

Ultrasound Measurements of the Lateral Abdominal Muscle Thicknesses in Girls With Adolescent Idiopathic Scoliosis

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Abstract

Background: It has been suggested that weakness and asymmetry of core stabilizing muscles have an important role in the development of scoliosis and its complications, especially low back pain. However there is insufficient data comparing symmetry and function of these muscles in scoliotic patients with the normal population. Also there are only a few studies assessing the relationship between the degree of spinal deviation and asymmetry of core stabilizing muscles. This study evaluates the thickness, symmetry, and activation of the external oblique (EO), the internal oblique (IO) and the transversus abdominis (TrA) muscles of patients with AIS and compares these data with a group of normal adolescents.

Objectives: The objective of this observational study was to know the asymmetry pattern of lateral abdominal muscles at rest and during the abdominal drawing-in maneuver (ADiM) in adolescents with idiopathic scoliosis and to compare it with a group of healthy adolescents.

Methods: Twenty healthy adolescents and twenty patients with AIS, aged 10 to 18 years, were included. The thickness of lateral abdominal muscles was measured, using ultrasound, at the end of normal exhalation at rest and during the abdominal drawing-in maneuver (ADiM). Muscular activity was represented as absolute difference and percentage change in the muscle thickness during the ADiM compared with rest.

Results: There was no side to side asymmetry in muscle thickness at rest and also during ADiM in two groups. Thickness of right EO [0.39 (0.09) in the AIS group compared to 0.51 (0.12) in the normal group] and left EO [0.38(0.10) in the AIS group compared to 0.50 (0.11) in the normal group] at rest was higher in the normal group ($P < 0.05$). The activity of right and left EO was higher in AIS group ($P < 0.05$). There was a positive correlation between the lumbar Cobb's angle with the right and the right-to-left difference of TrA thickness during the ADiM ($P < 0.05$). In other words, the more the lumbar Cobb's angle to the right, the thicker the right TrA relative to the left TrA during the ADiM.

Conclusions: The EO muscle was thinner and had higher activity during ADiM in the AIS group. Analysis of our data showed that in the AIS group the higher the lumbar spinal curve to the right, the thicker the right TrA compared to the left TrA.

Keywords: Scoliosis, Abdominal Muscles, Ultrasonography

1. Introduction

Adolescent idiopathic scoliosis (AIS) is a three-dimensional deformity of the spine which affects young people aged 10 or older (1,2). AIS progresses predominantly during growth spurt years, although it may continue into adulthood (3). The prevalence of AIS in the general population reaches 2 to 3 percent and it is more prevalent among girls than boys (4-6). Approximately 10 percent of these patients need a kind of treatment and 0.1 to 0.3 percent of diagnosed cases ultimately need operational interventions (4).

It has been hypothesized that trunk muscles, including the paraspinal and the lateral abdominal muscles, are associated with the initiation and progression of AIS. Some asymmetry patterns and morphologic changes of these muscles have been shown through ultrasound, MRI, electromyography, and histopathology (7-11). Evaluating the symmetry of abdominal muscles in mild AIS by ultrasound, Linek et al. showed that the thickness asymmetry of the TrA was greater in the AIS compared with the control group, although there was no similar finding for the external oblique and internal oblique muscles (12). In the men-

tioned study the symmetry of the abdominal muscles was not affected by the direction of curvature. In another ultrasound study for the assessment of abdominal muscles at rest and during the ASLR test among adolescents with scoliosis, the resting thickness of all tested muscles of both sides were smaller in the AIS group; and in the AIS group the activity of all muscles on the right side of the body was higher (13). Kennelly et al. examined the symmetry of lumbar multifidus size in 20 patients with AIS. Based on their findings the cross-sectional area of lumbar multifidus on the opposite side to the convexity of a primary thoracic curve and on the convex side of a lumbar or thoracolumbar curve was smaller (7). Some electromyographic studies have shown increased activity of muscles on the convex side of thoracic and lumbar curvatures (14, 15). It has been shown that the trunk muscle strength is lower in patients with scoliosis compared to normal population and also the pattern of these variations is asymmetrical (16-18). Using MRI, Zoabli et al. showed asymmetries in the volume of the erector spinae muscle at the convex and concave sides of the curves which was found more frequently at the apex of the curvatures (11). Minehisa found a correlation between the Cobb's angle and the intensity of alterations in the function of trunk muscles in patients with scoliosis (19).

Using ultrasound for the measurement of abdominal muscles thickness and thickness changes is a valid and reliable method in adolescent population (20, 21). In the only ultrasound study assessing the thickness of lateral abdominal muscles in adolescents with AIS the thickness of all three muscles (External Oblique - EO, Internal Oblique - IO and Transverse Abdominis - TrA) on both sides at rest were smaller in the AIS group compared to the control group (13). Also during the active straight leg raise the activity of these three muscles on the right side was higher in the AIS group. The authors of the mentioned study proposed that this finding may be due to the functional asymmetry of the abdominal muscles in patients with AIS which is unclear if it is the cause or the result of the scoliosis.

To the best of our knowledge to date no other study has investigated the association between the muscular asymmetry pattern of lateral abdominal muscles and the type and severity of the curvatures in the AIS patients. Hence, the objectives of this observational study were to; 1) know the asymmetry pattern of lateral abdominal muscles in AIS at rest and during the abdominal drawing-in maneuver (ADiM), 2) compare the thickness and thickness change (activity) of lateral abdominal muscles between AIS and healthy control adolescents, 3) know the correlation between the severity and type of the spinal curvatures and the muscular asymmetry pattern, if there is any, in the AIS group.

2. Methods

This observational case-control study was performed at the sports medicine research center from October 2014 to February 2015. The study was approved by the local medical ethics committee and all participants and their parents received written and verbal information about the study and a written consent form was signed by all participants and their parents.

2.1. Participants

The case group included 10 to 18 year-old girls with the diagnosis of AIS referred to the sports clinic center through some spine clinics. The inclusion criteria was AIS, which by definition is a Cobb's angle of 10 degree or more in a posterior-anterior spinal radiograph without any primary pathology or identified cause. Exclusion criteria consisted of: another scoliosis type (such as congenital scoliosis etc.), neuromuscular diseases (such as Polio, muscle dystrophies, and cerebral palsy), cervical torticollis, unilateral hearing or visual loss, history of spinal or abdominal surgery, history of low back pain during the last 6 months, and wearing a brace as a treatment method for the scoliosis.

Twenty girls, the same age category as the AIS group, without AIS or any other spinal disorder were recruited as control group. For the assessment of AIS in the control group, Adams' test was performed and a scoliometer used for the evaluation of the body rotation. Based on this examination, only the subjects in whom no body rotation angle was detected were included. They were relatively matched for the weight and the body mass index (BMI).

2.2. Baseline Characteristics

Baseline characteristics including age, height, weight, BMI, type of scoliosis (thoracic, lumbar or thoracolumbar), and Cobb's angle were collected from all participants. Spinal radiographs were not older than 4 months prior to the study.

2.3. Ultrasound Measurements

The thickness of lateral abdominal muscles including EO, IO and TrA, was measured at rest and during the ADiM on both sides. The participants were positioned supine with 30 degree flexion of the hip joints (the hook-lying position). The transducer was placed at 25 mm antero-medial to the midpoint between the last rib and ilium on the mid-axillary line. Thickness of abdominal muscles was recorded in B-mode format using a Sonosite Micromaxx (Sonosite Inc., Bothell, WA) US machine with a linear transducer (6 - 13 MHz) aligned perpendicular to the anterolateral abdominal wall. The distance between the inferior and

superior fascial layers at the center point of the image was documented as the thickness of each muscle (22-24). The thickness of three abdominal muscles was measured at the end of normal expiration. All ultrasound measurements were accomplished four hours after the last meal of the participants to avoid the effect of food consumption on the lateral abdominal muscles thickness (25, 26).

The participants were trained to perform ADiM for two repetitions using ultrasound as feedback and an additional instruction. The instruction included an explanation of the manoeuvre (27). After the training, at the same day all aforementioned measurements were performed once again during ADiM (28). Muscular activity was represented as absolute difference (muscle thickness during the ADiM - muscle thickness at rest) and percentage change [(muscle thickness during the ADiM - muscle thickness at rest)/muscle thickness at rest *100] of the muscle thickness during ADiM compared with rest.

Right-to-left difference of abdominal muscles refers to right abdominal muscle thickness minus left abdominal muscle thickness.

2.4. Statistical Analysis

Statistical analysis of data was performed via SPSS software version 20 (SPSS Inc., Illinois, US). Descriptive data are expressed by mean (SD). To compare data collected from patients with those from controls we used the independent t-test. To investigate the asymmetry pattern of muscles in each group paired t test was used. To evaluate the association between the intensity of asymmetry and the Cobb's angle we estimated the Pearson correlation coefficient. $P < 0.05$ is considered statistically significant.

3. Results

Twenty girls with AIS and 20 healthy girls participated in this study. None of the participants were excluded. Age, weight, and BMI of two groups had no significant difference. The most prevalent type of curve was right thoracic (RT) (50%), followed by right thoracic and left lumbar (RTLL) (30%), left lumbar (LL) (15%), and left thoracic and right lumbar (LTRL) (5%). Baseline characteristics of the participants with curvature degrees in AIS group is shown in Table 1. The thickness of all three muscles at rest and during the ADiM were positively correlated with weight ($P < 0.05$).

The thickness of right EO at rest ($P = 0.002$), left EO at rest ($P = 0.001$), and left EO during the ADiM ($P = 0.04$) in the AIS group was less than the control group. Table 2 shows the thickness of three abdominal muscles and the comparison between two groups.

Table 1. Baseline Characteristics of Participants^a

Variable	AIS Group (n = 20)	Non-AIS Group (n = 20)
Age, y	13.70 (1.99)	13.58 (1.44)
Height, cm	1.50 (.122)	1.56 (.09)
Weight, kg	45.27 (8.82)	51.84 (14.33)
BMI, Kg/m ²	20.01 (2.58)	20.96 (4.22)
Cobb's Angle, degree	RT; 27.70 (9.71) RTLL; T 29.16 (4.35), L -25.33 (7.22) LL; -13.33 (1.15) LTRL; T -18.00, L 18.00	

Abbreviation: BMI: Body Mass Index; RT: Right Thoracic; RTLL: Right Thoracic Left Lumbar; LL: Left Lumbar; LTRL: Left Thoracic Right Lumbar.

^aValues are expressed as mean (SD).

There was no significant difference between the thickness of right and left muscles at rest or during the ADiM, neither in the AIS group nor in the control group. Also comparing right to left difference of muscle thickness between two groups, we found no significant dissimilarity (Table 3).

During the ADiM the absolute change and percentage change of muscle thickness of right and left EO were significantly higher in the AIS group (right EO change $P = 0.04$, right EO percentage change $P = 0.02$, left EO change $P = 0.02$, left EO percentage change $P = 0.02$), (Table 4).

We also evaluated the association between the intensity of asymmetry and the Cobb's angle. There was a positive correlation between the lumbar Cobb's angle to the right and the right to left difference of TrA thickness (i.e., right TrA thickness minus left TrA thickness) during the ADiM ($P = 0.036$, correlation coefficient = 0.47). In other words, during the ADiM, the more the lumbar Cobb's angle to the right, the thicker the right TrA relative to the left TrA. Although, we did not find the same correlation between the lumbar Cobb's angle and the right-to-left difference of TrA thickness at rest ($P = 0.066$, correlation coefficient = 0.42).

4. Discussion

This was the first observation study where lateral abdominal muscles morphology at rest and during ADiM were evaluated in AIS with different deviations. Based on our findings there was no side to side asymmetry in muscle thickness at rest and also during ADiM in the AIS group. However, out of all lateral abdominal muscles (EO, IO and TrA), the EO rest thickness was higher in the control group compared to AIS group. The TrA had also tendency to higher thickness in the control group but the results were insignificant (P value around 0.05 - 0.09).

Table 2. Thickness of Abdominal Muscles and the Comparison Between Two Groups

Variable	AIS Group (n = 20)	Non-AIS Group (n = 20)	Comparison (P Value) ^a	Mean Difference (95% CI)
Right TrA ^b	0.27 (0.08)	0.33 (0.13)	0.09	-0.06 (-0.13 to 0.01)
Right TrA ^c	0.36 (0.07)	0.44 (0.16)	0.05	-0.08 (-0.16 to 0.00)
Left TrA ^b	0.26 (0.05)	0.34 (0.15)	0.05	-0.07 (-0.14 to 0.00)
Left TrA ^c	0.44 (0.16)	0.36 (0.06)	0.05	-0.08 (-0.16 to 0.00)
Right IO ^b	0.50 (0.12)	0.49 (0.11)	0.77	0.01 (-0.06 to 0.08)
Right IO ^c	0.55 (0.11)	0.54 (0.11)	0.72	-0.01 (-0.08 to 0.06)
Left IO ^b	0.50 (0.12)	0.46 (0.11)	0.27	-0.01 (-0.09 to 0.06)
Left IO ^c	0.56 (0.12)	0.54 (0.12)	0.61	-0.01 (-0.09 to 0.05)
Right EO ^b	0.39 (0.09)	0.51 (0.12)	0.002 ^d	-0.11 (-0.18 to -0.04)
Right EO ^c	0.43 (0.11)	0.49 (0.08)	0.06	-0.05 (-0.12 to 0.00)
Left EO ^b	0.38 (0.10)	0.50 (0.11)	0.001 ^d	-0.12 (-0.19 to -0.05)
Left EO ^c	0.49 (0.10)	0.42 (0.09)	0.04 ^d	-0.07 (-0.13 to -0.00)

Abbreviations: CI, confidence interval; EO, external oblique; IO, internal oblique; TrA; transverse abdominis.

^aIndependent t test.

^bMuscle thickness at rest (cm).

^cMuscle thickness during the abdominal drawing-in maneuver (cm).

^dSignificant difference.

Table 3. Comparison of Right to Left Difference of Abdominal Muscle Thickness Between Groups^a

Variable	AIS Group (n = 20)	Non-AIS Group (n = 20)	Comparison (P Value) ^b	Mean Difference (95% CI)
TrA ^c	0.005 (0.075)	-0.005 (0.027)	0.58	0.01 (-0.03 to 0.05)
TrA ^d	0.000 (0.080)	0.001 (0.024)	0.93	-0.00 (-0.04 to 0.04)
OI ^c	0.009 (0.026)	-0.015 (0.065)	0.13	0.02 (-0.01 to 0.06)
OI ^d	0.005 (0.070)	-0.001 (0.066)	0.76	0.01 (-0.04 to 0.05)
OE ^c	0.014 (0.058)	0.013 (0.096)	0.96	0.00 (-0.05 to 0.05)
OE ^d	0.006 (0.070)	-0.002 (0.053)	0.6	0.01 (-0.03 to 0.05)

Abbreviations: CI, confidence interval; EO, external oblique; IO, internal oblique; TrA; transverse abdominis.

^aValues are expressed as mean (SD).

^bIndependent t test.

^cRight-to-left difference of muscle thickness at rest (cm).

^dRight-to-left difference of muscle thickness during the abdominal drawing-in maneuver (cm).

Our results are very similar to those in the study of Linek et al. where the thickness of EO and TrA on both body sides were significantly lower in the AIS group than control group (13). However, in our study there was no significant (or close to significant) difference in IO rest thickness, whereas in Linek et al. (13) study this muscle differs significantly too. Lack of IO rest thickness differences between our study groups can be explained by different kind of spine deviations and/or different Cobb angle between both studies. Finally, patients included in our study were not treated with brace, though it is not indicated in the Linek et al. study if their AIS group were wearing a brace as a treatment. Although there is no study evaluating the ef-

fect of wearing a brace on the thickness of abdominal muscles in patients with scoliosis, it has been shown that using a lumbopelvic belt for 8 weeks decreases the thickness of these muscles (29). If the patients in the Linek et al study had been using a brace, its possible effect on the thickness of their abdominal muscles should be kept in mind. And it may be the source of divergences of two studies with regard to IO as well as TrA rest thickness.

In the present study there was no significant difference between the thickness of right and left muscles at rest or during the ADiM, neither in the patient group nor in the control group. Also comparing right to left difference of muscle thickness between two groups, we found no sig-

Table 4. Comparison of Absolute Difference and Percentage Change of Abdominal Muscle Thickness After ADiM Between Two Groups^a

Variable	AIS Group (n = 20)	Non-AIS Group (n = 20)	Comparison (P Value) ^b	Mean Difference (95% CI)
Right TrA ^c	0.08 (0.02)	0.10 (0.04)	0.08	-0.02 (-0.04 to 0.00)
Left TrA ^c	0.09 (0.05)	0.10 (0.04)	0.52	-0.01 (-0.04 to 0.02)
Right IO ^c	0.04 (0.05)	0.06 (0.06)	0.21	-0.02 (-0.06 to 0.01)
Left IO ^c	0.04 (0.04)	0.04 (0.07)	0.82	-0.00 (-0.04 to 0.03)
Right EO ^c	0.03 (0.04)	-0.02 (0.11)	0.04 ^d	0.06 (0.00 to 0.11)
Left EO ^c	0.04 (0.02)	-0.004 (0.08)	0.02 ^d	0.05 (0.01 to 0.09)
Right TrA ^e	35.44 (13.52)	34.50 (13.17)	0.82	0.94 (-7.60 to 9.49)
Left TrA ^e	37.04 (20.71)	33.50 (15.50)	0.54	3.54 (-8.17 to 15.25)
Right IO ^e	9.61 (10.29)	14.39 (14.82)	0.24	-4.78 (-12.95 to 3.38)
Left IO ^e	9.87 (9.69)	11.74 (14.31)	0.63	-1.87 (-9.73 to 5.98)
Right EO ^e	9.68 (10.41)	-1.35 (17.11)	0.02 ^d	11.04 (1.97 to 20.11)
Left EO ^e	13.36 (9.45)	1.01 (19.43)	0.02 ^d	12.36 (2.58 to 22.14)

Abbreviation: CI, confidence interval.

^aValues are expressed as mean (SD).

^bIndependent t test.

^cAbsolute change in the thickness (muscle thickness during the ADiM - muscle thickness at rest).

^dSignificant difference.

^ePercentage change of muscle thickness [(muscle thickness during the ADiM - muscle thickness at rest) / muscle thickness at rest *100].

nificant dissimilarity. In another study, Linek et al. (12) also found no differences in the percentage of asymmetry in the EO and IO muscle thickness in supine rest position. With regard to TrA, the Linek et al. (12) results showed that TrA was thicker by an average of 14% on the left side in the AIS group compared to the controls. However, the examined population was much more homogenous (they examined only thoracolumbar scoliosis) than in our study. There is no other studies pointing out these findings so that we can compare our results with theirs.

To the best of our knowledge, this is also the first study where correlation between lumbar Cobb's angle and lateral abdominal muscles were performed. We have found a positive correlation between the lumbar Cobb's angle to the right and the right-to-left difference of TrA thickness during the ADiM. This means that the more the lumbar Cobb's angle to the right, the thicker the right TrA relative to the left TrA during the ADiM. This finding could suggest a relationship between the type and severity of the scoliosis and the asymmetry pattern of the lateral abdominal muscles. Although we cannot conclude if this is the cause or the result of the scoliosis, we can use this asymmetry pattern in the rehabilitation and exercise therapy of the patients. However, we recommend this finding to be confirmed in a study with larger population.

Linek et al. have not evaluated the association between the asymmetry pattern of the lateral abdominal muscles and the direction and the degree of the curvatures (13). In

the study of Kennelly et al. the cross-sectional area of lumbar multifidus on the convex side of a lumbar or thoracolumbar curve and on the concave side of a primary thoracic curve was smaller (7). Some electromyographic studies have shown increased activity of muscles on the convex side of thoracic and lumbar curvatures (14, 15, 19). Reuber et al. concluded that this asymmetry in muscle action is a result of the scoliosis rather than its cause (14). Also Zetterberg et al. linked their finding to the secondary adaptation of muscles on the convex side with the higher load demands (15). Minehisa et al. found a correlation between the Cobb's angle and the intensity of alterations in the function of trunk muscles in patients with scoliosis (19).

Using ultrasound for the measurement of the abdominal muscles thickness is a valid and reliable method in adolescent populations (20, 21). Also previous studies on healthy subjects have shown the correlation between the body weight and the ultrasound measurements of the lateral abdominal muscles (22, 30, 31). In the current study age, weight, and body mass index of two groups had no significant difference.

Linek et al. used active straight leg raise (ASLR) for assessing the activity of lateral abdominal muscles in adolescents with scoliosis (13). In their study during the ASLR of the right leg statistically significant differences were found in the percentage change of the EO, IO, and TrA on the right side between two groups. In other words, the activity of the muscles in the AIS group was significantly higher than the

control group. Similar alterations were not found in the left side. During the ASLR of the left leg, the three right abdominal muscles and also the left EO showed higher activity in AIS patients. Based on the type of the curvature of the patients, they concluded that the percentage change in muscle thickness during the ASLR test is not correlated with the location and direction of the scoliosis. They proposed that this finding may be due to the functional asymmetry of the abdominal muscles in patients with AIS. Although, as they found no correlation between the type of scoliosis and the type of this functional asymmetry, which would be expected theoretically, it was suggested that the number, the location, and the direction of curvatures be considered in another study with a larger population. In our study during the ADiM the absolute difference and the percentage change of muscle thickness of EO on both sides was significantly higher in the patients group which suggest higher activity of the EO in both sides in the patients with AIS. These differences were not found for the IO and TrA muscles. Some researchers claimed that in the ADiM, the goal is to isolate the function of the TrA muscle, which depends on deep sensation, respiratory pattern and capacity of motor learning (32). However, the suggestion that only the TrA muscle is activated during ADiM (33) has not been confirmed in further studies on healthy adolescents (34). Therefore, it is likely that the TrA and IO muscles do not act independently, and their co-activation provides evidence that the functions of the two muscles are superimposed in adolescence (34). Thus, in AIS and control group similar increase in thickness of the IO and TrA were gained during ADiM but these results in AIS group were connected with higher increase in EO thickness. This should be considered as an improper performance of the ADiM in AIS group.

The small number of participants is the limitation of the current study. So we recommend that the findings of our study, especially the correlation between the muscular asymmetry pattern and the degree and the direction of the spinal curvatures, be investigated in another study with a larger population.

It should also be emphasised that correct performance of ADiM requires smooth generation of tonic, low-load, isometric abdominal contraction because ultrasound is sensitive to muscle contraction up to about 30% of the maximal voluntary contraction. In this work, the maximal voluntary contraction was not controlled.

4.1. Conclusions

In our study we found no asymmetry in the thickness of lateral abdominal muscles at rest and during the ADiM in the adolescents with idiopathic scoliosis. The EO muscle was thinner and had higher activity during ADiM in the

AIS group. Also the analysis of our data showed that in the AIS group the higher the lumbar spinal curve to the right, the thicker the right TrA compared to the left TrA which means a positive correlation between the lumbar Cobb's angle and the right-to-left difference of TrA thickness during ADiM. Although it is not clear if this finding is the cause or the result of scoliosis, we can use this asymmetry pattern in the rehabilitation and exercise therapy of the adolescents with idiopathic scoliosis.

Footnote

Conflict of Interest: The authors have no conflicts of interest to declare.

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