DYNAMIC STABILITY MEASUREMENTS OF ADOLESCENT IDIOPATHIC SCOLIOSIS COMPARED TO THE NORMAL SUBJECTS: A COMPARATIVE STUDY

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Abstract

Background: Adolescent idiopathic scoliosis is a twisting deformity in the curve of vertebral column to the lateral side with simultaneous rotation of the vertebrae, which occurs during the growing years from 10 years to the puberty. **Objective of the study:** Studies investigating balance problems specific to scoliotic patients showed that those patients reveal variable balance abnormalities. In this study we evaluated the difference in dynamic balance between female patients with adolescent idiopathic scoliosis and normal subjects. **Materials and Methods:** sixty subjects participated in this study. Thirty female patients with adolescent idiopathic scoliosis scoliosis with a mean age of (19.5 ± 3.26) years, with Cobb's angle ranged from 20º to 40° in the major curves, and thirty healthy female subjects with a mean age of (19.36 ± 2.41) years. Dynamic balance of both groups was evaluated by the Biodex Stability System. **Results:** MANOVA yielded a non-significant difference of the tested group on the overall stability, A/P stability, M/L stability, time, overall and forward (F= 1.458, p = 0.21, Partial η^2= 0.142). The tests of one way between subject MANOVA demonstrated a non-significant difference between both groups in the mean values of the all dependent variables (P>0.05). Subsequently, post hoc tests used for multiple pairwise comparison yielded a non-significant difference in the mean value of the all dependent variables (P>0.05). **Conclusion**: As there was no significant difference between both groups in balance response, it is not recommended to add balance training as an extra physical therapy program for adolescent idiopathic scoliosis female patients.

Key words: Adolescent idiopathic scoliosis, Dynamic stability

INTRODUCTION

Adolescent idiopathic scoliosis (AIS) is traditionally defined as a lateral curvature of the spine of 10 degrees or more in people 10 to 18 years of age that is not due to an incurable condition. (1)

Adolescent idiopathic scoliosis (AIS) is the most common type of scoliosis, accounting for more than 80% of scoliosis cases. (2) It is two types: Non - structural scoliosis is mild, non-progressive and fully correctable by ipsilateral bending and Structural scoliosis is moderate or severe with vertebral morphological changes which include wedging and rotation. (3)

The etiology of idiopathic scoliosis is still unknown, and multifactorial causes, including biological, mechanical, hormonal, and genetic factors, are thought to contribute to its onset and progression. Postural control involves the position of the body in space for the dual purposes of stability and orientation, often described as the ability to control the body's center of mass (COM) relative to the base of support (BOS) while postural orientation is the ability to maintain an appropriate relationship between the body and the environment for a task. (4)

The capacity to regulate the center of mass (COM) in relation to the base of support (BOS) is commonly referred to as the definition of postural stability. In order to accomplish both of the goals of stability and direction, the body's location in space is maintained through posture. (5)

The capacity to maintain a suitable interaction between the body and the environment for an activity is defined as postural orientation. (6-7)

One's upright posture and capacity for maintaining balance can also be impacted by outside factors, such as carrying a load. Since there is evidence that postural lopsidedness can worsen AIS, it is especially concerning in children with AIS. In this way, additional equilibrium problems brought on by carrying school bags may contribute to the progression of scoliotic deformities. (8)

There many studies studded balance in scoliosis, the postural stability control of AIS patients would show less stability than the healthy controls (9), (10), (11), (12), (13).

These studies suggest that postural changes in the body attitude associated with scoliosis may be the cause of the balance issues that have been reported in adolescent idiopathic scoliosis. Others may experience no noticeable effects from scoliosis (14), (15), or they may experience increased stability. (16)

Other study showed greater body-sway oscillation amplitude observed during ankle proprioception reintegration. Whether vision was available or not, strongly suggested that balance control deficit is not only related to the three dimensional deviation of the spine but difficulty in dynamically adjusting sensory inputs to tailor the balance control command to the postural context). (17)

Other study suggested that idiopathic scoliosis mainly affects the head trunk coordination. (18)

Subjects with idiopathic scoliosis had reduced body sway compared with normal subjects across simple and complex balance tests. (19) However, this difference was only significantly different than controls when predictable anterior-posterior oscillations were generated from the movement of the support surface (eyes opened or closed). Furthermore, subjects with progressive curves performed the balance tests with significantly less body sway than those with non-progressive curves. Thus, those subjects with IS demonstrated more well adapted balance reactions than age-matched controls.

There is a need to determine if there is a difference in postural stability in patient with adolescent idiopathic scoliosis.

Objectives of the study:

The study was designed to measure dynamic stability in female with adolescent idiopathic scoliosis compared to the normal subjects.

MATERIALS AND METHODS

This study was conducted to evaluate dynamic balance in female with adolescent idiopathic scoliosis compared to the normal subjects.

Study Design:

The study design was cross sectional study.

Ethical approval:

The study was evaluated and approved by the Research Ethics Committee at King Khalid University (HAPO-06-B-001), (Approval number: ECM#2023-2105). The Helsinki Declaration Criteria for human research were followed in this study. A written informed consent was obtained from each patient.

Clinical Trials.gov Protocol Registration and Results System (PRS) Receipt, Release Date: January 26, 2024, ClinicalTrials.gov ID: NCT06219772.

Subjects:

Participants were identified and recruited over 9-month period from 26 / 1 / 2026 to 26 / 10 / 2025. Two groups of subjects with age ranged from 10-20 years old were participated in the present study.

The first group is the control group (A) which included 30 healthy normal female subjects. The second group is experimental group (B) which included 30 female patients with idiopathic structural scoliosis; each patient in the involved group was referred from the orthopedic surgeon with Cobb's angle ranged from (20º to 40º).

Inclusion Criteria:

- Age between (10-20). (1)
- Average Cobb's angle was varied between 20º to 40º. (3)
- Female patients (students, office worker and shish weapon players). (4)

Exclusion Criteria:

History of previous back surgery. (14)

Neurologic deficit or Current lower extremity symptoms. (14)

Symptoms of vertigo or dizziness. (15)

No other disorders in the vertebral column (disc prolapse, spondylitis, and fracture). (16)

Instrumentation:

Biodex Stability System

Biodex stability system (Biodex Medical Systems Inc, Shirley, NY, USA) is used to measure dynamic balance. It utilizes a dynamic multiaxial platform, which can be set at variable degrees of instability. The system is interfaced with computer software monitored through the control panel screen and is supplied with Epson printer to print the test results (Fig. 1). Biodex Stability system showed fair within -day test retest reliability for AP stability index (intraclass correlation coefficient (ICC) =0.71) and ML stability index (ICC = 0.73). The time of the test and stability level was the same as that used in the current study. (20) There is high reliability for dominant single limb standing (ICC = 0.95) and fair reliability for nondominant single limb standing (ICC = 0.78). (21)

surface appear the numbers from 1 to 21 (22).

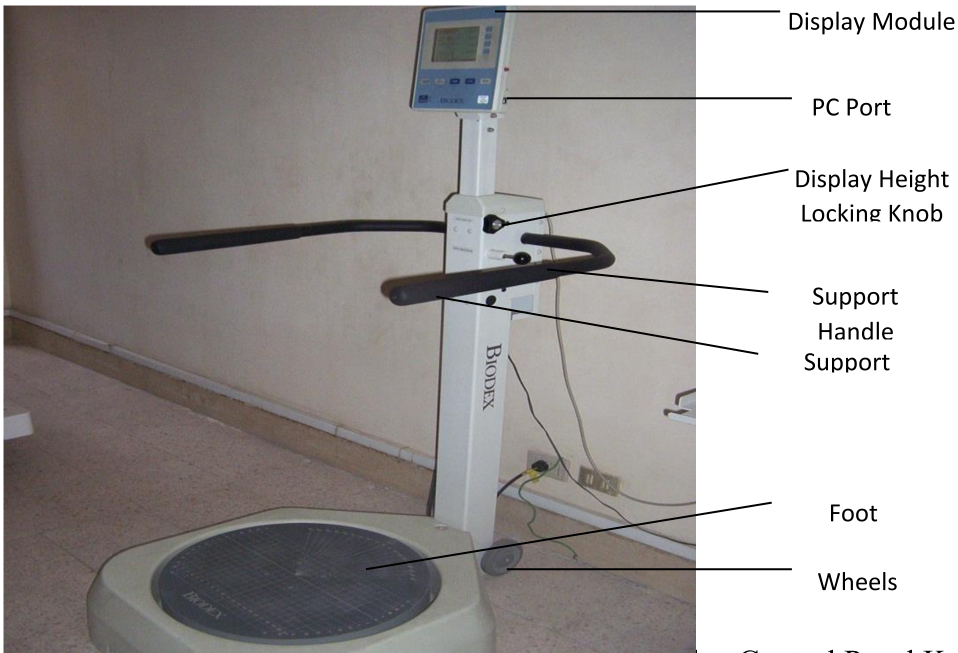

Fig. (1) Biodex Stability System

The Foot Platform

The foot platform allows for approximately 20 degrees deflection from horizontal in all directions. Platform diameter is 21.5 inches. Stability is provided by 8 metal springs located at the perimeter of the foot platform. Each spring has an uncompressed length of 13.97 cm, an outside diameter of 3, 11 cm; a wire diameter of 0, 24 cm, the maximum weight capacity of the platform is 300 pounds. The platform has a foot grid for determination of foot position, which is important for centering process of the subject before testing to position the COG nearly over the point of the vertical ground reaction force and also to ensure consistency in each test condition trial. On the surface of the foot platform appear the alphabetic letters from A to P (on the far ends of both sides) with parallel lines joining between them. On the lower most part of the platform

Display Control Panel Keys

The display control panel has many keys, which have different functions. On the lowermost left corner of the control panel lays the on / standby key to turn the system on or to standby. From left to right directly under the display screen, the following function keys are present:

(Previous screen) key: to return to the screen immediately prior to the current screen.

(Next screen) key: to advance to the next logical screen.

(Start) key: to activate the foot platform and the clock after the test protocol screens have been completed.

(Stop) key: pushing this key at any time during the test returns the foot platform to the fully locked position.

(Enter) key: is used to confirm numeric entries, save selected testing parameters, and advance to the next logical screen where applicable.

There are four keys on the right side of the control panel, namely S1, S2, S3, and S4.

Every key has a function, which itself differs according to the screen displayed. The function is indicated in the current screen just beside the key. These functions include selecting from menu, increasing or decreasing parameters or numerical values, and system utilities adjustments etc. (23)

Operating the Stability System

When the system is on, the first displayed screen shows the main menu. It allows the clinician, to choose entering testing, training, or system utilities. Choosing to enter testing shows the next screen, which allows for determining the test parameters as test duration and the stability level chosen? It also records the weight and height of the subjects. The next screen is used to record if feet, right foot, or left foot test condition is applied. The next screen is used for centering process.

The next screen is the stability test screen. Pushing start key while on this screen unlocks the platform and begins the test. A cursor appears during the test tracing the movement of the platform while the clock counts till the time of the test ends. The next screen shows a menu. Choosing numeric report from this menu allows for showing the numeric report screen. Pressing start while on this screen begins printing the report, which includes the numeric value of the AP stability index, ML stability index, and overall stability index. (23)

The outcome from tests includes:

Overall Stability Index: represents the subject's ability to control their balance in all direction.

Anterior/ Posterior Index: represents the subject's ability to control their balance in front to back direction.

Medial/ Lateral Index: represents the subject's ability to control their balance from side to side.

Limits of Stability: the maximum angle one's body can achieve from vertical without losing balance.

Procedures:

Testing procedures:

The first test (test of dynamic balance):

The subject's weight and height were entered to control screen display located in front of the subject.

Position of the support handle and its height were adjusted according to the subjects height and comfort, to grasp it during the initiation of the test, and the subject asked to leave it as the test proceed.

The subject was centered by informing her to stand on both feet, grasp the balance system hard rail.

The test duration was set for 30 sec. through 2 levels (1-8).

The test duration instructed to try to achieve a centered position on the platform to which is easy to keep the cursor on the visual feedback screen directly in front of the subject.

Keeping the cursor in the center of screen grid meant that the platform was kept leveled beneath to subject feet while standing in a comfortable up right position.

The second test: (The limits of stability)

Centering the subject again and instructing her to try to shift to move the cursor over the blinking target and back to the center target as quickly and with little deviation as possible.

The same process is repeated for each of eight targets.

Then readjusting the apparatus was done and repetition of the same procedures on the scoliotic patients in experiment all group.

Patients or subjects during both tests were with: eye open without hard support both feed striding without foot wear.

Outcome from Tests:

1- Overall Stability Index.
2- Anterior/Posterior Index.
3- Medial/Lateral Index.
4- Total time in (limits of stability).
5- Overall directional control.

Statistical analysis:

Data obtained from the study was coded and entered using the statistical package SSPS. Descriptive statistics for demographic data and outcome measures were expressed as mean and standard deviation .Comparisons between groups were done using unpaired t- test. P values less than 0.05 and was considered statistically significant.

RESULTS

A total of sixty female subjects participated in this study. They were assigned into two groups; the control group (group A) which consisted of 30 normal female subjects with mean age of 19.36 (± 2.41) years, mean weight of 60.53 (± 8.81) kg, and mean height of 162.63 (± 5.42) cm. The experimental group (group B) consisted of 30 females patients with adolescent idiopathic scoliosis with a mean age of 19.5 (± 3.26) years, mean weight of 57.7 (± 10.62) kg and mean height of 162.76 (± 7.20) cm.

Using unpaired t-test showed that there was no significant difference between both groups before assessment for their demographic data. (Table 1)

Table 1 – Demographic data of both groups:

Variables	Normal (A)	Scoliotic (B)	t-value	p-value
Age	19.36 (±2.41)	19.5 (±3.26)	0.17	0.85 NS
Weight	60.53 (±8.81)	57.7 (±10.62)	1.12	0.26 NS
Height	162.63 (±5.42)	162.76 (±7.20)	0.08	0.93 NS
BMI	23.064 (±5.42)	21.98 (±7.20)	0.05	0.83 NS

The activation onset and duration of the tested muscles:

One way between subject MANOVA yielded a non-significant difference of the tested group on the overall stability, A/P stability, M/L stability, time, overall and forward (F= 1.458, p = 0.21, Partial $\eta 2$= 0.142). The univariate tests of one way between subject MANOVA demonstrated a non-significant difference between both groups in the mean values of the all dependent variables (P>0.05). Subsequently, post hoc tests used for multiple pairwise comparison yielded a non-significant difference in the mean value of the all dependent variables (P>0.05). (Table 2)

Table 2: Descriptive and inferential statistics for overall stability, A/P stability, M/L stability, time, overall and forward between both groups.

Test	Group A	Group B	MD	F- value	p- value	Partial Eta Squared
Overall stability	6.39±2.32	5.89±1.36	0.5	1.02	0.317	0.017
A/P stability	5.10±1.75	4.59±1.13	0.51	1.785	0.187	0.03
M/L stability	4.26±1.69	3.65±1.32	0.61	2.35	0.131	0.039
Time	176.13±73.81	197.23±7522	-21.1	1.202	0.277	0.02
Overall	9.43±5.82	8.7±4.82	0.73	0.282	0.597	0.005
Forward	11.43±9.3	11.43±8.49	0.000	0.000	1.00	0.0001

Data were displayed as mean ± standard deviation, A/P=Anterior posterior, ML=Mediolarteral, MD=mean difference, P-value=probability value, *the significant level was set at P < 0.05.

Overall Stability Index: represents the subject's ability to control their balance in all direction. Anterior/ Posterior Index: represents the subject's ability to control their balance in front to back direction. Medial/ Lateral Index: represents the subject's ability to control their balance from side to side. Time: time to complete the test. Overall: represents the subject's ability to control their balance in all direction in second test. Forward represents the subject's ability to control their balance in front to back direction in second test.

DISCUSSION

This study was conducted to evaluate postural stability in women with scoliosis compared to normal subjects. Thirty healthy subjects (group A) and thirty female patients (group B), ages 10 to 20, participated in this study. They were assessed by the Biodex stability system (24), in the form of the stability index (gross, anteroposterior, medial lateral) and the dynamic limits of stability (general control of direction, time taken to complete the test). Patients in the experimental group were diagnosed as moderate to severe idiopathic skeletal scoliosis with the main curve ranging from 20° to 40° Cobb angle. They were referred from an orthopedic surgeon.

A. Test of Dynamic Balance:

1- Overall stability index:

It has been revealed from statistical analysis that there was no significance difference between the scoliotic and normal subjects in the record of the overall stability index, and this result has been supported by (3), who stated that, the most recent prospective studies with scoliosis have shown a lower incidence of brainstem and cord abnormalities than previously suggested.

During the progression stage, the control of postural stability in IS girls appears to be on line with that of healthy girls. (25)

Investigation of balance problems specific to scoliotic patients showed that those patients revealed variable balance responses, in which balance response in patients with idiopathic scoliosis comparing them with age-matched controls showed that subjects with IS had similar simple static balance responses when the somatosensory system was stable (with or without vision or head turning. (26)

In actuality, reasoned that subjects with idiopathic scoliosis had diminished body influence contrasted and typical subjects across basic and complex equilibrium tests. In any case, this distinction was just critical than controls when unsurprising anteroposterior motions were produced from the development of the help surface (eyes opened or shut). Besides, subjects with moderate bends played out the offset tests with altogether less body influence than those with non-moderate bends. Consequently, those subjects were exhibited more very much adjusted balance responses than age-matched controls, This would make sense of our outcome, as there were no huge distinction yet to be determined between the trial bunch and the benchmark group, as we select our patients with cobb point 20 to 40 degrees which were viewed as a moderately moderate, might be a direct result of the remuneration which ended up revising the deviation of the storage compartment. (19)

In adolescents with idiopathic scoliosis much is still unknown about how scoliosis compromises pelvic mobility. Original pelvis alignment (three- dimensional) plays an essential part in chine- pelvis biomechanics. Spatial concurrency in pelvic alignment was noted and the findings indicated that separate parameters don't adequately characterize the effect of scoliosis on pelvic dynamic. (27)

Dysfunction of colorful equilibrium factors has been set up to be associated with adolescent idiopathic scoliosis. Some authors set up significantly poorer postural control in cases with AIS compared with normal children in all of their testing situations. They concluded that their results laterally indicate the possibility of a postural disequilibrium as a contributory causative factor, and also, subjects with idiopathic scoliosis had difficulty passing the sensitive-challenged balance tests but they performed as well as, if not better than, controls on the simple static balance tests (26). But we shouldn't generalize this result on the all degrees of the idiopathic scoliosis.

2- Anteroposterior (A/P) Stability index:

Antero-posterior (A/ P) Stability indicator Antero-posterior stability indicator represents the standard divagation of platform relegation in degrees from position for stir in the sagittal aero plane (Operation and service primer, Biodex Stability System, 1998). Concerning the A/ P stability indicator we noticed that there was no difference between normal and scoliotic.

The scoliotic patients were selected with Cobb's angle ranges from 20° to 40° for the major curves, and it's generally accepted that the spine does not require surgical correction because such curves do not represents a threats to life or limbs and seldom are associated with an unsightly trunk or chest deformity. (3)

These cases would not have the hypokyphosis in the thoracic region which will disturb the A/P stability index, increased anterior vertebral height at the apex is associated with wedging posteriorly in the vertebral end plate and disc, producing hypokyphosis (< 20°) or a lordosis (< 0°), were the normal kyphosis should be between 20° and 45°. (26)

The ability to keep the body's center of mass over its base of support is what makes balance the single most crucial factor underlying techniques for movement with the closed kinetic chain. As a result of various systems interacting flawlessly and naturally, our nervous system receives correct and exact information. This information would not be accurate with an aberrant spinal curve, such as that found in scoliotic patients in the frontal or sagittal plane. (28)

3- Mediolateral (M/L) stability index:

According to the operating and service manual for the Biodex Stability System from 1998, the mediolateral stability index is the standard deviation of platform displacement measured in degrees from level for motion in the frontal plane.

We found that there was not a significant distinction from normal and scoliotic patients for the (M/L) stability index.

The average center of gravity adjustment in healthy subjects was less in the mediolateral direction than in the anteroposterior direction, and due to the center of support of the platform in the mediolateral direction was more controllable than in the anteroposterior direction through extending the space between both feet, as observed also in this study, supported our findings in the M/L stability index. So that the mediolarteral direction can be balanced, sick or healthy persons are capable of controlling it. (29)

On the other hand, this function has been linked to adolescent idiopathic scoliosis in a number of balance parameters. In all of their tests, several writers observed that patients with AIS had much worse control of their posture than normal children. (26)

B. Test for the Dynamic limits of stability:

The restrictions of stability test and the directional control examination are two more subtests included in this test. The largest angle that a person's body may make from a vertical posture without losing balance is referred to as the limit of stability. The limit of direction control, which is a measure of motor control abilities, is expressed as a percentage of the theoretical excursion value. Perfect control is 100%. (24)

In our investigation, the results of both tests between the healthy and scoliotic groups did not vary significantly.

There is no instability in scoliotic subjects because their brainstems are normal, whereas the presence of anomalies would have an impact on the patient's balance. (3)

In a different study focusing on balance issues unique to scoliotic patients, demonstrated variable balance abnormalities, particularly those with complex sensory challenged balance tasks when the somatosensory system was obstructed by an unsteady foot position, particularly when the eyes were closed, and also claimed that patients with mild to severe idiopathic scoliosis may have some predicative processing dysfunction. His study had been conducted with closed eyes, which would significantly influence balance, but in the present study, our tests were conducted with open eyes. (30)

Our findings are supported by another study (19), which found that people with idiopathic scoliosis showed less body sway than normal subjects. Because none of the balance settings in the Adler investigation presented a challenge to medial-lateral stability, their findings were what were seen in this study. The resistance to movement that their subjects were exhibiting was similar to the protection rigidity seen in a patient with vertigo who avoided movement to prevent oneself from becoming symptomatic because they feared they could reach their limits of stabilization and lose control.

These results were also refuted by other study (26) results, which showed that in all of the testing scenarios, AIS patients' postural control was significantly worse than that of kids that are healthy of the same age. The change was most noticeable in tests where keeping postural stability depended heavily on proprioceptive processes. Additionally, findings challenge our findings and contend that while AIS participants' gait patterns are similar to those of normal subjects, they produce larger levels of sway area, lateral sway, and sagittal sway than do normal subjects. (31)

Additionally, individuals with AIS have remarkable parallels with control participants in terms of their adaptation techniques for controlling their locomotor velocity and their balance through segmental stability. However, the absence of yaw head stabilizing techniques, which primarily rely on the utilization of vestibular information, likely indicates the presence of vestibular abnormalities in AIS patients. (32)

Another study found that AIS sufferers had less standing stability. This might be brought on by a spinal deformity, which alters the posture of scoliotic patients by altering the relationships between body segments as well as the structure of the trunk. This increased body wobble when standing upright may be related in part to these postural adjustments to the scoliotic curvature. (33)

Conclusion

It is concluded that there is no defect of dynamic balance in female with structural scoliosis compared to healthy subjects, either in measuring the dynamic balance for A/P, M/L and overall stability index, or measuring the dynamic limits of stability for the overall direction control or the time to complete this test.

This is due to the low severity of the Cobb's angle taken in the study, as the trunk deformity will increase with high severity or great Cobb's angle, especially beyond 40°, which also will disturb the response of the dynamic balance test. So the information gained in this study might be useful to save the effort from the patient and therapist, and avoid extra physical therapy program of balance training for the patients with AIS.

Recommendations

- Further studies are needed to correlate type, severity and progression of scoliosis relative to measured balance dysfunction.

- Further studies are needed for a thoroughly evaluation of dynamic balance for AIS subjects at different stability levels for different length trials while varying the visual, sensory or vestibular input of balance.
- Future work is needed to make an analysis of lumbar spine motion with electromyography during dynamic balance testing to increase the understanding about dynamic postural compensations in AIS patients.
- Further studies are needed to examine the dynamic balance measures among different age groups, different history of injury and among athletes in various sports.

Authors Contributions:

GMR and AMF took part in the concept and design of the study. AMF contributed to applying each treatment according to the treatment schedule. GMR participated in acquisition of data. RSR and IAA contributed to Data analysis and interpretation. All authors collaborated on the study's statistical analysis, interpretation of the data, writing, and editing.

Conflict of interest:

Authors state no conflict of interest.

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