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Research Article

Effect of Eight-week Core Stabilization Exercises on Static and Dynamic Balance Indices in Girls with Hyperlordosis: A Controlled Laboratory Study

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Abstract

Background: Postural control can be affected by hyperlordosis and the effect of core training on postural control has yet to be established in students with hyperlordosis. Therefore, the aim of this study was to investigate the effect of core stabilization exercises on balance indices in girls with hyperlordosis.
Methods: In this controlled laboratory study, we divided 32 girls (14-15 years old) with hyperlordosis inTehran schools into experimental and control groups in 2018. The experimental group received two core exercise sessions per week for a period of eight weeks. Before and after exercises, we evaluated the balance indices of center of pressure (COP) and time to stabilization (TTS). To analyze the data, statistical analysis of the t-test was used via SPSS software.
Results: We observed significant differences in the COP indices of R.AP (P=0.038) and V.AP (P=0.001) and TTS indices of vertical (P=0.012), antroposterior (P=0.032), and mediolateral directions (P=0.001) before and after stability exercises in the experimental group; however, no significant difference was found in R.AP (P=0.221), R.ML (P=0.192), V.AP (P=0.461), and V.ML (P=0.195) in the control group. Furthermore, the results implied a significant difference in the COP indices of R.AP (P=0.001) and V.AP (P=0.023) and the TTS indices of vertical (P=0.001), antroposterior (P=0.001), and mediolateral directions (P=0.001) between the two groups in the post-test condition.
Conclusions: The study findings revealed that the eight weeks of core stabilization exercises could be considered as an appropriate training method for improving the postural control for 14-15-year-old girls with hyperlordosis.

Keywords: Lordosis, Exercise, Balance, Force plate, Posture

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1. Introduction

Under both static and dynamic conditions, balance control is a necessary conditioning factor for people's daily physical activity (1). Accordingly, postural control and balance index have been studied as important parameters in the evaluation of people with various disorders including neuromuscular and musculoskeletal disorders (2).

One of the most prevalent abnormalities in high school students is hyperlordosis (3). It is a deformity in the spine that develops in the sagittal plane and excessively increases the lumbar curvature angle to more than 40° (4). This deformation can impair the postural balance (5) and muscle function (6). Balance maintenance is a complex function involving many neuromuscular processes. Postural control includes the complex interplay between sensory afferents and motory efferents required for maintaining posture and balance (7). Various exercises have been proposed for improving balance, and research has shown that core exercises are a good approach to enhancing postural balance (8, 9). In this regard, some studies have categorized such exercises into a balance exercise (10). There exist various methods for evaluating the postural balance (11). In this study, we used a jump-landing test on a force plate as a dynamic balance index and standing on the force plate with open and closed-eye test as a static balance index. Jump-landing is a dynamic, functional task that can be performed to calculate the Time To Stability (TTS) (12). TTS measures neuromuscular control and demonstrates the body's ability to minimize postural oscillation when transitioning from a dynamic to a static condition (13); it is highly sensitive to postural stability disorders (14). On the other hand, the Center Of Pressure (COP) displacement is defined as the point in space between the legs and the ground, which is the result of the total body

force entering the ground. Some studies have focused on the effect of posture and postural changes on maintaining body balance. For instance, Nault and colleagues showed that the center of displacement of the foot pressure was higher in the scoliotic group than in the control group, indicating a poorer balance function (15). Meanwhile, Aydog and colleagues reported no significant difference in postural fluctuations and pressure center between the two groups of ankylosing spondylosis and the control group (16). According to Kibler and colleagues, core exercises and strength exercises are important components in maximizing balance and performance in both lower and upper extremity movements (12).

In this connection, Cosio-Lima and colleagues compared the effect of Swissball exercise program and training on the ground on the balance in women; they showed that training with Swiss ball significantly increased the balance (9). However, Sato and Mokha did not observe a significant improvement in the subjects' balance after implementing six weeks of core stability exercises (17). According to numerous studies, core muscle strength is one of the most important components of improving balance and function (18). Kahle and colleaguesexamined the effect of core stability exercises on balance in healthy young people; their results showed improved distance traveled with legs in most directions of the SEBT (anterior, internal, posteroanterior) (19). In a review on core stability and its relationship with lower extremity function and injury, Wilson and colleagues concluded that injury might be attributed to reduced core stability (20). On the other hand, Kimberly and colleaguesexamined the effect of a five-week core stability training program on dynamic balance in tennis players and reported no significant difference in the dynamic balance between the two groups (21). Given that hyperlordosis can impair postural balance (5), the objective of this study was to investigate the effect of eight weeks of core stabilization exercises on static and dynamic balance indices in girls with hyperlordosis.

2. Methods

Participants

In this controlled laboratory study, the population included 14-15-year-old girls in Tehran province. An a priori power analysis (G* power ver. 3.1.2; Franz Faul, University of Kiel, Kiel, Germany) revealed that a sample size of at least 32 subjects was required for an alpha type I error of 0.05, an effect size of 0.90, and a beta type II error of 0.2 with a two-group design(Faul, Erdfelder, Lang, & Buchner, 2007). Therefore, 32 girls with hyperlordosis were selected for this study by simple random sampling. Afterwards, the participants were randomly allocated to an experimental group and a control group in a 1:1 ratio (16 participants in each group); this was done viaa computer-generated random allocation number by an investigator who was not involved in the study (Table 1). Also, instead of letters A and B, she used the codes I and C (I for the experimetal group and C for the control group) to avoid further confusion. Inclusion criteria were: 14-15 years, 18-24 body mass index (BMI), and the presence of hyperlordosismeasured with Flexicurve (angles >40° are considered as hyperlordosis). The exclusion criteria were lower-extremity injury in the previous six months, musculoskeletal injury in the previous two months, neurological and pathological conditions, or lower-extremity surgery within the past one year. The Ethics Committee of the medical faculty of the Allameh Tabataba'i University approved the study (Ethics Code Number: S/9/18/45261).

Procedures

The core stability exercises were performed two sessions a week (on even days) for eight weeks(Table 2). Each session lasted 15 to 20 minutes, including warm-up for 3 minutes, core stabilization exercises for 10 minutes, and cooling down for 2 minutes. Initially, the participants performed the warm-up and stretching exercises before starting the main protocol to prevent possible injuries to the neuromuscular system. There was a two-minute break between each set and each movement. Of note, there was a mutual trust between the patients and the therapist. The re-evaluation was done following the training period (eight weeks).

The outcome measures employed in the current research were COP and TTS measurement both of which were assessed at the start of the study and at the end of the eight-weekintervention.

Table 1: Participant demographics

Parameter	Experimental group (mean±SD)	Control group (mean±SD)	P-value
Age (year)	14.51±2.05	14.67±2.21	0.176
Height (cm)	152.17±4.22	152.08±5.44	0.152
Weight (kg)	38.54±5.53	37.77±6.28	0.580

Table 2: Core stability exercise protocol
CORE stability exercise, Week 1-2
1. Abdominal contraction in a supine position
2. Abdominal drawing-in in a prone position
3. Abdominal drawing-in in a squat position
Each exercise was done 3 times, each with 20 repetitions
CORE stability exercise, Week 3
1. Abdominal contraction in a supine position with flexion/shortening the feet (3 times, each with 20 repetitions)
2. Abdominal drawing-in in a prone position with flexion/shortening the feet (3 times, each with 20 repetitions)
3. Side bridge for each side, 6 times, 10 s of rest
CORE stability exercise, Week 4
1. Abdominal contraction in a supine position with limb elevation and closing hands and feet
2. Quadrupted position by elevating one foot from behind
3. Trunk rotation with overload/weight (for each side 3 times, each with 20 repetitions)
CORE stability exercise, Week 5
1. Sitting on a Swiss ball and performing abdominal drawing-in (3 times, each with 10 repetitions)
2. Squatting while placing a Swiss ball between a wall and scapula (3 times, each with 15 repetitions)
3. Concurrently elevating the feet and hands in a prone position (3 times, each with 10 repetitions)
CORE stability exercise, Week 6
1. Lunge in one direction with a 45 degree angle to the left and right (3 times, each with 12 repetitions)
2. Bridging on one foot (3 times, each with 15 s of rest)
3. Isometric contraction while lying on a Swiss ball, plantar on the ground, lumbar on the ball (3 times, each with 20 repetitions)
CORE stability exercise, Week 7
1. Lying on a Swiss ball, plantar on the ground, lumbar on the ball, and side trunk rotation (3 times, each with 15 repetitions)
2. Lying on a swiss ball, plantar on the ground, lumbar on the ball, and side trunk rotation with 0.25 kg weight on the hand (3 times, each with 15 repetitions)
3. Unilateral bridge together with on foot elevation
CORE stability exercise, Week 8
1. Lying supine on a Swiss ball and drawing-in maneuver (3 times, each with 20 repetitions)
2. Contralateral hand-foot elevation in a quadruped position (3 times, each with 20 repetitions)
3. Unilataral bridge on a Swiss ball (3 times, each with 15s of rest)

Instrumentation

A 30 cm flexible ruler was used to measure and evaluate the lumbar lordosis angle of the subjects in the pre-test phase; in Iran, the reliability and validity of this tool were 98% and 82%, respectively (22). A three-axial force plate (Ver 3.0.2 (50.40.8) manufactured by Danesh Salar Iranian Company) was used to record and measure the COP and TTS indices.

Method for Measuring Lumbar Lordosis Curvature

To measure the lumbar curve, the patients stood with knees extended, feet approximately shoulder-width apart;the lordosis was then measured between the L1-S2 prominences. At first, the bilateral posterior superior iliac spine was detected, and their midpoint was considered as S2. To determine L1, the top of the iliac crest was found for the level of L5 spinous process. Next, the examiner counted up from this point and marked L1. After that, in a comfortable standing position, the patients looked forward, the flexi ruler was placed along L1-S2, and an equal pressure was applied until it resembled the lumbar lordosis.The shape of the rulerwas then plotted on a piece of paper. The angle between L1 and S2 was named Θ angle and calculated using the following formula: $\Theta=4[\text{Arc tan}(2H/L)]$. The line L was formed by connecting the two ends of this curve. The maximum distance between L and the curve was labeled the H line. According to previous studies, the normal lordosis angle is 30° and angles >40° are considered as hyperlordosis (22).

How to Evaluate COP Changes

COP variability indices to examine the two-legged state with open and closed eyes include: range of changes in the anterior-posterior direction (R.AP), range of changes in the medial-lateral direction (R.ML), the velocity of COP in the anterior-posterior direction (V.AP), and the velocity of COP in the medial-lateral direction (V.ML). For evaluation, a force plate was used to examine the changes in subjects' COP in a 30-second time frame in a fixed state and

with open and closed eyes. After warming up, they were first asked to keep their legs on the center of the device, place their hands on the pelvis, hold their head up and face forward, and try to maintain their balance. This exercise was initially repeated as a test by the subject; the tester then instructed the participants on how to move, and once they were ready, the test was performed. Each subject went to the device after announcing readiness, and the ground reaction force information was recorded by the force plate from the moment of stepping foot on the force plate (Figure 1). Reaction force information was recorded in both lateral and anterior-posterior directions by the force plate. This information was stored on a computer device for later analysis (23, 24).

How to Assess TTS

To determine the time to reach stability in vertical, antro-posterior (AP), and mediolateral (ML) directions, the participants were asked to stand on a step height of 40 cm which was 70 cm away from the force plate (25). The participants were asked to land on the center of the force plate with one foot (the dominant leg); as soon as positioned, they were asked to place their hands on the pelvis area, hold their head up and face forward, and try to maintain balance. Prior to performing the step landing test, the subjects were asked to perform the task at least twice to become familiarized with the conditions and manner of performing the test. Prior to the test, the examiner provided explanations onhow the test was performed. After landing on the device, the ground reaction forces information was recorded by the force plate for 20 seconds (Figure 2). Also, the ground reaction force was used to detect foot contact with the ground. This data was recorded at a sampling frequency of 200 Hz. The vertical component of the force plate output reaching more than 10 Nwas considered as the moment of foot impact to the ground (26). Reaction force information was recorded in both lateral and antro-posterior directions by the force plate. This information was stored on a computer device for further analysis.

Protocol of Core Stabilization Exercises

The exercise program was performed according to a study conducted by Jeffreys on students in 2002 (27). These exercises consisted of three different training levels: Level 1 consisted of static contractions in a stable condition, Level 2 comprised dynamic movements in a stable condition, and Level 3 included dynamic movements in an unstable condition (28).

Figure 1: This photo was taken of the participant by the author while center of pressure was being examined, a) open eyes and b) closed eyes.

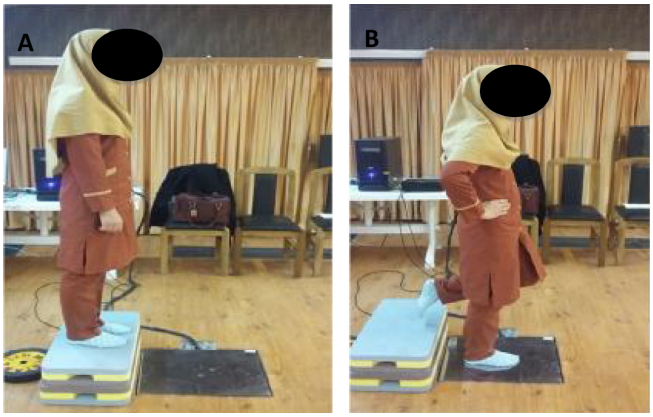

Figure 2: This photo was taken of the participant by the author while examining time to stability

Statistical Analysis

Descriptive analysis (mean and standard deviation) was performed on all the variables. The Shapiro–Wilk test was used to ascertain whether the data showed a normal distribution. Therefore, to compare the mean of within-group differences (pre- and post-test data) the paired t-test was used, and the independent t-test was utilized for between-group comparisons. Statistical significance was set at $P<0.05$. We used SPSS (version 18.0, Microsoft Corp., Redmond, WA) for all analyses.

3. Results

No significant differences were found between the groups in terms of age, height, weight, or BMI (Table 1).

Evaluation of Open-eye Center of Pressure Variability Indices in Girls with Hyperlordosis between Experimental and Control Groups

The results of the paired t-test showed no significant differences in R.AP (Control: P=0.241, Experimental: P=0.125), R.ML (Control: P=0.291, Experimental: P=0.582), V.AP (Control: P=0.142, Experimental: P=0.276), and V.ML (Control: P=0.698, Experimental:

P=0.224) before and after the stability exercises (pre-post) between the control and experimental groups. Furthermore, the results ofthe independent t-test implied no difference between the two groups in pre-test (R.AP=0.175, R.ML=0.491, V.AP=0.946, V.ML=0.248) and post-test (R.AP=0.163, R.ML=0.195, V.AP=0.987, V.ML=0.537) conditions (Table 3).

Evaluation of COP Variability Indices with Two Legs and Closed Eyes in Girls with and Without Hyperlordosis

The results of paired t-test showed significant differences in R.AP (P=0.038) and V.AP (P=0.001) before and after stability exercises (pre-post) in the experimental group; however, no significant difference was found in R.ML (P=086) and V.ML (P=296). In the control group, no significant differences were found among R.AP (P=0.221), R.ML (P=0.192), V.AP (P=0.461), and V.ML (P=0.195) before and after stability exercises. Furthermore, theindependent t-test showed a significant difference in the R.AP (P=0.001) and V.AP (P=0.023) between the two groups in the post-test condition; however, there was no difference among R.AP (P=0.221), R.ML (P=0.192), V.AP (P=0.461), and V.ML (P=0.195) in the pre-test condition (Table 4).

Evaluation of TTS Indices in Single-leg Landing in Girls with and Without Hyperlordosis

In the experimental group, the paired t-test revealed significant differences in vertical (P=0.012), antroposterior (P=0.032), and mediolateral (P=0.001) directionsbefore and after stability exercises (pre-post); in the control group, however, there was no significant difference before and after stability exercises (pre-post) in the vertical (P=0.748), antroposterior (P=0.228), and

Table 3: The effect of core stability exercise on it COP with two legs and opened eyes in girls with hyperlordosis (mean±SD)

Center of pressure Variability indices	Group	Pre-test	Post-test	Paired t-test
R.AP (mm)	Control	26.12±3.04	25.96±4.27	0.241
	Experimental	26.31±5.17	25.14±6.41	0.125
Independent t-test		0.175	0.163	
R.ML (mm)	Control	15.45±2.11	15.22±1.85	0.291
	Experimental	16.40±2.25	16.08±2.21	0.582
Independent t-test		0.491	0.195	
V.AP (mm/s)	Control	118.51±19.16	118.01±14.17	0.142
	Experimental	117.85±15.71	109.14±31.01	0.276
Independent t-test		0.946	0.987	
V.ML (mm/s)	Control	90.24±21.75	88.31±17.51	0.698
	Experimental	91.14±13.78	85.15±26.30	0.224
Independent t-test		0.248	0.537	

*Significant difference at alpha level of 0.05. COP: Center of Pressure, R.AP: Range of changes in anterior-posterior direction, R.ML: Range of changes in the medial-lateral direction, V.AP: The velocity of the center of pressure in the anterior-posterior direction, V.ML: The velocity of the center of pressure in the medial-lateral direction.

Table 4: The effect of core stability exercises on COP with two legs and closed eyes in girls with hyperlordosis (mean±SD)

Center of pressure Variability indices	Group	Pre-test	Post-test	Paired t-test
R.AP (mm)	Control	32.18±9.74	30.28±5.35	0.226
	Experimental	33.41±10.47	24.62±7.69	0.038*
Independent t-test		0.221	0.001*	
R.ML (mm)	Control	19.21±8.74	18.79±4.84	0.228
	Experimental	19.40±8.05	16.98±8.52	0.182
Independent t-test		0.192	0.086	
V.AP (mm/s)	Control	141.25±41.10	135.26±13.18	0.142
	Experimental	139.58±36.05	102.14±28.78	0.001*
Independent t-test		0.461	0.023*	
V.ML (mm/s)	Control	105.25±31.72	102.41±18.47	0.260
	Experimental	104.33±29.88	94.45±36.21	0.097
Independent t-test		0.195	0.296	

*Significant difference at alpha level of 0.05. COP: Center of Pressure, R.AP: Range of changes in anterior-posterior direction, R.ML: Range of changes in the medial-lateral direction, V.AP: The velocity of the center of pressure in the anterior-posterior direction, V.ML: The velocity of the center of pressure in the medial-lateral direction.

Table 5: The effect of core stability exercises on TTS in girls with hyperlordosis (mean±SD)

Time to stability Variability indices	Group	Pre-test	Post-test	Paired t-test
Vertical (seconds)	Control	0.81±0.21	0.80±0.18	0.748
	Experimental	0.80±0.19	0.68±0.16	0.012*
Independent t-test		0.157	0.001*	
Anterior-posterior (seconds)	Control	0.78±0.14	0.76±0.15	0.228
	Experimental	0.80±0.18	0.66±0.11	0.032*
Independent t-test		0.215	0.001*	
Medial-lateral (seconds)	Control	0.75±0.10	0.75±0.09	0.175
	Experimental	0.73±0.11	0.64±0.13	0.001*
Independent t-test		0.169	0.001*	

*Significant difference at alpha level of 0.05. TTS: Time to Stabilization

mediolateral (P=0.175) directions. Independent t-test further showed a significant difference between the two groups in the vertical (P=0.001), antroposterior (P=0.001), and mediolateral directions (P=0.001) in the post-test condition; nonetheless, there was no difference in the vertical (P=0.157), antroposterior (P=0.215), and mediolateral (P=0.169) directions in the pre-test condition (Table 5).

4. Discussion

The main purpose of this study was to assess the effect of eight weeks of core stabilization exercises on static and dynamic balance indices in girls with hyperlordosis. Based on the results, in girls with hyperlordosis, there was a statistically significant difference in COP (static balance index) and TTS (dynamic balance index) after the intervention between the experimental and control groups. Therefore, the eight-week core stabilization exercises can improve the COP and TTS in subjects with hyperlordosis. The results of the present study (improved balance after core stabilization exercises) are in line with those of Johnson and colleagues, Kahle and Gribble, Khani and colleagues, and Karimi and colleagues. Johnson and colleagues suggested that core stabilization exercises could increase the body's proprioception, resulting in increased balance (27). In one study, Kahle and Gribble examined the effect of six-week core stabilization exercises on star test (SEBT) and demonstrated its positive effect on core muscle strength in dynamic balance (8); using the Swiss ball, Khani and colleaguesexamined the balance of adolescent soccer players, concluding that core stabilization exercises improved their balance and performance (29). In another study, Karimi and colleagues reportedthat 10 sessions of core stabilization enhanced the postural balance and the speed of performing dynamic stability movements (30), one of which might be due to the increase in proprioception and efficiency of muscles in maintaining balance. According to previous research, one of the potential contributors to improved postural control is facilitating proprioception and enhancing lumbar and thigh muscle function following core stabilization exercises (2, 31). In this regard, Carpes and colleagues reported that after seven weeks of core stabilization exercises, the anteroposterior COP variability significantly decreased in the two-legged position with open and closed eyes and the side COP, which is consistent with the results in the present study (32). Core stabilization exercises appear to utilize the stabilization system, which includes the trunk muscles, the spine, and the pelvis and reduce the displacement of the center of pressure while standing (33, 34). The present study suggested that core stabilization exercises could improve static and dynamic balance and time to stability. These factors can enhance postural stability and athletic performance.

This research had a few limitations. First, the participants in this study were 14-15-year-old female students, so we were not able to generalize our results to men. It is recommended that more research be done in larger groups including both genders. Second, we did not evaluate the effect of exercise on muscle function in these subjects, which could have otherwise given us a better view of the effect of the exercises.

5. Conclusion

The study findings revealed that the eight-week core stabilization exercises could be considered as an appropriate training method for improving the postural control (COP and TTS) in 14-to-15-year-old girls with hyperlordosis.

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Ethical Approval: The research proposal was approved by the Ethics Committee of Allamah Tabataba'i University under the following number: S/9/18/45261. Informed consent was obtained from the students and the school principal.

Conflicts of interest: None to declare.

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