. Since only limited studies have been performed in this regard, these results still warrant further investigation.

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Introduction

Scoliosis is defined as a three-dimensional deformity of the spine associated with lateral deviation from the normal vertical direction and mostly with rotation of vertebras. The scoliosis research Society (SRS) has defined it as asymmetry in the forward bending test and Cobb angle greater than 10° [1-4]. Scoliosis may occur at any age and can be idiopathic or with a known etiology [1]. There are several types of scoliosis, each with its own characteristics. Meanwhile, around 80% of cases are adolescent idiopathic scoliosis. The other types include congenital scoliosis (10%) and neuromuscular (5-7%) [2]. Adolescent idiopathic scoliosis occurs without any known etiology and in those over 10 years of age [3].

Previous studies have reported different prevalences of adolescent idiopathic scoliosis, ranging from 0.3 to 15.3% [1, 4, 5]. Prevalence of scoliosis is higher in girls than in boys, with a ratio of 1.5:1-3:1, which increases with age [1]. It can be stated that at the deviation of around 10°, the prevalence is almost the same, but at deviations larger than 30°, the prevalence is up to 10 times greater in girls than in boys [3]. Progression of the deviation depends on various factors including the primary Cobb angle, the maturation stage measured with Risser sign, beginning of menstruation, and age [3].

Impaired function and reduced quality of life are the complications of scoliosis resulting from asymmetry of the body, lack of muscular balance, back pain, severe respiratory disturbance, and flexed posture in the elderly, all of which result in altered self-image and diminished self-esteem [6]. The goal of treating scoliosis proposed by The Society on Scoliosis Orthopaedic and Rehabilitation Treatment (Sosort) should focus on conservative treatment to help prevent progression of the curvature, and improving aesthetic appearance, quality of life, psychological well-being, disability, pain, and respiratory function. Generally, the treatment involves observation for curves less than 25°, brace and intensive rehabilitation for curves between 25 and 45°, and surgery for curves greater than 45° [3, 4, 7].

Depending on which region of the spine has been affected by the vertebral displacement, scoliosis is categorized into thoracic, lumbar, and thoracolumbar. Involvement of thoracic spine alone or in combination with the lumbar region is the primary cause of respiratory or cardiovascular problems [5]. Scoliosis can cause impaired respiration and asymmetry in the chest wall on both concave and convex sides during respiration. Trunk deformity constrains the mobility of the thorax, causing diminished breathing volume [6]. Researchers have found that rib mobility on the concave side is restrained in scoliosis, which can lead to limitations and impaired respiratory ventilation [2]. All these can be attributed to the fact that due to the complex relationship between the spine, sternum and ribs, the displacement and rotation of vertebras in thescoliosis affect the shape of the chest wall causing either convexity or concavity. The anteroposterior and transverse diameters on each side of the thorax are significantly different from each other, and thus inflation of the lungs will be asymmetric. Furthermore, the expansion of the thoracic cavity will be limited because the motion of ribs prevents its mobility. Therefore, the chest wall motion diminishes and breathing becomes significantly more difficult even in the absence of any pulmonary disease [5]. For air transfer in the thorax, respiratory muscles play an important role. These muscles include three major groups. The diaphragm is the primary respiratory muscle. The second group consists of intercostal muscles including external and internal intercostal muscles. The third group consists of muscles including the abdominal wall muscles. Although scoliosis does not directly affect the respiratory muscles, it may limit their function (for example intercostal muscles may be overstretched or fail to stretch because of the changes in the intercostal space) and their effect (for example by limiting the ability of the thorax to expand). The distortion of the thorax can compromise the proper function of the thoracic cage, thus increasing the breathing work, even when the lungs are healthy themselves [5]. Generally, scoliosis is associated with preliminary restriction which manifests itself with diminished total capacity of the lungs in the pulmonary functional test. The reduction in the total lung capacity is often associated with increased residual volume leading to high residual volume to the total lung capacity ratio. This is a common index for air trapping which is often observed in obstructive pulmonary disorders such as asthma or cystic fibrosis. The airway tract function is almost normal and healthy in patients with mild to moderate scoliosis. However, in more severe cases, expiratory flow rates are improperly high, suggesting rapid emptying of the lungs. The inspiratory flow rate is also similar to that of the expiration. As the condition worsens, the patients may show evidence of obstruction of the distal airway tract [5]. Although these justifications have been expressed by specialists, studies performed on the extent of chest mobility as well as the respiratory volume and function of muscle in scoliosis patients have reported different results. In a study by Floresa on examining the respiratory function and strength of respiratory muscles in adolescent idiopathic scoliosis patients, they found that in these patients, the forced expiratory volume in one second (FEV1), forced vital capacity (FVC), and peak expiratory flow (PEF) were significantly lower compared to healthy individuals. In measuring the respiratory muscles, both maximum inspiratory pressure (MIP) and maximum expiratory pressure (MEP) were significantly higher in healthy individuals. In the group of scoliosis patients, no relationship was found between the variables of respiratory function and MIP or MEP [8]. In a study by Kotani on chest wall analysis and diaphragm motions in patients with idiopathic scoliosis it was found that the chest wall motions are considerably constrained in scoliosis patients, though the diaphragm motions were normal. Also, some relationship existed between the respiratory motions and its functional tests [9]. In a study by Jones on mechanical insufficiency of the chest wall in scoliosis, it was found that vital capacity,

forced expiratory volume in one second, the gas transfer factor, and the static maximum expiratory pressure reduced significantly. The total volume of the lungs and the maximum inspiratory pressure were lower compared to healthy people, though the difference was not significant. In measuring the constraint of the chest wall motions, it was found that the chest wall in scoliosis children is similar to that of healthy individuals, that is, no difference was found [10]. In a study by Mohammadi on comparing electromyography of respiratory muscles of idiopathic scoliosis and healthy individuals, it was found that the root mean square (RMS) of the external intercostal muscles on the convex and concave sides and diaphragm on the concave side were significantly lower in idiopathic scoliosis patients compared to healthy individuals. Moreover, the degree of scoliosis and reduction in the function of intercostal muscles in convexity and concavity had a relationship, but no relationship was found between the degree of scoliosis and diminished function of the diaphragm muscle [11]. Among the factors and complications examined in idiopathic scoliosis, respiratory disorder has claimed a less share. Based on the studies performed to measure and compare the factors affecting respiration in those with adolescent idiopathic scoliosis and the relatively contradictory results obtained, this systematic review study was designed so that by investigating and assessing the respiratory characteristics as well as the studies performed in this area, better understanding would be gained about the effect of scoliosis on the respiratory system and pulmonary functioning. Indeed, one goal is to answer the following question: "Is respiration and its effective factors different in those with adolescent idiopathic scoliosis and healthy individuals"?

Methods

The procedure of this systematic review was based on PRISMA guideline (Figure 1) [12]. Accordingly, an internet search was performed in databases including PubMed, Web of Science, Ebsco, and Science Direct. The keywords were searched in combination with each other:

(Adolescent Idiopathic scoliosis), (Respiratory function) (Respiratory problem), (Respiratory system), (Ventilatory function), (Ventilatory problem), (Ventilatory system), (Chest wall motion), (Respiratory muscle), (Exercise capacity).

In order to increase the scope of search, the references of the initially found papers were also examined to find more suitable papers. The title and abstract of every study were assessed by the author. The first criterion for paper selection was whether the title or abstract respond to the research question or not. The second stage of selection proceeded based on the following criteria:

1. Papers should be written in English.
2. Papers should include subjects /patients over 10 years of age with idiopathic scoliosis.
3. Papers should have subjects with no other deformities.

Exclusion criteria:

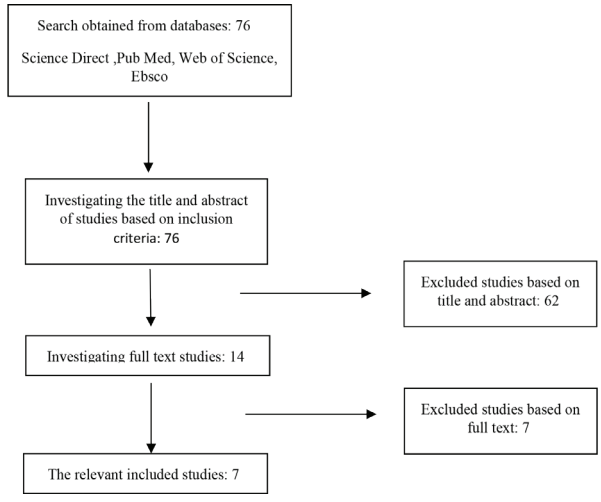

Figure 1: PRISMA diagram

Papers in which the subjects had underlying diseases.

The level of evidence in each paper was specified based on the main search plan, which was scored from 5 to 1 as follows respectively; randomized control trials, prospective controlled trial, case control, pre- post and observational or clinical consequences. The quality of the method of implementing each paper was assessed using the Down and Blank instrument [13, 14]. The validity and accuracy of this test has been proven as a tool to assess the quality of research studies. This instrument includes four parts of reporting (10 items), external validity (3 items), internal validity-bias (7 items), confounding internal validity (6 items), and power (1 item). The scoring range of this instrument is 0-32, with 32 representing the maximum methodological quality. All items of this instrument have options yes (=1) or no/cannot be determined (=0), except for item 5 which has the options no (=0), almost (=1), and yes (=2). Further, item 27 is scored from 0 to 5.

Results

Based on the mentioned keywords, 76 papers were found. Finally, only seven papers met the inclusion criteria and were chosen. Table 1 summarizes the characteristics of the participants, methodology, and results of the selected papers. Only a few studies existed on comparing respiration and its characteristics in those with scoliosis and healthy individuals. The results of quality assessment of each paper are reported in Table 2. The level of evidence of all studies was 5. The scores of reporting, external validity, internal validity - bias, internal validity-confounding (selection bias), and power varied within 5-7, 0-2, 2-4, 0-3, and 2-5, respectively.

Discussion

Respiratory function depends on various complex factors, one being mechanical factors including the shape and volume of the thorax, airway tract, as well as the strength of respiratory muscles. Scoliosis as a common deformity of the spine which can cause

Table 1: Methodology and results of the reviewed studies

Study	Subject(sex & age)	Parameters (variables studied)	Methode	Result
F. Floresa et al(2015)	12 females with AIS (15.1±1.6 years of age) and 12 age-matched controls (15.2±1.4 years of age)	Forced expiratory volume in one second (FEV1), forced vital capacity (FVC),peak expiratory flow (PEF) and the fraction of FVC expired in one second (FEV1, FVC%), Maximal inspiratory pressure (MIP), maximal expiratory pressure (MEP).	(FEV1), (FVC), (PEF) and the fraction of FVC expired in one second (FEV1, FVC%) (computerized spirometer) (MIP) and (MEP) (digital mouth pressure meter).	The AIS group presented significantly lower FEV1, FVC and PEF than the control group. Both MIP and MEP were significantly higher in the control group. In the AIS group, no correlation was found between pulmonary function variables and MIP and MEP.
Kotani, Toshiaki et al(2004)	18 patients with idiopathic scoliosis and 9 healthy individuals	The chest wall and diaphragm motions.	The chest wall and diaphragm motions (Dynamic fast spoiled gradient-recalled echo sequences). The chest wall and diaphragm motions were evaluated using a cineloop view and a fusion display of maximal inspiratory and expiratory images.	Respiratory chest wall movements were significantly restricted in patients with scoliosis, although the diaphragm motion was normal.. There was some correlation between the values of respiratory motions and pulmonary function tests.
R S JONES et al (1981)	23 children(all girls) with scoliosis and 27 normal children and 24 normal young adult females.	lung function, Lung volumes, The transfer capacity, The maximum static airway pressures	lung function tests (the belt restriction method), Lung volumes (the helium dilution closed circuit technique),The transfer capacity (the steady state carbon monoxide method), The maximum static airway pressures (modification of the technique of Cook et al'2 and Bird and Hyatt).	The vital capacity, FEV1, gas transfer factor, and the maximum static expiratory airway pressure were all significantly reduced. Total lung capacity and the maximum inspiratory pressure were lower than in the normal subjects, but the difference was not significant. Restriction of thoracic cage movement by a belt showed that the thorax in the children with scoliosis was as mobile as in the normal subjects.
RJ SMYTH et al(1984)	44 adolescents (12 boys, 32 girls) with idiopathic scoliosis	Spirometric indices, lung volumes, maximum voluntary ventilation(MVV), MIP and MEP	Spirometric indices (computerised system), Maximum voluntary ventilation (a 12 second test), Functional residual capacity (the helium dilution method), MIP and MEP (a modification of the method of Black and Hyatt," using a mercury filled U tube).	six subjects (13.6%) showed a restrictive defect with FVC less than 80% of predicted. In 12 subjects (27.3%) MVV was reduced to less than 80% of predicted normal. FVC was significantly correlated with MIP and MEP but was not related to the degree of thoracic curvature.
Pirayeh Mohammadi et al(2014)	20 female patients with adult idiopathic scoliosis (mild, moderate) and 10 healthy matched individuals	The root mean square (RMS: indicator of intensity of muscles activity) and the median frequency (indicator of respiratory muscle fatigue)	Electromyography values were recorded through rest phase. In addition, the electromyography values of external intercostal muscles and diaphragm were recorded bilaterally. The test was performed in a relaxed and sitting position with the arm resting in 90 degrees of elbow flexion.	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. 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.
Evandro F. Sperandio et al(2014)	29 patients with AIS and 20 healthy adolescents (aged between 11 and 18 years old)	Oxygen uptake (VO2), incremental shuttle walk distance (ISWD), ΔVO2/ Δwalking velocity, ΔHR/ΔVO2, ΔVE/ΔVCO2, and linearized Δtidal volume (VT)/ΔlnVE, (FEV1), and (FVC).	performing of two ISWTs, and the data used were acquired in the second test. lung function and respiratory muscle strength (spirometry test and manovacuometry)	AIS patients showed significant lower values of ISWD, VO2, and ventilation at the end of the ISWT, as well as lower FEV1 and FVC; they also presented significantly shallower slope of DVT/DlnVE, whereas VO2 related significantly with ISWD, FVC, FEV1, and ΔVT/ΔlnVE.
J. Martı´nez-Llorens (2010)	60 patients with Scoliosis and in 25 healthy	TLC FVC FEV1 FEV1/FVC FRC MIP MEP VO2max Respiratory rate	Spirometry, electrically braked cycloergometer	Patients with AIS had only mild to moderate abnormal ventilatory patterns. The function of respiratory and exercise capacity were below normal limits in AIS patients, and were significantly lower than in controls. Exercise capacity was correlate with the function of inspiratory, expiratory muscles which There appeared to be no connection between spinal deformity and lung function or exercise capacity.

Table 2: The results of quality assessment of the papers

Reference	Author	Level of Evidence	Reporting (10)	External Validity (3)	Internal Validity		Power (1)	Total (32)
					Bias (7)	Confounding (selection bias) (6)		
8	F. Floresa	5	7	0	4	1	2	14
9	Kotani, Toshiaki	5	6	0	4	1	2	13
10	R S Jones	5	5	0	2	0	2	9
14	RJ Smyth	5	6	1	3	1	4	15
11	Pirayeh Mohammadi	5	7	0	3	1	5	16
15	Evandro F. Sperandio	5	7	2	3	3	4	19
17	J. Martı´nez-Llorens	5	7	1	2	3	5	16

cardiovascular and respiratory problems through directly affecting the chest [15]. Thus, the main question propounded in this research is; 'is there any difference between the respiration of healthy individuals and those with scoliosis, and in what characteristics have these differences been observed?' The quality of the studies used in this review paper lay within the range of 9-19 (Table 2). By looking at Table 1, it can be seen that the factors evaluated, affecting the quality of respiration in scoliosis patients, fall into four main categories: lung function, respiratory muscle function, chest wall motion, and exercise capacity.

From the studies included in this research, 5 had dealt with comparing the lung function of respiratory muscles [8, 10, 15-17]: characteristics such as FEV1, FVC, MEP, MIP, and the fraction of FVC expired in one second (FEV1, FVC%). In all of these studies, the mentioned factors were lower in scoliosis patients compared to normal individuals. The possible mechanisms which can be proposed for the effects of scoliosis on lung volumes can include abnormal growth of the chest wall, increase in the elastic force of the respiratory system, which affect the muscular force created during inhalation and exhalation, as well as the effects of abnormality on the development of the expiratory and inspiratory muscle force [16]. These results are contradictory with the findings obtained by Muirhead. By comparing the lung function in scoliosis children, he found that lung volumes were normal or close to normal in most subjects with idiopathic scoliosis. Moreover, no relationship was found between the vital capacity and degree of scoliosis in children with idiopathic scoliosis [18]. Since respiratory volumes have diminished in children with infantile or congenital scoliosis, and this reduction has had a relationship with the degree of scoliosis, and given the fact that the normal growth of lungs up to 8 years of age leads to increases in air alveoli, it justifies the normality of respiratory volumes in children with idiopathic scoliosis and reduction of these volumes in the children with congenital and infantile scoliosis. It also suggests that the primary factor affecting the reduction of respiratory volumes is the growth of lungs rather than the severity of deformity. Moreover, the onset age of scoliosis can affect the influence of this abnormality on respiratory volumes as well as the severity of deformity [18].

Since different references have reported that MIP and MEP reflect the strength of respiratory muscles, and the reviewed articles showed its reduction in acute scoliosis patients compared to normal individuals, it suggests reduction of the strength of respiratory muscles in these individuals [8, 16]. Moreover, Smyth reported that there is a high relationship between the strength of respiratory muscles and reduction of the lung volume, and the mechanical factors are not the only factors affecting the reduction of respiratory volume. Rather, since FVC has a stronger relationship with the strength of respiratory muscles compared to the severity of scoliosis, the reason for decreased strength of respiratory muscles in mild scoliosis can be physiological [16]. Moreover, since there has been a significant relationship between body weight and MIP, MIP reduction may be due to developmental disorder that occurs in scoliosis which can lead to decreased muscular volume [16]. Flores stated that inability in MIP and MEP production can be due to chest wall abnormality, leading to mechanical insufficiency of respiratory muscles. However, he found no relationship between MIP and MEP and other functional factors of the lungs [8]. Martinez-Llrons stated that most subjects showed significant reduction in MIP and MEP. Moreover, this reduction was associated with impaired lung volumes rather than the severity of disorder [17]. This researcher took into consideration the reason for this reduction as alteration of the length-tension relation in response to the chest wall abnormality as well as systemic disorders [17]. This may be due to the different methods of evaluating MIP and MEP, because the methods of these studies have differed. Although studies in this regard and the obtained results are very limited, based on the score of these three studies in the quality assessment, on the whole, the results obtained by Martinez Llorns and Smyth could be more relied upon and it can be concluded that there could be a relationship between the strength of respiratory muscles and lung volume [16, 17].

Jones considers the cause of reduction in respiratory volumes as mostly mechanical insufficiency and states that when the volume changes, the ventilation will also change accordingly based on the following parameters: chest wall motion, the volume of each side of the chest wall and the range that can change with the strength of muscles and the elastic force available. He stated that if the available forces are assumed normal, a decrease of pressure represents reduction of mechanical sufficiency. He also noted that secondary abnormalities of the spine and the link between the vertebras lead to diminished volume of each side of the chest wall, reduced intercostal space and an increase of these two factors on the opposite side. Moreover, inflation of lungs on both sides of the chest wall is not normal and this asymmetry leads to

decreased total capacity of the lungs. This in turn causes reduced cooperation between the intercostal muscles and diaphragm. This results in diminished MEP given the association between maximum expiratory pressure and the degree of lung inflation, which itself is related to the expiratory position of the chest wall on the concave side [10].

Sperandio and Martı´nez-Llorens also observed less MIP and MEP in scoliosis patients compared to healthy individuals [15, 17]. Other studies have also reported results suggesting weakness of respiratory muscles and relationship between the strength of respiratory muscles and FVC [15]. There is also some evidence demonstrating generalized muscle weakness disorder in scoliosis patients, whose etiology is still unknown, though nutritional status, level of physical activity, and systemic inflammation play a significant role in this deformity [15, 17].

Sperandio and Martı´nez-Llorens evaluated the respiratory function and exercise capacity of scoliosis patients in an exercise test [15, 17]. Speranido observed a series of characteristics associated with exercise aerobic capacity were also lower in scoliosis individuals compared to healthy people, except respiratory factors examined in other papers. One of these factors is peak VO2 and its reduction has been attributed to respiratory restriction disorder in scoliosis patients. It has been reported based on the relationship between the peak VO2 as well as the respiratory indices and respiration patterns during walking in these individuals. The reason for diminished functional exercise capacity in scoliosis was also attributed to altered cardiovascular status or impairment in peripheral muscles, as they found no relationship between the degree of scoliosis and respiratory disorder. He also stated that rotation of the chest wall can compress bronchi against the mediastinal, causing constrained airway tract.

Martı´nez-Llorens [15] also measured factors such as the peak VO2 and maximum works rate in an exercise test and observed that most subjects ceased continuation of the exercise due to leg fatigue. Moreover, since breathing at the highest level of exercise was almost high and no change was found in the blood oxygen uptake, he concluded that unlike other authors who believe that cardio-respiratory limitations are the main reason of decreased exercise capacity in scoliosis patients, there was a relationship between exercise capacity and the function of different muscles. Furthermore, the factors related to the muscular strength and function were the main predictors for the exercise capacity in these patients. He reported that when the deformity progressed, because of the abnormality of the chest wall, lung function and cardiac disorders were implicated in limiting the exercise capacity [17]. The relative difference of the results of these two studies can be due to the different subjects and type of exercise tests by which measurement was carried out.

Regarding chest mobility, 2 papers were evaluated and compared; it was [9, 10]. Jones stated that in the method they applied to determine chest mobility in scoliosis patients, although the total volume of the lungs had decreased in scoliosis patients, this reduction was similar to healthy individuals. Since the residual volume was similar in both scoliosis and healthy groups, they concluded that the thorax was as mobile in scoliotic individuals as in the healthy subjects, but the capacity for expanding the lungs is lower in this group [10]. However, Kotani, by assessing the chest wall motions in different dimensions, concluded that chest wall motion is less and restrained in scoliosis patients compared to healthy people. The difference in these conclusions might be attributed to the results of the different methods through which the data had been collected. It has also been stated that the positioning of the chest and the part of the chest examined could have led to these differences [9]. Considering the quality of the mentioned papers, most probably the results of the study by Kotani are currently more reliable. It can be concluded that the chest motion is restrained in scoliosis patients compared to healthy individuals. Nevertheless, there are very sparse studies in this regard and given the contradictory results found, it is better to conduct studies in this area more precisely.

Two articles have worked on the respiratory muscles: one examined the strength of respiratory muscles (diaphragm and intercostal muscles) and the other examined the diaphragm motions [9, 11]. The results of these two studies with regards to the diaphragm muscle were very similar. Kotani investigated the diaphragm motions and concluded that the motions of this muscle are not different in people with scoliosis and healthy individuals. On the other hand, Mohammadi investigated the diaphragm and concluded that its function is weaker in those with scoliosis compared to normal individuals on the concave side, but it was not different on the convex side. No relationship was observed between the diaphragm function and severity of scoliosis. Mohammadi indicated that the external intercostal muscles had a weaker function in those with scoliosis on both concave and convex sides compared to healthy individuals. A relationship was also found between the severity of scoliosis and the function of the external intercostal muscles [11]. Note that respiratory muscles are not limited to the major muscles and the importance of auxiliary respiratory muscles such as sternocleidomastoid and scalene, which keep and stabilize the upper airway tract and their role in the airflow transfer cannot be neglected [19]. Moreover, as these muscles have not been examined in this deformity, future studies are recommended to deal with that. This is because these muscles are involved both in posture and respiration. Considering the very limited studies on respiratory muscles, future research is recommended.

Conclusion

Based on the studies which have been carried out to date, scoliosis affects the respiratory function effective factors including respiratory volumes, chest wall motions, and strength of respiratory muscles, respiratory patterns, and the respiratory system function during exercise. Although

some studies have shown contradictory results, relying on the majority of results, it can be stated that these effects had been noted mostly as adverse effects on the mentioned factors. Among the results obtained they can be attributed to mechanical insufficiency and muscular disorders, which themselves are caused by developmental and systemic disorders associated with scoliosis. The relations between respiratory volumes, strength of respiratory muscles, and chest wall motions are still unclear and since limited studies have been performed in this regard, these results are still open to discussion.

Conflict of Interest: None declared.

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