J. Phys. Ther. Sci. 29: 1658–1663, 2017

The Journal of Physical Therapy Science

Original Article

H-reflex changes in adolescents with idiopathic scoliosis: a randomized clinical trial

Mohamed Salaheldien Mohamed Alayat, PhD, PT[1)*],
Ehab Mohamed Abdel-Kafy, PhD, PT[1)], Ashraf Mohamed Abdelaal[1)]

[1)] *Department of Physical Therapy, Faculty of Applied Medical Sciences, Umm Al-Qura University: Mecca 21955, Saudi Arabia*

Abstract. [Purpose] To detect H-reflex asymmetry and investigate the effect of direction sensitive exercise therapy protocol among patients with thoracolumbar and/or lumbar scoliosis. [Subjects and Methods] Fifty patients (10–17 years), Cobb's angle 10–20 degrees with thoracolumbar and lumbar scoliosis participated in the study. Soleus H-reflex was tested on both sides during prone lying position and standing position. Patients were randomly assigned into two groups. Group I received direction sensitive exercise therapy while the participants in group II received traditional exercise. Exercises were applied three times per week for twelve successive weeks. [Results] There were significant differences indicating asymmetry in the H-reflex amplitude on concave side. Cobb's angle significantly decreased and the H-reflex amplitude on concave side as well as H concave/convex ratios in both lying and standing significantly increased in both groups. Direction sensitive exercise therapy showed a more significant increase in the measured outcomes than traditional exercises therapy protocol. [Conclusion] H-reflex test was effective in discovering the asymmetry between concave and convex sides. Based on H-reflex test, direction-sensitive exercise therapy was more effective than traditional exercises in decreasing Cobb's angle and increasing H-reflex values as well as H/H percent in concave side in patients with adolescent idiopathic scoliosis.

Key words: Direction sensitive exercise therapy, Exercises, Idiopathic scoliosis

(This article was submitted May 27, 2017, and was accepted Jun. 19, 2017)

INTRODUCTION

Scoliosis is a spinal deformity that has abnormal lateral curvature of the spine with the Cobb angle is greater than 10°[1)]. It affects the school-going children during the growth spurts of adolescents involving coronal, sagittal and axial angulations with unknown etiology[2)] and considered as adolescent idiopathic scoliosis (AIS)[3)].

It affects girls to boys equally in adolescents with spinal curvatures of 10 degrees. With Cobb's angle greater than 30 degrees, the ratio increases to 10 girls for every boy, and the scoliosis in girls tends to progress more often[4)]. The prevalence of AIS is 2–3% of the growing age population between 10 and 16 years of age[4)]. In Saudi Arabia, the prevalence was reported to be in the range of 0.16 to 0.5% from which 59% are AIS with mean age of discovery was 12.5 years[5)].

The conservative therapies include exercises, physiotherapy, intensive rehabilitation programs and bracing[6, 7)]. Previous studies provide evidences support the efficacy of physiotherapy and rehabilitation programs in treatment of AIS[8–12)]. Exercises could correct a complex three-dimensional structural deformity, reduce the Cobb angles of individuals and improve strength, mobility and balance that occurs in AIS[4, 11, 13)].

Previous studies suggest the muscle imbalance as a main cause of this disorder but scant or even no researches attributed its occurrence to the central or peripheral nervous system problems. Thus, there is a true need to search for possible underlying neural causes for AIS. The H-reflex is an electrophysiological procedure for diagnosing side-to-side latency differences

*Corresponding author. Mohamed Salaheldien Mohamed Alayat (E-mail: mohsalahpt@hotmail.com)

Table 1. Physical Characteristics of the patients in the two treatment groups

	DSET (N=25)	TETP (N=25)
Age (years)	14.1 ± 1.6	14.4 ± 1.7
Height (cm)	151 ± 5.6	152.2 ± 4.5
Weight (kg)	52.1 ± 4.4	50.8 ± 3.8
BMI (kg/m^2)	22.9 ± 2.2	21.9 ± 1.6
Male to female ratio	10/15	8/17
Cobb's Angle	13.20 ± 4.1	12.68 ± 3.7
Thoracolumbar scoliosis	17	19
Lumbar scoliosis	8	6
Left to right ratio	10/15	10/15

DSET: direction-sensitive exercise therapy; TETP: traditional exercises therapy protocol; BMI: body mass index
Data expressed in mean ± standard deviation.

at the lumbosacral spinal level[14, 15]. With the evidence of prolonged latency in case of lumbar radiculopathy, the H-reflex amplitude asymmetry may be more evident than latency changes in nerve root involvement as compared with latency[16]. Limited studies have suggested, but not tested the neural source or causes of AIS that the spinal cord trigger the changes in spinal reflex asymmetry[17]. Previous studies using neural structures as a cause initiating the AIS was the neuro-dynamic effects of the vestibular system[18–20]. Asymmetry of sensory signal would be the most likely source of vertebral misalignment in AIS[20].

Detecting a reflex asymmetry at an earlier stage of development would be an alerting signal to intervene for correction before other subservient structures e.g. muscle, soft tissues and bony components to be involved. The rationale for the use of H-reflex as a measure of neural compromise is the fact that H-reflex is the most sensitive measure for nerve root function[21]. A nerve root (L5 or S1) may contain several thousand-nerve axons that transmit the peripheral signal to the spinal cord. Such signal must be symmetrical if originated from equally symmetrical organs (sensory sources). If these input signals from both lower limbs tend to be asymmetric, it would be interpreted by the spinal cord as such. The spinal cord response would be to adjust the spinal alignment of the vertebrae to offset such asymmetry causing the scoliotic curve. This theoretical assumption is clearly noted in sciatic scoliosis and is reasonable to be assumed in AIS.

If proved, this concept may slow the progress of such curves and it may help in reversing the occurrence of such curve by applying appropriate intervention stress on improving the amplitude of H-reflex and correcting this asymmetry. Direction sensitive exercise therapy (DSET) based on reflex asymmetry. It has been significantly useful in eliminating lower back pain in patients with lumbar radiculopathy. DSET might be useful in reducing the progress of the pathologic curvature in AIS subjects by improving H-reflex symmetry. Therefore, the aim of the study was to detect H-reflex asymmetry and investigate the effect of DSET protocol among patients with thoracolumbar and/or lumbar scoliosis.

SUBJECTS AND METHODS

The study design was a randomized clinical trial. The Ethics Review Committee at Umm Al-Qura University, Faculty of Applied Medical Sciences, Makkah, Saudi Arabia approved the study with a local approval number (13-1319-10).

The study was approved by the research committee of physical therapy department. Faculty ofApplied Medical Sciences in Umm Al-Qura University, Makkah, Saudi Arabia. Approved Number: FAMS20160319. A pre-experimental design with sample size was calculated based on; power=0.80, α=0.05, to detect the difference between two independent means (two groups), expected effect size=0.80 with a result of sample size of a total 52 participants (26 patients in each group). The number of recruited patients was increased to 60 for possible dropout.

A total number of 146 patients with AIS was found while screening the schools of the western region of Saudi Arabia. 86 patients were excluded because they had; double curves (58 patients), Cobb's angle >20° (38 patients), thoracic scoliosis (16 patients) and only 60 patients with thoracolumbar or lumbar scoliosis were recruited to participate in the study (Table 1).

The inclusion criteria were patients with thoracolumbar and lumbar AIS confirmed through (loaded) X- rays by an orthopedic specialist. Their age range was from 10–17 years. Patients with Cobb's angle 10–20 degrees measured from standing three-foot anteroposterior chest radiograph was included in the study. They had good healthy condition except scoliosis, able to tolerate H reflex including electric stimuli of the lower amplitude, can understand and communicate with no mental abnormalities. Patients were excluded if they were cerebral palsy or other neurological disorders, patients with nutritional disorders e.g. diabetes or vascular disorders.

After initial evaluation, patients were randomly assigned into two equal groups. The Group I received DSET while the participants in group II received traditional exercise therapy protocol (TETP). Randomization was performed by a random number generator. Patients, evaluator and therapists were blinded from the process of randomization.

Assessment of Soleus H-reflexes asymmetries to both legs was performed by EMG unit (Cadwell Lab., Kennewik, WA, USA). The skin was abraded using light sand paper and cleaned with alcohol in order to reduce the skin impedance before applying the electrodes. The recording electrode was placed 3 cm, distal to the bifurcation of the gastrocnemii muscles, over the soleus muscle using surface electrodes with electro conductive gel. Subjects were instructed not to turning their head or moving arms or legs during testing. A ground metal electrode was placed to the skin of the lateral gastrocnemius. EMG unit was set at a gain of (1–5 mv./div.) and filter bandpass of 10 Hz–10 kHz elicited the soleus H-reflex by electrically by stimulate the tibial nerve at the popliteal fossa with pulse duration=1.0 ms and frequency=0.2 Hz. Ten traces were elicited and recorded for each side. The stimulation intensity for H-maximum (H_{max}) was maintained by verifying the constant amplitude of the minimal M-wave[16]. H-reflex was examined from lying and standing positions. The H_{max} (peak-to-peak amplitude) and the side-to-side amplitude (H/H) ratios for the concave and convex side from lying and standing positions were obtained and recorded. Measurements were taken at the beginning of the study and after 12 weeks (post treatment) after the completion of the treatment intervention in both treatment groups.

Patients in the group I received DSET. Based on H-reflex measurements, the H-reflex amplitude was measured during neutral standing posture, side bending and rotation (right and left). Also, H_{max} was measured while the patient in forward, backward bending and during side bending and rotation (to the right and left sides). The position of maximum neural decompression (H-reflex recovery) was considered as the optimum spinal posture (OSP) and maximum compression (H-reflex depression) considered as unwanted spinal posture (USP) was identified. After determining the OSP for each patient, a custom position and exercise program that encourage this posture were applied 3times per week for 12 weeks and at home. Patients were asked to sleep or sit in the decompression posture as long as possible. Positioning, exercises, and mobilization stressed on the mobility more than the strengthening phase of this protocol.

TETP was applied for patients in group II 3 times/week for 12 successive weeks and the same program was repeated at home. A handout was given to the patient describing the exercise program illustrating by photos. Treatment was included stretching on the concave side, strengthening on the convex side, postural correction, mobilizing and breathing exercises[22].

Cobb's angle, H_{max} on both sides during lying and standing was recorded from all patients. The percentage of H_{max} (concave to convex) sides from lying and standing were also calculated. Standing to lying rations on the concave and convex sides were also calculated.

Calculation of the estimated sample size based on power analysis was performed by G-Power 3.1 for Windows. Patient demographic data as age, weight, height and BMI were analyzed by un-paired t-test using SPSS program for Windows, version 16. Comparison between groups were carried out by un-paired t-test. Comparison between the baselines, after 12 weeks of treatments in each group was performed by paired t-test. The level of significance was set at $p>0.05$ for all tests.

RESULTS

A total number of 60 patients participated in the study. Ten patients withdrew and did not complete the study (5 patients from each group). There were no significant differences in the patient's age, weight, height, BMI among treatment groups (Table 1). In baseline values, there were no significant differences in the outcome measured. Analysis of post treatment mean values revealed significant differences among treatment groups in the H_{max} on concave side and the concave/convex ratio with non-significant changes in the H_{max} on convex side. In each group, there were significant changes in both groups in Cobb's angle, H_{max} on the concave side during lying, standing and the concave/convex ratio from standing and lying in both treatment groups. Moreover, there was no significant changes in standing H_{max} on convex side in group II with a significant change in group I (Table 2).

DISCUSSION

The result of the present study showed significant differences indicating asymmetry in H_{max} on concave side. Cobb's angle significantly decreased and the H_{max} on concave side as well as H concave/convex ratios in both lying and standing significantly increased in both groups. DSET showed a more significant increase in the measured outcomes than TETP.

The etiology of AIS may include biological factors such as menarche, lateralization of the brain, handedness, the thoracic cage, the intervertebral disc, and the role of melatonin have been studied in children referred from school screening programs[23]. Other factors, such as proprioceptive defects, genetics, asymmetric or abnormal growth, soft tissue or neuromuscular conditions, have been scrutinized as potential causes, but none have been shown as a consistent factor in all scoliotic adolescents[2, 24–26]. The possible etiologic theories existed with possible bone malformation during development, asymmetric muscle weakness, abnormal postural control because of possible dysfunction of the vestibular system[27], and genetic factors predisposing specific children for pathology[3].

H-reflex amplitude changes (e.g., asymmetry, absence, reduction) were found to be more evident than latency changes (e.g., prolongation, side-to-side differences) in patients with radiculopathy[16]. With continued patterns of faulty posture and aggravation of the radiculopathy during functional daily activities, the severity of neural compromise at the root level may increase[16]. The continued barrage of sensory effect from the lower limb's sensory afferents would be the most likely source

Table 2. Changes in H reflex amplitude among treatment groups

Groups	Cobb's		H Concave (lying)**		H convex (lying)		H Concave (Stand)**		H convex (Stand)		Concave/Convex ratio (lying)**		Concave/Convex ratio (Standing)**	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
DSET	13.2 ± 4.1	5.2 ± 2.7*	3.3 ± 0.9	4.5 ± 0.7*	5.2 ± 0.9	5.2 ± 0.9	2.3 ± 0.7	3.1 ± 0.8*	3.72 ± 0.9	3.81 ± 0.8*	67.3 ± 20	87.9 ± 16.3*	63 ± 19.9	82 ± 20.4*
	−60.6%		32.7%		0.9%		34.2%		2.3%		30.6%		23.2%	
TETP	12.6 ± 3.7	7.6 ± 3.1*	3.1 ± 0.8	3.5 ± 0.9*	5.1 ± 1.1	5.1 ± 1.1	2.2 ± 0.7	2.6 ± 0.6*	3.4 ± 1.1	3.4 ± 1.1	64 ± 20.3	71.1 ± 21.8*	66.8 ± 22.1	78.7 ± 23.4*
	−40.4%		13.1%		1.5%		18.3%		1.1%		11.1%		17.7%	

DSET: direction-sensitive exercise therapy; TETP: traditional exercises therapy protocol
Data expressed in mean ± standard deviation and percentage of improvement.
*Significant changes in post treatment as compared to pretreatment mean values.
**Significant changes in post treatment among treatment groups.

of feeding the signal to maintain the vertebral curvature. Asymmetry of such sensory signal would be the most likely source of vertebral misalignment in AIS[20].

Neurophysiologic concepts stressed on the fact that the sensory signal always precedes the motor signal and adjust it for the demand of the body segment. Such sensory signal would be more located in the afferents of sensory nerve roots and its adjacent spinal cord root ganglia. Muscular and body structure may follow as subservient to the neural components[28].

The result of the present study suggests that a reflex asymmetry may precede muscular and bony structures. Furthermore, it is important to mention that the posture control lies mainly in the central nervous system. Such control arises from spinal peripheral neural structures such as muscle spindle afferents, Golgi tendon organs, cutaneous and joint receptors in association with the central integrating circuits of the spinal cord[29]. The rates of neural axis abnormalities in infantile and juvenile idiopathic scoliosis may be as high as 50%[30]. Such abnormalities in the spinal cord may cause variation to the output by spinal cord alpha motoneurones to the axial vertebral muscles and resulting in weakness in one side and more activity in the contralateral side and eventually the scoliotic curve. A reflex asymmetry at one level would initiate a more caudal or rostral corrective neural or reflex response causing a secondary curve.

In a previous study applied on normal subjects, it was reported 73% difference from both sides in lying while about 72% difference between the right and left sides in standing position while the difference between lying to standing was about 70%. This study suggesting the use of H-reflex testing in such functional positions as a useful diagnostic tool in detecting subtle changes in root impingement[31]. Another study comparing the difference in H-reflex amplitude in patients with radiculopathy. The result showed 67% of the asymmetry between both sides while the side to side difference was 83% in normal[16]. The values obtained by the current study was consistent with those previous studies as it showed that the H/H standing to lying ratio at the concave side was about 68.11% at the pre-treatment in both groups and the concave/convex asymmetry was 65.7% in lying and 64.9% in standing.

Exercises were effective in the treatment of patients with AIS. Exercise was applied 3 times a week for 12 weeks was found to be effective even at a 40-degree or higher Cobb's angle[32]. Core stabilization training in addition to traditional exercises was effective in the correction of vertebral rotation and reduction of pain in AIS[33]. A 10-week core strengthening exercises decreases Cobb angle and improves back muscle strength in patients with functional scoliosis[34]. Schroth exercises applied for five sessions in the two weeks with a daily home program in supervised sessions improved the quality-of-life and back muscle endurance[35]. Swiss ball exercise and chest resistance exercise training applied for 30 min per day, five times per week, for eight weeks were effective in improving the static balancing ability[36], the respiratory function and trunk control ability of patients with scoliosis[37]. Adding Game-Trak to three dimensional (3D) interactive game to specific physiotherapeutic scoliosis-specific exercises intervention improved exercise performance[38]. Physicians who believe in using exercise during conservative management of AIS appreciate not only their capability to influence positively the spinal curvature but also to increase the neuro-motor control and stability of the spine, reduce postural collapse, and increase breathing function[11]. There are also several reports, which include positive results of treatment of scoliosis of 10–25° by means of exercises only[39, 40].

Exercises, based for choosing a position that H-reflex was recovered and being in maximum value, was more effective than traditional exercises in improving the H-reflex value as well as the H/H ratios on the concave side. DSET is considered as 3D exercises as it may include flexion or extension with bending and rotation to one side. As it was reported that 3D exercises can be used for the treatment of small curves (15–30 degrees) together with the physio-logics program[10].

The H-reflex test was effective in discovering the asymmetry between both sides in patients with AIS. Based on the H-reflex test, DSET was more effective in decreasing Cobb's angle and increasing H-reflex values as well as H/H percent at concave side in patients with AIS. Future studies investigating changes in other variables like pain, trunk range of motion and muscle fiber action potentials at both sides of the curve during measuring H-reflex to correlate the changes of H-reflex with the myogenic potentials. Studies on more complicated cases, as in double curves and Cobb's angle 20° will be considered in future research.

Funding

This project was funded by the National Plan for Science, Technology and Innovation (MAARIFAH), King Abdulaziz city for science and Technology, the Kingdom of Saudi Arabia, award number (13-MED1319-10).

ACKNOWLEDGEMENTS

Research team acknowledge the funding provided by the National Plan for Science, Technology and Innovation (MAARIFAH) for the project. The authors express their appreciation to all subjects who participated in this study with their consent and cooperation, and would like to give special thanks to their colleagues at the Department of Physical Therapy, Faculty of Applied Medical Science, Umm AL-Qura University, Saudi Arabia.

REFERENCES

1) Schwab FJ, Smith VA, Biserni M, et al.: Adult scoliosis: a quantitative radiographic and clinical analysis. Spine, 2002, 27: 387–392. [Medline] [CrossRef]
2) Lowe TG, Edgar M, Margulies JY, et al.: Etiology of idiopathic scoliosis: current trends in research. J Bone Joint Surg Am, 2000, 82-A: 1157–1168. [Medline] [CrossRef]
3) Mordecai SC, Dabke HV: Efficacy of exercise therapy for the treatment of adolescent idiopathic scoliosis: a review of the literature. Eur Spine J, 2012, 21: 382–389. [Medline] [CrossRef]
4) Negrini S, Fusco C, Minozzi S, et al.: Exercises reduce the progression rate of adolescent idiopathic scoliosis: results of a comprehensive systematic review of the literature. Disabil Rehabil, 2008, 30: 772–785. [Medline] [CrossRef]
5) Sadat-Ali M: School screening for scoliosis: have we done enough? Saudi Med J, 1998, 19: 210–211. [Medline]
6) Berdishevsky H, Lebel VA, Bettany-Saltikov J, et al.: Physiotherapy scoliosis-specific exercises—a comprehensive review of seven major schools. Scoliosis Spinal Disord, 2016, 11: 20. [Medline] [CrossRef]
7) Lenssinck ML, Frijlink AC, Berger MY, et al.: Effect of bracing and other conservative interventions in the treatment of idiopathic scoliosis in adolescents: a systematic review of clinical trials. Phys Ther, 2005, 85: 1329–1339. [Medline]
8) Weiss HR, Weiss G, Petermann F: Incidence of curvature progression in idiopathic scoliosis patients treated with scoliosis in-patient rehabilitation (SIR): an age- and sex-matched controlled study. Pediatr Rehabil, 2003, 6: 23–30. [Medline] [CrossRef]
9) Weiss HR, Hollaender M, Klein R: ADL based scoliosis rehabilitation—the key to an improvement of time-efficiency? Stud Health Technol Inform, 2006, 123: 594–598. [Medline]
10) Weiss HR, Klein R: Improving excellence in scoliosis rehabilitation: a controlled study of matched pairs. Pediatr Rehabil, 2006, 9: 190–200. [Medline] [CrossRef]
11) Weiss HR, Negrini S, Hawes MC, et al. members of the SOSORT: Physical exercises in the treatment of idiopathic scoliosis at risk of brace treatment—SOSORT consensus paper 2005. Scoliosis, 2006, 1: 6. [Medline] [CrossRef]
12) Weiss HR, Goodall D: The treatment of adolescent idiopathic scoliosis (AIS) according to present evidence. A systematic review. Eur J Phys Rehabil Med, 2008, 44: 177–193. [Medline]
13) Fusco C, Zaina F, Atanasio S, et al.: Physical exercises in the treatment of adolescent idiopathic scoliosis: an updated systematic review. Physiother Theory Pract, 2011, 27: 80–114. [Medline] [CrossRef]
14) Han TR, Kim JH, Paik NJ: A study on new diagnostic criteria of H reflex. Electromyogr Clin Neurophysiol, 1997, 37: 241–250. [Medline]
15) Sabbahi MA, Khalil M: Segmental H-reflex studies in upper and lower limbs of patients with radiculopathy. Arch Phys Med Rehabil, 1990, 71: 223–227. [Medline]
16) Alrowayeh HN, Sabbahi MA: H-reflex amplitude asymmetry is an earlier sign of nerve root involvement than latency in patients with S1 radiculopathy. BMC Res Notes, 2011, 4: 102. [Medline] [CrossRef]
17) Chen Z, Qiu Y, Ma W, et al.: Comparison of somatosensory evoked potentials between adolescent idiopathic scoliosis and congenital scoliosis without neural axis abnormalities. Spine J, 2014, 14: 1095–1098. [Medline] [CrossRef]
18) Lambert FM, Malinvaud D, Gratacap M, et al.: Restricted neural plasticity in vestibulospinal pathways after unilateral labyrinthectomy as the origin for scoliotic deformations. J Neurosci, 2013, 33: 6845–6856. [Medline] [CrossRef]
19) Waller T, Nowak R, Tkacz M, et al.: Familial or sporadic idiopathic scoliosis—classification based on artificial neural network and GAPDH and ACTB transcription profile. Biomed Eng Online, 2013, 12: 1. [Medline] [CrossRef]
20) Wu L, Qiu Y, Wang B, et al.: The left thoracic curve pattern: a strong predictor for neural axis abnormalities in patients with "idiopathic" scoliosis. Spine, 2010, 35: 182–185. [Medline] [CrossRef]
21) Aminoff MJ: Electromyography in clinical practice. Menlo Park: Addison-Wesley Pub, 1978.

22) Kisner C, Colby LA: Therapeutic exercise: foundations and techniques. 2013.
23) Grivas TB, Vasiliadis E, Savvidou OD, et al.: What a school screening program could contribute in clinical research of idiopathic scoliosis aetiology. Disabil Rehabil, 2008, 30: 752–762. [Medline] [CrossRef]
24) Porter RW: The pathogenesis of idiopathic scoliosis: uncoupled neuro-osseous growth? Eur Spine J, 2001, 10: 473–481. [Medline] [CrossRef]
25) Miller NH: Genetics of familial idiopathic scoliosis. Clin Orthop Relat Res, 2007, 462: 6–10. [Medline] [CrossRef]
26) Miller NH: Idiopathic scoliosis: cracking the genetic code and what does it mean? J Pediatr Orthop, 2011, 31: S49–S52. [Medline] [CrossRef]
27) Kisner C, Colby LA: Therapeutic exercise: foundations and techniques. 2007.
28) Zhang F, Deshpande N: Sensory interactions for head and trunk control in space in young and older adults during normal and narrow-base walking. Mot Contr, 2016, 20: 21–32. [Medline] [CrossRef]
29) Wu G, Chiang JH: The significance of somatosensory stimulations to the human foot in the control of postural reflexes. Exp Brain Res, 1997, 114: 163–169. [Medline] [CrossRef]
30) Koç T, Lam KS, Webb JK: Are intraspinal anomalies in early onset idiopathic scoliosis as common as once thought? A two centre United Kingdom study. Eur Spine J, 2013, 22: 1250–1254. [Medline] [CrossRef]
31) Ali AA, Sabbahi MA: H-reflex changes under spinal loading and unloading conditions in normal subjects. Clin Neurophysiol, 2000, 111: 664–670. [Medline] [CrossRef]
32) Kim KD, Hwangbo PN: Effects of the Schroth exercise on the Cobb's angle and vital capacity of patients with idiopathic scoliosis that is an operative indication. J Phys Ther Sci, 2016, 28: 923–926. [Medline] [CrossRef]
33) Gür G, Ayhan C, Yakut Y: The effectiveness of core stabilization exercise in adolescent idiopathic scoliosis: a randomized controlled trial. Prosthet Orthot Int, 2017, 41: 303–310. [Medline] [CrossRef]
34) Park YH, Park YS, Lee YT, et al.: The effect of a core exercise program on Cobb angle and back muscle activity in male students with functional scoliosis: a prospective, randomized, parallel-group, comparative study. J Int Med Res, 2016, 44: 728–734. [Medline] [CrossRef]
35) Schreiber S, Parent EC, Moez EK, et al.: The effect of Schroth exercises added to the standard of care on the quality of life and muscle endurance in adolescents with idiopathic scoliosis—an assessor and statistician blinded randomized controlled trial: "SOSORT 2015 Award Winner". Scoliosis, 2015, 10: 24. [Medline] [CrossRef]
36) Song GB, Kim JJ, Park EC: The effect of Swiss ball exercise and resistance exercise on balancing ability of scoliosis patients. J Phys Ther Sci, 2015, 27: 3879–3882. [Medline] [CrossRef]
37) Kim JJ, Song GB, Park EC: Effects of Swiss ball exercise and resistance exercise on respiratory function and trunk control ability in patients with scoliosis. J Phys Ther Sci, 2015, 27: 1775–1778. [Medline] [CrossRef]
38) Wibmer C, Groebl P, Nischelwitzer A, et al.: Video-game-assisted physiotherapeutic scoliosis-specific exercises for idiopathic scoliosis: case series and introduction of a new tool to increase motivation and precision of exercise performance. Scoliosis Spinal Disord, 2016, 11: 44. [Medline] [CrossRef]
39) Negrini S, Negrini A, Romano M, et al.: A controlled prospective study on the efficacy of SEAS.02 exercises in preparation to bracing for idiopathic scoliosis. Stud Health Technol Inform, 2006, 123: 519–522. [Medline]
40) Negrini S, Zaina F, Romano M, et al.: Specific exercises reduce brace prescription in adolescent idiopathic scoliosis: a prospective controlled cohort study with worst-case analysis. J Rehabil Med, 2008, 40: 451–455. [Medline] [CrossRef]