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CASE SERIES

Evaluation of upper extremity function and its relation to curve pattern in female adolescents with idiopathic scoliosis: a pilot study

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Abstract

Study design Cross-sectional and clinical measurement.

Objective To evaluate upper extremity function and its relation to the curve pattern in idiopathic scoliosis.

Summary of background data Postural alterations and trunk distortions—caused by three-dimensional deformity itself in idiopathic scoliosis—may lead to functional changes in the upper extremity of subjects.

Methods Handgrip, pulp and lateral pinch strengths, hand dexterity, hand reaction time, coordination of upper extremity, upper extremity performance, throwing accuracy, and self-reported upper extremity disability were evaluated in 96 subjects. These subjects were divided into 3 groups: 47 with main thoracic curve pattern scoliosis (Lenke type 1), 31 with thoracolumbar/lumbar curve pattern scoliosis (Lenke type 5), and 18 unaffected (healthy control). Comparisons were performed between these three groups.

Results The thoracic scoliosis group showed a significant decrease in concave lateral pinch strength, concave hand dexterity of turning, coordination of the upper extremities, and concave hand reaction time than the thoracolumbar/lumbar scoliosis group ($p < 0.05$). Bilateral handgrip strengths decreased in thoracic scoliosis group when compared to healthy controls. Healthy individuals demonstrated greater throwing accuracy than individuals with scoliosis.

Conclusions Upper extremity function was found to be affected based on the curve pattern. Individuals with main thoracic curves are likely to have deteriorated upper extremity function, especially for hand-specific motor skills, on the concave side, when compared to lumbar curves and healthy controls.

Level of evidence Level III.

Keywords Scoliosis · Hand · Upper extremity · Outcome assessment

Introduction

Idiopathic scoliosis is a progressive spine and rib cage deformity, which includes deviations in all three spatial dimensions [1]. The deformity includes lateral deviation and axial rotation of the vertebras as well as changes in the sagittal plane. Postural distortions of the trunk affect the whole body alignment and cause scapular, shoulder, waist, and pelvic asymmetries [2].

Asymmetrical loading, postural disturbances, and misalignment of the trunk in idiopathic scoliosis have been considered to change the spatial perception (postural awareness of the body) of an individual, resulting in the requirement of patient-specific adaptive biomechanical strategies [3]. Previously, upper extremity proprioceptive dysfunction was found in subjects with idiopathic scoliosis, when compared to healthy individuals [4]. This defect was reported as a causative factor of spinal asymmetry. Cook et al. reported significant asymmetry between the convex and the concave side of the upper extremity of scoliotic subjects in their threshold for detection of joint motion and in their estimation of extremity position [5]. But they did not find any relation between extremity performance and direction of

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the curvature. Additionally, significant asymmetry between right- and left-sided thresholds of vibration was demonstrated in girls with idiopathic scoliosis in a study by Wyatt et al. [6]. From a biomechanical perspective, scapular disorientation, altered scapular kinematics, and muscle activation during the elevation of the arm was reported in both the convex and concave sides in relation to spinal deformity in scoliosis [7, 8]. Together, these findings indicate that upper extremity function would be affected by scoliosis deformity in patients with idiopathic scoliosis.

When evaluating upper extremity function, various parameters such as strength, endurance, manual dexterity, coordination, and reaction time need to be assessed [9]. In addition, patient-perceived disability regarding their upper extremity, using self-reported questionnaires, is considered to be fundamental [10]. Together, using these multidirectional assessments, several potential functional alterations can be predicted. If these compensatory strategies for the convex or concave side of upper extremity function—secondary to the scoliosis pathology—can be established, the therapists would become aware of the possible functional changes, which in turn might help physicians to improve idiopathic scoliosis rehabilitation protocols. Therefore, the aims of this study were (1) to evaluate upper extremity function, including grip strength, hand dexterity, hand reaction time, coordination of the upper extremity, upper extremity performance, throwing accuracy, and the individual's perspective of their upper extremity health status in idiopathic scoliosis; (2) to examine whether there are differences in upper extremity function between healthy individuals and ones with scoliosis; and (3) to explore the relationship between curve pattern and upper extremity function in individuals with adolescent idiopathic scoliosis.

Materials and methods

Participants

Seventy-eight adolescent idiopathic scoliosis and 18 age-matched healthy controls participated in this cross-sectional study. The inclusion criteria for subjects with idiopathic scoliosis included an age of 11–17 years, a main thoracic and main thoracolumbar or lumbar scoliosis, and a standing Cobb angle with a main curve of 10°–45°, right handedness, and no prior history of scoliosis treatment. Then, the inclusion criteria for the healthy group included a normal weight with a body mass index of 18.5–25.5 kg/m^2, an age of 11–17 years, the absence of any disease, and the absence of medication usage. Based on the main curve classification by Lenke [11], the subjects with idiopathic scoliosis were divided into the main thoracic group, including 47 patients with a main thoracic curve pattern (Lenke type 1), and the main thoracolumbar/lumbar group, including 31 patients with a main thoracolumbar/lumbar curve pattern (Lenke type 5). Participants who showed any evidence of renal, cardiac, liver, or pulmonary diseases or had active sport participation were excluded from the study. Active sport participation refers to current, non-professional participation in leisure-time sport activities.

The University Research Ethics Board approved this current study. All patients and their parents were informed about the study and signed an informed consent form.

Procedures

Demographic, anthropometric, and scoliosis-specific characteristics

Subject characteristics, including age, height, body weight, and body mass index, were recorded for each patient. All subjects were female and right handed.

The Cobb angle of the main curve was measured with standard standing full-length postero-anterior spinal X-rays to evaluate the curve magnitude. Axial trunk rotation (ATR) of the subjects was assessed with a scoliometer in the forward bending test [12]. All thoracic scoliosis had convexity to the right, while all thoracolumbar/ lumbar scoliosis had convexity to left.

Upper extremity function

The handgrip strength of the subjects was bilaterally measured with a Jamar Hand Dynamometer (Sammons Preston, Inc., Bolingbrook, IL, USA) according to the recommendations of the American Society of Hand Therapists [13]. Next, the pinch strength was bilaterally measured of the hand using a pinch meter (model PG.60, B&L Engineering, Santa Fe, CA, USA). Then, the pulp and lateral pinch strengths were measured [14]. All strength procedures were repeated three times with 30-s periods between trials for both hands. The three trials were performed, and the mean score determined.

Hand dexterity was evaluated with the Minnesota Manual Dexterity Test. This standardized test is commonly used to evaluate the ability of an individual to move small objects over various distances [15]. In the present study, placing and turning tests were used, where the subject is standing in front of a test table. For the placing test, the subject had to place 58 blocks in various holes as quickly as possible with a unilateral hand movement. For the turning test, the subject had to turn the blocks over and reposition them in the same hole, which also had to be done with a unilateral hand movement. The time spent to complete the tests was recorded as the test score.

The Nelson's Hand Reaction Time Test was used to measure the reaction time of both hands from the subject in response to visual stimulus [4]. The examiner would drop a 30-cm ruler at random intervals, and the subject—sitting in a chair and with the hand at the appropriate position—had to catch the ruler using only the thumb and index finger. The number, caught between the fingers, represented the test's score in cm. An average of ten trials was recorded and taken as the mean test score; higher scores indicated better performance.

Upper extremity coordination was evaluated with the finger-to-nose test [16]. The subject was asked to first touch her nose with the tip of her index finger and then to touch the examiner's finger, which was held at the limit of reach and required almost the full extension of the subject's elbow. The number of executions for each hand within 20 s was recorded as the test score.

Upper extremity performance was evaluated with the Closed Kinetic Chain Upper Extremity Stability (CKCUES) test. The test is cost effective and easily understood, making it very applicable to measure the stability and performance of the upper extremity in adolescents [17]. This test consists of counting how many times the subject performs alternating touches on the opposite hand in a closed kinetic chain position (push-up) over 15 s. The average number of hand-to-hand touches were repeated three times and was recorded as the test score.

Throwing accuracy was determined with the Functional Throwing Performance Index [18]. The subject stood 4.57 m away from a 30.48 × 30.48-cm square target placed on a wall at the height of 1.22 m. The objective of the test was to throw a rubber playground ball (50.8 cm in circumference) on the target as many times as possible over three 30-s trials. The mean percentage of successful throws during the 30-s trials was recorded as the test score.

The shortened Disabilities of the Arm, Shoulder and Hand (Quick-DASH) questionnaire was used to assess the patients' own perspective of their upper extremity health status [19]. The Quick-DASH consists of 11 items from the original 30-item DASH. Each item has five response options and its own scores, from which the final scale scores are calculated, ranging from 0 (no disability) to 100 (severest disability).

The clinical assessments were taken from subjects with clothes on by a single examiner (second author) who was blinded to subjects' clinical status. However, the order of tests was randomized using a Latin squares design for each patient and the appropriate time interval between tests was simply organized so that the patient can have adequate time to rest. Time interval between tests was arranged based on the specific test procedures as well as patients' verbal statement. All strength procedures were repeated three times with 30-s periods between trials for both hands with a 2-min rest interval between sides. [20]. For manual hand dexterity test, 30 s rest was given between placing and turning tests [21]. Resting time between different tests differs from 10 to 20 min according to patients' need.

Statistical analysis

All data were analyzed using SPSS Release 15 for Windows (SPSS Inc, Chicago, USA). Sample size was determined based on pilot study with ten patients per group using a power of 0.80 and $\alpha = 0.05$. The mean hand dexterity (sec) from the pilot study was 80, 73 and 60 for the thoracic scoliosis group, lumbar scoliosis group and controls, respectively with the standard deviation of 14.8. It was calculated minimum 54 participants in total, eighteen participants per group, considering primary outcome of hand dexterity. The independence, variance, and normal tests were applied to all results to verify which statistical tests were applicable. The differences between groups were analyzed with the Kruskal–Wallis analysis of variance test with Dunn's post hoc test. Comparisons between right and left side for unilateral upper extremity functions within thoracic scoliosis group, lumbar scoliosis group and healthy group were carried out with the use of Wilcoxon Signed Rank test. Comparisons in convex side and concave side were made between thoracic and lumbar scoliosis groups. Patients' right side was compared with right side (left side with left side) of healthy controls. A p value of < 0.05 was considered statistically significant.

Results

The demographic and anthropometric data are summarized in Table 1.

First, comparisons between the right side and the left side within each scoliosis group (Thoracic and lumbar) and healthy control group were performed (Table 2). For healthy group, the difference between right and left sides was only significant for hand dexterity of placing. Left side required a significantly longer time to achieve hand dexterity of placing, while there was no difference in any other upper extremity functions between the right and left side. Right side showed increased lateral pinch strength, pulp pinch strength, hand dexterity of placing and turning than the left side in the thoracic scoliosis group ($p < 0.05$). No differences in upper extremity functions between the right and left side were reported in the lumbar scoliosis group ($p > 0.05$).

The thoracic scoliosis group performed significantly weaker convex and concave side handgrip strengths than healthy controls ($p < 0.05$). In addition, the thoracic scoliosis group showed a significant decrease in concave lateral pinch strength, concave hand dexterity of turning, coordination of the both convex and concave side upper extremity, and concave hand reaction time than the thoracolumbar/lumbar

Table 1 Demographic and anthropometric data of the subjects

	Thoracic scoliosis group (*n* = 47)		Lumbar scoliosis group (*n* = 31)		Control group (*n* = 18)		*p* value
	X ± SD	Min–max	*X* ± SD	Min–max	*X* ± SD	Min–max	
Age (years)	13.8 ± 1.8	11–17	14.5 ± 2.2	11–17	14.0 ± 1.7	11–17	0.335
Height (cm)	155.6 ± 11.5	130–176	159.8 ± 7.8	146–172	160.2 ± 9.9	142–173	0.219
Weight (kg)	44.9 ± 9.8	28–70	47.6 ± 10.1	29–75	51.1 ± 12.2	34–77	0.158
BMI (kg/m^2)	18.4 ± 2.1	15.6–22.6	18.5 ± 3.0	13.1–27.5	19.7 ± 3.0	14.3–25.7	0.199
Cobb angle (°)							
Thoracic	22.6 ± 8.9	(13–45)	n/a		n/a		
Lumbar	n/a		22.2 ± 9.2	(12–42)	n/a		n/a
Axial Trunk rotation (°)							
Thoracic	5.8 ± 2.9	(2–15)	n/a		n/a		
Lumbar	n/a		6.6 ± 3.8	(3–15)	n/a		n/a

Data shown as mean ± standard deviation

BMI body mass index

Table 2 Comparisons between right and left side for unilateral upper extremity functions within each group

Upper extremity functions	Thoracic scoliosis group (*n* = 47)	Lumbar scoliosis group (*n* = 31)	Control group (*n* = 18)
	p value	*p* value	*p* value
Handgrip strength (kgf)	0.935	0.409	0.308
Lateral pinch strength (kgf)	0.023*	0.346	0.261
Pulp pinch strength (kgf)	0.034*	0.304	0.107
Hand dexterity (sc)			
placing	0.001*	0.509	0.007*
turning	0.040*	0.194	0.272
Hand reaction Time (cm)	0.104	0.086	0.266
Upper ext. coord. (rept/20sc)	0.345	0.071	0.118

Data shown as mean ± standard deviation

kgf kilogram force, *sc* second, *upper ext. coord.* upper extremity coordination

*$p < 0.05$

scoliosis group ($p < 0.05$). Healthy individuals demonstrated greater throwing accuracy than individuals with scoliosis ($p < 0.05$) (Table 3).

However, there was no difference in pulp pinch strength, upper extremity performance or self-reported measure of upper extremity disability between three groups ($p > 0.05$) (Table 4). No differences between the groups were found regarding lateral pinch strength, hand dexterity of placing and turning, hand reaction time for the convex side of the subjects ($p > 0.05$).

Discussion

The present study provides descriptive information regarding upper extremity function, including grip strength, hand dexterity, reaction time, upper extremity performance, coordination, and self-reported function, in adolescent idiopathic scoliosis subjects with a curve magnitude from 10° to 45°. The study investigated whether individuals with scoliosis have differences in upper extremity function when compared to healthy individuals. In addition, differences in upper extremity function for both the convex and concave sides—between the main thoracic and main lumbar scoliosis curve pattern—are reported. The findings of this study demonstrate that subjects with main thoracic scoliosis had a significantly decreased concave lateral pinch strength, concave hand dexterity of turning, coordination of the upper extremities, and concave hand reaction time when compared to subjects with main thoracolumbar/lumbar scoliosis. Subjects with thoracic scoliosis had weaker handgrip strength in both convex and concave sides than healthy peers. Healthy individuals demonstrated greater throwing accuracy than individuals with scoliosis.

Table 3 Pairwise comparisons

	Group comparison	Dunn's test *p* value
Convex handgrip strength	Thoracic vs lumbar	0.676
	Lumbar vs control	0.348
	Control vs thoracic	0.033*
Concave handgrip strength	Thoracic vs lumbar	0.645
	Lumbar vs control	0.288
	Control vs thoracic	0.024*
Concave Lateral pinch strength	Thoracic vs lumbar	0.023*
	Lumbar vs control	0.331
	Control vs thoracic	1.000
Concave hand dexterity of placing	Thoracic vs lumbar	0.152
	Lumbar vs control	0.077
	Control vs thoracic	1.000
Concave hand dexterity of turning	Thoracic vs lumbar	0.035*
	Lumbar vs control	0.095
	Control vs thoracic	1.000
Concave hand reaction time	Thoracic vs lumbar	0.040*
	Lumbar vs control	0.243
	Control vs thoracic	1.000
Convex upper limb coordination	Thoracic vs lumbar	0.016*
	Lumbar vs control	1.000
	Control vs thoracic	0.008*
Concave upper limb coordination	Thoracic vs lumbar	< 0.001*
	Lumbar vs control	0.574
	Control vs thoracic	0.141
Throwing accuracy (%)	Thoracic vs lumbar	1.000
	Lumbar vs control	0.018*
	Control vs thoracic	0.029*

Significance is indicated by p values < 0.05

The right side/left side comparisons showed that the differences between sides in the scoliosis group may be associated with presence of deformity. The fact that there was no difference between the right and left side in the healthy group made us think that the differences observed in scoliosis group may not be affected by hand dominance. The general literature on handedness supports that the dominant hand is significantly stronger in right handed subjects compared with non-dominant hand [22]. But in our young population with no deformity, this rule has not been confirmed. The grip strength has been reported to be affected from many conditions such as fatigue, time of the day, age, state of nutrition, pain, cooperation of the patient and joint mobility [22]. Therefore, possible change in any of these factors might be responsible of this finding of the present study. In thoracic scoliosis group, right side, which was convex side, had better lateral pinch strength, pulp pinch strength, hand dexterity of placing and turning than the left side. Although we did not find significant differences in upper extremity functions between the right side and left side in the lumbar scoliosis group, a trend toward better functions in the left side, which was the convex side, was observed. Convex side seems to have better upper extremity functions in patients with single thoracic and lumbar scoliosis in this study.

Because handgrip is critical for many daily activities, its strength is suggested as an evaluator in clinical settings to indicate the overall physical strength and health of an individual [23]. In this cohort, the thoracic scoliosis group had weaker handgrip strength for the both convex and concave side than the healthy control group. In addition, they showed weaker lateral pinch strength than lumbar scoliosis group. One factor that may contribute to this finding is the possible alteration in the upper extremity kinetic chain that is related to the thoracic curve. The kinetic chain, which refers to the distal linkage of proximal segments regarding transferring forces and motion, requires optimal anatomy, physiology, and mechanics [24]. In scoliosis, these factors deviate and might be responsible for the decrease in capacity of handgrip force generation. Handgrip strength, isometric trunk muscle strengths, and flexibility of the spine were found to be associated with each other previously [25]. Therefore, another factor, which was responsible for decrease in handgrip

Table 4 Comparison of upper extremity functions between groups

Upper extremity functions	Thoracic scoliosis group ($n=47$)	Lumbar scoliosis group ($n=31$)	Control group ($n=18$)	p value
Handgrip strength (kgf)				
Convex side	14.0 ± 4.8	14.9 ± 4.8	18.4 ± 5.9	0.036*
Concave side	13.7 ± 3.9	15.1 ± 4.5	19.8 ± 7.4	0.026*
Lateral pinch strength (kgf)				
Convex side	4.8 ± 1.4	4.9 ± 1.0	4.8 ± 1.3	0.986
Concave side	4.4 ± 1.0	5.1 ± 1.2	4.6 ± 1.2	0.025*
Pulp pinch strength (kgf)				
Convex side	2.9 ± 0.7	3.1 ± 1.1	3.2 ± 1.1	0.879
Concave side	2.7 ± 0.8	3.1 ± 0.9	2.9 ± 1.1	0.181
Hand dexterity (sc)				
Convex placing	72.5 ± 14.6	73.0 ± 10.3	74.5 ± 10.2	0.195
Concave placing	76.4 ± 9.6	71.7 ± 6.6	79.2 ± 11.9	0.049*
Convex turning	76.9 ± 14.0	74.7 ± 9.6	76.8 ± 12.1	0.723
Concave turning	79.9 ± 11.8	73.5 ± 8.8	79.9 ± 10.7	0.023*
Hand reaction time (cm)				
Convex side	14.0 ± 3.5	16.5 ± 10.1	13.4 ± 3.0	0.333
Concave side	13.4 ± 3.9	17.8 ± 11.1	14.1 ± 3.0	0.006*
Upper ext. coord. (rept/20sc)				
Convex side	25.3 ± 6.1	29.0 ± 5.4	30.9 ± 5.9	0.002*
Concave side	24.5 ± 6.3	30.6 ± 6.4	28.1 ± 6.0	< 0.001
Upper ext. perform. (rept/15sc)	15.3 ± 3.8	15.7 ± 3.8	19.9 ± 7.1	0.113
Throwing accuracy (%)	34.0 ± 25.6	32.4 ± 27.5	52.6 ± 22.1	0.020*
Quick-DASH score (points)	12.9 ± 8.9	9.5 ± 7.4	11.4 ± 10.7	0.162

Data shown as mean ± standard deviation. Comparisons in convex side and concave side were made between thoracic and lumbar scoliosis groups. Patients' right side was compared with right side (left side with left side) of healthy controls

kgf kilogram force, *sc* second, *upper ext. coord.* upper extremity coordination, *upper ext. perform.* upper extremity performance, *rept* repetitions

*$p < 0.05$

strength in thoracic scoliosis, might be related with possible alterations in trunk muscle strength coming along with curved spine. In addition, hand muscle activity was found to be connected with shoulder muscle activity in relation with shoulder biomechanics in the study of Sporrong et al. [26].

Hand dexterity, reaction time, and coordination assessments have been used to evaluate upper extremity motor function in clinical practice. Deterioration of these parameters corresponds to a greater upper extremity impairment [27]. In this study, subjects with thoracic scoliosis had poorer hand dexterity of turning and hand reaction time than subjects with lumbar scoliosis in their upper extremity at the concave side. In addition, coordination of the both upper extremity was found poorer in thoracic scoliosis group than lumbar group. The Minnesota test is a gross manual dexterity test of the hand, which provides a quantitative measurement of unilateral hand function and also assesses the endurance performance [15]. Factors that affect hand dexterity might be tremors, muscle strength, or alterations in the positioning of the proximal joints such as the elbow, the shoulder, and the scapula-thoracic [28]. A decrease in reaction time has been associated with poor depth perception and eye-hand coordination [29]. The finger-to-nose test is a well-accepted measure of demonstrating deficits and progress in coordination performance [16]. Coordination is defined as the capacity to execute a controlled movement with accuracy and rapidity. A decrease in coordination may originate from the impaired ability to judge the force, movement time, or the range of movement [30]. Given the used methods within the current study, it is not possible to determine which mechanisms were responsible for these functional declines. Nevertheless, these findings report a significant decrease in upper extremity motor performance of the concave side of the curve for patients with main thoracic scoliosis. Burwell et al. reported an abnormal increase of the upper arm length asymmetry, which was correlated with the age and curve magnitude in adolescents with right thoracic scoliosis [31]. They found early skeletal overgrowth affecting convex side upper arm. In another study, the less residual growth of the convex side was related with a possible change in biomechanical, postural, melatonin signaling, and other factors that sustain and aggravate the curve in thoracic scoliosis [32]. Then, Cook et al. found significant asymmetry between the right and left upper extremity in the joint position and motion sense without being associated with direction of the curve. They reported a proprioceptive function deficit of the upper extremities in subjects with idiopathic scoliosis [5]. Finally, subjects with idiopathic scoliosis also demonstrated reduced eye-hand coordination compared to the healthy ones in a study by Adler et al. [33]. But they did not report whether convex or concave side affected the result. In contrast to previous studies, we found that concave side upper extremity was more affected than convex side. Although this finding contradicts with the studies of Burwell et al. [31, 32], it is in parallel with other study of our group, which shows altered scapular and shoulder kinematics on the concave side in adolescents with idiopathic scoliosis [8]. Furthermore, in the present study, functional changes in upper extremity were seen in main thoracic scoliosis, while lumbar curves seem to be preserved from this effect. This result suggests that the changes in the upper extremity functions may be related to the altered scapular mechanics, which was reported in previous studies [7, 34]. However, a more systemic reason such as biochemical or central neurologic may be the cause of this functional asymmetry.

The CKCUES test is a low cost and sensitive clinical tool to measure the overall upper extremity functional stability, especially for shoulder segment in closed kinetic chain [17]. In the present study, the test did not vary significantly across groups. Based on these findings, we have proposed that scoliosis does not seem to affect upper extremity functional stability. This study shows that scoliosis deformity appears to affect hand functions rather than shoulder or global upper extremity functions. This finding may be explained that evaluation methods used for the hand were more sensitive than the methods we use for the shoulder functions.

Throwing accuracy function was found to be decrease in subjects with scoliosis (both thoracic and lumbar scoliosis group) when compared with healthy controls. Throwing requires bilateral coordinated movements of the upper extremities that needs proper individual's focus of attention, joint position sense, movement velocity, movement path and reaction timing in each wrist, elbow and shoulder segments for accuracy [18]. Therefore, reduction in throwing accuracy in individuals with scoliosis could be due to several factors and may provide area for future research.

Patient-reported outcome measures have become an important part of the assessments used in clinical studies. In this regard, Quick-DASH is a comprehensive tool for assessing upper extremity functional deficits in activities of daily living [19]. The Quick-DASH scores indicated for all groups a relatively high self-reported level of upper extremity physical function. We could not demonstrate any significant difference about DASH score among groups. In addition, the difference between groups was less than the minimal clinically important difference of the questionnaire [35]. In a study by Roden et al., the DASH showed a higher disability of upper extremity dysfunction for adolescents with main thoracic idiopathic scoliosis compared to healthy developing adolescents [34].

There are multiple strengths of this study that deserve highlighting. For instance, this study provides descriptive data for various upper extremity function parameters in individuals with idiopathic scoliosis. Choosing a certain pattern of scoliosis, including main thoracic and main thoracolumbar/lumbar, may enable a particular comparison between scoliosis individuals. Similar age, gender, and anthropometric characteristics for the three groups were provided, allowing group comparison with a more appropriate reference. However, there were certain limitations to our study. The findings of this study, due to its design, should not be generalized to other scoliosis types, curve magnitudes, age groups, or the male gender. In a bigger population including patients with other curve patterns of scoliosis, and different curve magnitudes results may change. The present study did not determine whether the difference between groups were clinically significant. Clinically meaningful difference would be strongly recommended to examine for future studies. Further investigation of upper extremity physical function in the scoliosis population is for this reason required.

Conclusion

In conclusion, this study demonstrated that upper extremity functions are affected especially in individuals with main thoracic idiopathic scoliosis. This alterations in upper extremity functions was particularly for the concave side and for lateral pinch strength, hand dexterity of turning, upper extremity coordination, and hand reaction time when compared to subjects with main thoracolumbar/lumbar scoliosis. It is recommended to study these effects observed in mild and moderate curves for individuals with severe spinal deformities. The results of this study imply that scoliosis should not be considered only as a trunk pathology. We suggest that rehabilitation of idiopathic scoliosis should include upper extremity functional assessment, especially the concave side hand.

Key points

- Adolescents with main thoracic scoliosis tend to have decreased upper extremity function on the concave side of the curve, compared with adolescents with main lumbar scoliosis.

- Bilateral handgrip strengths decreased in thoracic scoliosis group when compared to healthy controls.
- Convex side upper extremity tends to have better functions than concave side in subject with scoliosis
- Subjects with scoliosis demonstrated decreased throwing accuracy than healthy peers.

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Compliance with ethical standards

Conflict of interest The authors report no conflicts of interest.

Ethical approval The study was approved by the University of Hacettepe Research Ethics Board. The patients were informed regarding the treatment and its potential benefits as well as evaluation methods; and thereby, signed informed consent forms were obtained.

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