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RESPIRATORY FUNCTION IN ADOLESCENT GIRLS WITH MILD AND MODERATE IDIOPATHIC SCOLIOSIS

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ABSTRACT

Objective: First, this study aimed to compare the respiratory function in adolescent girls with idiopathic scoliosis (AIS) who were not involved in any previous treatment and compare them with an age-matched control group in girls. Second, it investigated the relationship between respiratory function (RF) and curve magnitude and location of the curvature in patients.

Materials and Methods: Thirty-five females with AIS, aged 10 to 17 years, and thirty-five age-matched healthy females were involved in the study. RF was measured using a handheld spirometer. Measurements included the forced vital capacity (FVC), forced expiratory volume in one second (FEV1), peak expiratory flow (PEF), and the FEV1/FVC ratio. The AIS group was classified according to the location of the major Cobb angle (thoracic, lumbar, and thoracolumbar). Statistically, all results were compared between groups, and the RF was correlated with the major curve magnitude and the location of the curvature in patients with AIS.

Results: The mean value of the major Cobb angle in degrees was 35.2°±6.5° (minimum-maximum: 22°-48°). Ten patients had thoracic, 16 had lumbar, and nine had thoracolumbar scoliosis. When compared with the results of the RF test, females with AIS had significantly lower values in all tests ($p<0.05$). There was no relationship between RF and the degree of the major Cobb angle. There was a significant negative correlation ($p=0.033$) between thoracic scoliosis and PEF values.

Conclusion: Patients with AIS with the mild and moderate scoliosis had worse RF than healthy adolescents. Thoracic scoliosis was more negatively affected. Exercise programmes should consider strengthening respiratory muscles in patients with AIS, especially those with thoracic scoliosis.

Keywords: Adolescent idiopathic scoliosis, respiratory function, idiopathic scoliosis

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is defined as the abnormal lateral curvature of the spine more than 10° that is measured using the Cobb method from a standing posterior radiograph from an anterior radiograph of an individual who is between 10 years old and the end of maturity[1]. AIS comprises about 80% of all idiopathic scoliosis (IS), and its common prevalence ranges from approximately 2% to 4%[2,3]. The female to male ratio is 1.3:1 when the scoliosis is mild (Cobb angle 10°-20°), but the ratio increases to 5.4:1 when the Cobb angle is between 20° and 30°[4]. Spinal deformities are seen in the sagittal, frontal, and transverse planes in scoliosis because of the vertebral rotation[5]. The thoracic cage is directly affected by this three-dimensional deformity, aesthetically as well as functionally[6]. A narrower rib cage in children with AIS was documented earlier when compared with their counterparts without scoliosis[2]. It was reported that lung compliance is reduced secondary to scoliosis. So, much effort is needed to breathe at rest and/or during physical activity, especially in children with severe IS[7-9]. Although it has been well established that restrictive lung disorder is characteristic of severe scoliosis, less data is available on the respiratory function (RF) of patients with AIS with both mild and moderate Cobb angles, and conflicting results have been reported. Some authors suggest that respiratory dysfunction occurs in scoliosis cases in which the Cobb angle exceeded 50 or 65 degrees[8,10-12]. However, other researchers have confirmed respiratory disorders in mild scoliosis (Cobb angles below 30 degrees)[13,14]. It is reported that AIS with mild curves do not have significant reductions in ventilatory parameters when compared with healthy subjects.

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On the other hand, the results showed a reduced exercise capacity in these patients[15].

Our first aim in this study was to investigate whether IS negatively influences ventilatory function in adolescents with mild and moderate curve when compared with healthy children. Second, we aimed to show whether there is a relationship between ventilatory function tests and curve magnitude with a different apex location. If it is possible to show the reduced RF variables, it will be advisable and essential to add exercises to individualised exercise programmes of patients to improve RF. We think that these exercises will be an essential rehabilitative factor for the quality of life in patients with AIS.

MATERIALS AND METHODS

This study is the first step of our main ongoing study named "The impact of scoliosis-specific exercises and bracing on RF in adolescents with IS". It was a prospective, non-randomised controlled study. The research protocol was approved by the scientific research ethics committee of the Haliç University (decision no: 150, date: June 28, 2017). After a detailed explanation of the study objectives and evaluation procedures, written informed parental consent was obtained from all participants.

Study Design

Between June 2017, and January 2019, 35 females with IS, aged 10 to 17, recruited from two clinics (Formed Scoliosis Centre and Special Özülkü Medical Centre) were assigned to the study group. Another 35 age-and gender-matched healthy adolescent females, who were free of scoliosis, were assigned as the control group. Age, weight, height, body mass index [weight (kg)/height^2 (m^2)], menarche status of all participants in the two groups were recorded for the demographic data. Screening via the Adams' test using a scoliometer was conducted for all participants. They were screened by two experienced physicians. A standing anteroposterior standard radiograph that was performed only for participants who were initially diagnosed as having scoliosis (depending on the forward bending test and scoliometer results)[16]. The diagnosis of AIS was confirmed based on the Cobb angle method[4]. All Cobb angles were measured digitally by the same experienced physiatrist. The subjects with scoliosis were classified into three groups for further analysis according to the location of the major Cobb degree of lateral curves; thoracic (T2-T11/12 disc), lumbar (L1/L2 disc-L4) and thoracolumbar (T12-L1)[4].

Inclusion and Exclusion Criteria

All subjects with AIS were diagnosed according to the guideline of the Scoliosis Research Society[4] and enrolled based on the following inclusion criteria: (1) age of scoliosis onset between 10-17 years, (2) Cobb angle >10° with axial rotation and (3) unknown aetiology of scoliosis.

The exclusion criteria included: Boys, adolescents who had been previously or were already being managed for scoliosis by any type of treatment, thoracic or abdominal surgery, smoking, obstructive and/or restrictive ventilatory defects, previous respiratory complaints in the last two months.

Evaluation of Respiratory Function

Respiratory function was performed using a handheld spirometer (Contec SP10W) in a sitting position. The test was explained and shown to all participants by a physical therapist and a physiatrist before the data were collected. All measurements were taken three times, and the highest values of them were recorded. The measurement was composed of volume and flow parameters. We analysed forced vital capacity (FVC), expiratory volume in the first second (FEV1), peak expiratory flow (PEF) in absolute values and the FEV1/FVC ratio in the percentage of predicted values by validated reference data[17].

Statistical Analysis

The statistical analysis was performed using the statistical package SPSS version 20. Numeric data are presented with the mean and standard deviations (SD) as mean ± SD. The Kolmogorov-Smirnov test was used to assess the normal distribution in all data. Descriptive statistics were used to represent the mean values of the evaluated variables. An independent t-test was used for comparisons between groups for normally distributed data. The Mann-Whitney U test was used for the comparison between the groups for data that were not normally distributed. Pearson's and Spearman correlation tests were used to examine the relationship of each variable with the subgroups. The level of significance was set at $p<0.05$.

RESULTS

In this study, we evaluated 35 females diagnosed with AIS (study group) and 35 healthy females as the control group to compare RF. The demographic and anthropometric characteristics of the two groups are shown in Table 1. There were no significant differences regarding age, weight, height, BMI and menarche status ($p>0.05$).

Table 1. Characteristics of the girls in AIS group and control group

	AIS group (n=35)		Control group (n=35)		p
	Mean	SD	Mean	SD	
Age (yr)	12.9	1.89	13.02	1.5	0.595
Height (cm)	157.3	9.2	161.1	7.5	0.069
Weight (kg)	49.05	11.83	49.41	6.93	0.404
BMI (kg/m²)	19.6	3.6	19.01	2.20	0.981
Menarch status (yr)	12.4	1.15	12.09	0.9	0.125

AIS: Adolescent idiopathic scoliosis, BMI: Body mass index, SD: Standard deviation
Mann-Whitney U test, Significance was set to p<0.05

In the AIS group, the mean value of the major Cobb angle in degrees was 35.2°±6.5° [maximum-minimum (max-min); 48°-22°]. When we classified the curves according to the location of the major Cobb angle, we have determined that 10 patients had thoracic scoliosis, 16 had lumbar scoliosis. Nine had thoracolumbar scoliosis (Table 2). The mean values of Cobb angle in degrees of these subgroups were thoracic 31.2°±8.64°, lumbar 34°±7.64° and thoracolumbar 33.1°±5.48°.

The results of RF tests in the two groups were compared. The AIS group had significantly lower values than the control group in FEV1, FVC and PEF values ($p<0.05$). The mean values were; FEV1 (2.20±0.52 vs 2.47±0.35), FVC (2.34±0.38 vs 2.61±0.43) and PEF (4.48±0.81 vs 5.41±0.97) in the AIS group and control group, respectively. The mean values of the FEV1/FVC ratio were lower in the AIS group than the control group (91.2% vs 94%), but it was not statistically different ($p>0.05$) (Table 3).

The correlation between the location and magnitude of curves with RF test parameters is shown in Table 4. Correlation analysis indicated that there was no significant relationship between the patients' major Cobb angle with any RF test ($p>0.05$). There was a statistically significant relationship between thoracic scoliosis and PEF values ($r=-418$, $p=0.033$) (Figure 1). No significant relationship was found between the location of the curve with FVC values, and FEV1 and FEV1/FVC ratio values ($p>0.05$) (Table 4).

Table 2. Size and types of curves in AIS group

	n	Mean	SD	Range
Thoracic	10	31.2°	8.6	10-45°
Lumbar	16	34.0°	7.6	20-48°
Thoracolumbar	9	33.1°	5.4	24-42°
Major Cobb angle	35	35.2°	6.5	22-48°

AIS: Adolescent idiopathic scoliosis, SD: Standard deviation

DISCUSSION

Although the deteriorating effect of severe scoliosis (more than 65°) on RF is well known, little is understood about the impact of mild and moderate scoliosis (less than 50°) because of conflicting results[2,18,19]. AIS is generally seen in apparently healthy children, and the absence of other underlying disorders; mild to moderate scoliosis does not produce significant respiratory signs and symptoms[2,5]. However, ventilatory abnormalities, which are secondary to structural rib cage deformation, can probably be seen in these patients. The main purpose of the present study was to determine whether mild to moderate IS affects the RF in adolescents at rest compared with healthy adolescents and then to analyse its relationship with

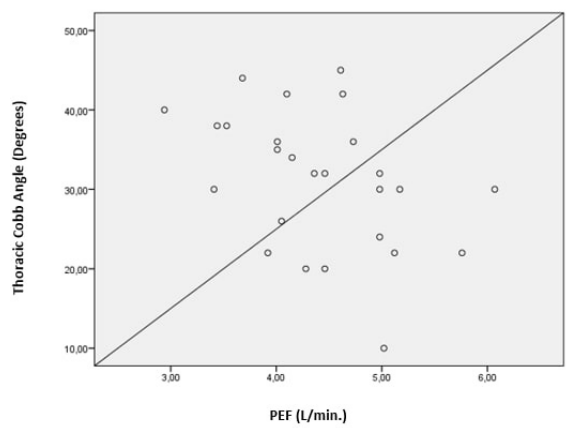

Figure 1. Correlation of Thoracic Cobb angle with PEF values
PEF: Peak expiratory flow

Table 3. Respiratory function test results in AIS and healthy girls

	AIS group (n=35)		Control group (n=35)		p
	Mean	SD	Mean	SD	
FEV1 (L)	2.20	0.52	2.47	0.35	*0.002
FVC (L)	2.34	0.38	2.61	0.43	*0.009
PEF (L/min)	4.48	0.81	5.41	0.97	*0.000
FEV1/FVC (%)	91.2	0.16	94	0.56	0.115

AIS: Adolescent idiopathic scoliosis, FEV1: Forced expiratory volume in 1 second, FVC: Forced vital capacity; PEF: Peak expiratory flow, SD: Standard deviation, Mann-Whitney U test, *Significance was set to $p<0.05$

Table 4. Correlation between respiratory function tests and curve size and types

	FEV1	FVC	PEF	FEV1/FVC %
Thoracic curve	0.364	0.180	*0.033	0.872
Lumbar curve	0.059	0.344	0.225	0.382
Thoracolumbar curve	0.863	0.951	0.699	0.871
Major Cobb angle	0.199	0.305	0.328	0.557

AIS: Adolescent idiopathic scoliosis, FEV1: Forced expiratory volume in 1 second; FVC: Forced vital capacity; PEF: Peak expiratory flow, Spearman correlation test, *Significance was set to $p<0.05$

curve features. Using traditional pulmonary function testing is a reliable and valid method to measure lung function in normal and pathological adolescents[6]. Lung volume is assessed with the value of FVC and is decreased in restrictive respiratory diseases. At the same time, the flow function is evaluated with FEV1 and PEF, which are reduced in an obstructive pattern. The FEV1/FVC ratio is measured for the identification of obstructive or restrictive ventilator defects[17].

The present study revealed that the FVC, FEV1 and PEF were significantly lower in patients with AIS than in patients in the control group consistent with previous studies[5,20]. It was reported that patients with mild AIS were vulnerable to mild ventilatory and functional impairment[5]. However, Barrios et al.[15] did not show any significant differences between mild and moderate scoliotic and healthy females in basal ventilatory parameters such as FVC and FEV1.

Another ongoing ambiguity is the correlation between the Cobb angle degree and RF in mild and moderate scoliosis[18,19]. In our AIS group, the mean value of the major Cobb angle was 35.2°±6.5° (max/min; 48°-22°). When we correlated RF tests with all patients' major Cobb angle, no significant relationship between them could be found and, therefore, was consistent with the previous study[5]. Johari et al.[21] evaluated 38 preoperative patients with AIS and demonstrated that an inverse relationship between Cobb angle and FVC as well as FEV1; however, it was not statistically significant. In addition, they found a significant negative correlation between the thoracic curve and FVC. Vitale et al.[22] found that the thoracic curve degree was negatively correlated with FEV1 and FVC. It was emphasised that spinal curvature in a more cranial location had a potentially greater negative impact on the pulmonary function of patients[2]. In this study, after classifying the AIS group to the location of the major Cobb angle as thoracic (n=10), lumbar (n=16) and thoracolumbar (n=9), a significant correlation existed between only thoracic scoliosis and PEF values. However, there was no significant correlation between the FEV1, FVC, FEV1/FVC ratio values and thoracic scoliosis. These results can be associated with a relatively small study sample size and a considerable amount of lumbar scoliosis. While both FEV1 and PEF are accepted as spirometric measures that provide information about the level of airflow obstruction, the PEF primarily reflects large airway flow and depends on the voluntary effort and muscular strength of the patient[23]. We think that our result associated with the PEF was probably due because of the strength of expiratory muscles rather than the obstruction of airways in patients. It is known that expiratory flow rates decrease in proportion to the restricted lung volume, although the mean FEV1/FVC ratio is normal[2]. In our study, although it was not significantly different, the FEV1/FVC ratio in the AIS group (91.2±0.16%) was lower than in the control group (94±0.56%), and both were in the normal predicted range. The factors that affect the pulmonary function in children with AIS are hypothesised in different ways. A deformed thoracic cage increases the stiffness of the chest wall, reduces the force of the respiratory muscles and causes mechanical dysfunction of the diaphragm[21,24]. Also, respiratory muscle weakness is a potent contributor to ventilatory impairment in mild, moderate and severe forms of scoliosis[25,26]. The weakness of the respiratory muscles is caused by trunk rotation and distortion of the rib cage and results in abnormal mechanics of the intercostal muscles and diaphragm[25,27,28]. Therefore, the respiratory impairment observed in patients is in a restrictive pattern. However, obstructive or mixed lung disease has been reported in patients with scoliosis but is uncommon.

Study Limitations

Our study's important limitation is lack of measurement of respiratory muscles' strength. It would be valuable if we could show the role of intercostal or diaphragm in terms of respiratory dysfunction in our patients.

CONCLUSION

Our study showed that the RF of children with AIS with a mild and moderate Cobb angle is negatively affected when compared with that of healthy controls. We think that, although a restrictive pattern usually accompanies scoliosis, the factors causing obstructive disease should be considered, especially respiratory muscle function and strength. Therefore, we recommend designing in individualised exercise programmes regarding the strengthening of respiratory muscles in children with AIS, especially those with thoracic scoliosis.

Ethics

Ethics Committee Approval: The research protocol was approved by the scientific research ethics committee of the Haliç University (decision no: 150, date: June 28, 2017).

Informed Consent: Informed consent was obtained from all patients.

Authorship Contributions

Concept: H.Y., Design: H.Y., Data Collection or Processing: A.K.Ö., B.Y., Analysis or Interpretation: A.K.Ö., B.Y., H.Y., Literature Search: A.K.Ö., H.Y., Writing: A.K.Ö.

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