

## An 8-week thoracic spine stabilization exercise program improves postural back pain, spine alignment, postural sway, and core endurance in university students: a randomized controlled study

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Received: 25.11.2015 • Accepted/Published Online: 07.09.2016 • Final Version: 18.04.2017

**Background/aim:** To investigate the effects of an 8-week thoracic stabilization exercise program on back pain, spinal alignment, postural sway, and core endurance in university students.

**Materials and methods:** University students were randomly allocated into exercise (n: 28) and control (n: 25) groups. The exercise program was carried out 3 days a week for 8 weeks. Postural pain, spinal alignment, postural sway, and core endurance were assessed via visual analogue scale, Spinal Mouse, Biodex Balance System, and McGill's trunk muscle endurance tests at the baseline and after 8 weeks of training.

**Results:** Differences were observed for postural pain, thoracic and lumbar curvature, dynamic stability index (eyes closed), and core endurance scores in the exercise group between baseline and week 8 ( $P < 0.05$ ) and all the parameters were significantly different when compared to those of the control group ( $P < 0.05$ ).

**Conclusions:** The program decreased postural pain, spinal curvatures, and postural sway, and increased core endurance in university students. The program can be effective in postural pain and misalignment of spine problems related to core weakness and balance disorders.

**Key words:** Postural pain, spine alignment, postural sway, core endurance, thoracic spine, exercise

### 1. Introduction

Spine alignment as posture was defined by the Posture Committee of the American Academy of Orthopedic Surgeons as the relative arrangement of the parts of the body (1). Good posture was declared as the state of muscular and skeletal balance. In a balanced structure, local and global muscles activate accordingly to protect the body and spine from an injury during activities such as lifting, sitting, standing, and moving (1,2). However, a faulty relationship of various parts of the body with abnormal spinal curves may impair this balance (1). The thoracic spine, especially kyphotic posture (hyperkyphosis), in combination with thoraco-lumbo-pelvic relation has been frequently declared to be a source of spinal disorder and pain (3). Increased kyphotic posture has been associated with spinal extensor muscle weakness, decreased spinal extension mobility, lumbo-pelvic pain, postural changes, sensory deficit, and alterations in muscle activation with inappropriate scapular positioning (4-6).

Postural back pain and/or low back pain, diminished physical performance, impaired respiratory function, and low quality of life arise as a result of kyphotic posture (7-11). Moreover, increased thoracic kyphosis has a negative effect on postural stability. The role of the thoracic spine in relation to the lumbar spine and overall body has been reported as to maintain vertical posture and provide kinesthetic awareness and head stability (10,12,13). The lumbar spine has been described as the center of the functional kinetic chain, and the activation of core muscles has been focused on in the literature for the prevention and the treatment of spinal disorders (14-17). However, the roles played by the thoracic spine, the activation of the related muscles, and postural alignment in prevention or treatment have been underestimated.

Lately, programs for the prevention of spinal alignment have been important because of nonergonomic working or studying conditions, inactive lifestyles, and emotional stress in modern life. These conditions have been strongly

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associated with spinal impairment (18–22). Young adult university students who spend too much time sitting with a slouched posture during studying, computer use, or daily activities are a risk group. Moreover, sedentary behavior, inadequate nutrition, and stress in this group may increase the potential risk (23–25). Revealing accurate strategies for prevention and treatment might be of utmost importance.

Numerous scientific studies have been designed for evaluating risk factors of postural alignment and developing diagnosis and treatment methods (4,26–29). Different exercise approaches, such as spinal extension strengthening exercises, yoga, Pilates-based exercises, and respiratory-muscle exercise have been commonly used for prevention and treatment of kyphotic posture and pain (26–29). Core stabilization exercises, back extensor strengthening exercises, and balance training have been reported to have positive effects on postural control systems and change the overall postural sway (30–33). However, the thoracic spine has been a forgotten source and the effects of thoracic stabilization exercises on spine alignment, postural sway, and core endurance as a lumbo-pelvic relation indicator have not been established. Moreover, the new generation, sedentary, young adults studying at university have been ignored.

Therefore, the current study aimed to investigate the effects of an 8-week thoracic stabilization exercise program on postural back pain, spinal alignment, postural sway, and core endurance in university students.

## 2. Materials and methods

### 2.1. Design

A prospective, randomized, single-blind, controlled trial design was used. This study was conducted in accordance with the rules of the Declaration of Helsinki. Written informed consent was obtained from each participant. It was approved by the Human Research Ethics Committee of the University (Approval number: 12/12-1).

### 2.2. Subjects

University students, aged between 18 and 25 years, who had not performed any regular physical activity (activities carried out 2 or 3 days a week for 8–12 weeks) for at least 1 year were recruited on a voluntary basis. All subjects provided a health certificate obtained from a general practitioner documenting that they were apparently healthy and had no systematic diseases or any problem preventing their participation in any exercise program. The subjects were subjected to a self-reported health history questionnaire for eligibility criteria. They were not included in the study if any of the following criteria were met: (i) having a systemic pathology, including inflammatory, rheumatologic, or metabolic diseases; (ii) having any musculoskeletal injury, pathology, or structural deformity related to the spine or extremities; or (iii) having any active

intervention including corticosteroid or any medication in the previous 3 months. The exclusion criteria were set according to previous similar studies (33–35).

### 2.3. Randomization

The study was conducted at university physiotherapy and rehabilitation school facilities. A total of 102 university students were assessed. Sixty-eight of them were eligible for the study. Eight of the subjects did not want to participate in the study and were excluded. The participants were allocated to either of the groups using computer generated random numbers. The training therapist (DOK) randomly allocated each eligible participant to exercise or control groups by opening an opaque and sealed envelope, and a card inside indicated the group to which the participant was randomly allocated. Sixty volunteers were randomly divided into exercise and control groups. The groups were age- and sex-matched. At the end of 8 weeks, 53 participants (exercise:  $n = 28$ , control:  $n = 25$ ) completed the study. Details of included and excluded subjects are provided in the Figure as a flowchart.

### 2.4. Outcome measures

Measurements related to postural back pain, spinal alignment, postural sway, and core endurance were administered at baseline and after the 8-week training program. All measurements were administered by a physiotherapist (STC) who was blinded to the group allocation.

The physical characteristics including age, sex, smoking, and alcohol consumption were recorded. Body composition was evaluated by Bodystat 1500 Bio-impedance Analyzer (Bodystat Ltd, Douglas, Isle of Man, UK). Subjects' age, sex, height, weight, and waist and hip circumference values were entered into the Bodystat analyzer. This is a noninvasive technique to measure the subject's body fat and fat-free mass (lean mass). The subjects were instructed to be in a state of normal hydration during measurements (no exercise or alcohol/caffeine consumption in the preceding 12 h and no eating or drinking in the preceding 4–5 h). Two electrodes were placed on the right hand and two on the left foot to perform a whole body measurement by passing a safe signal at a low 400  $\mu\text{A}$  and a frequency of 50 kHz through the body. The results were displayed within seconds on a two-line screen of a small portable measuring device (36).

The subjects were examined for any back pain while maintaining sitting or standing positions for a long time during studying, using a computer, or work-related activities. In the presence of pain, a visual analogue scale (VAS) was used to assess its level. The VAS involves a 10-cm horizontal line, where 0 indicates "no pain" and 10 indicates "unbearable pain" (37). The participants were asked to mark the strength of their ongoing postural pain on the horizontal line.

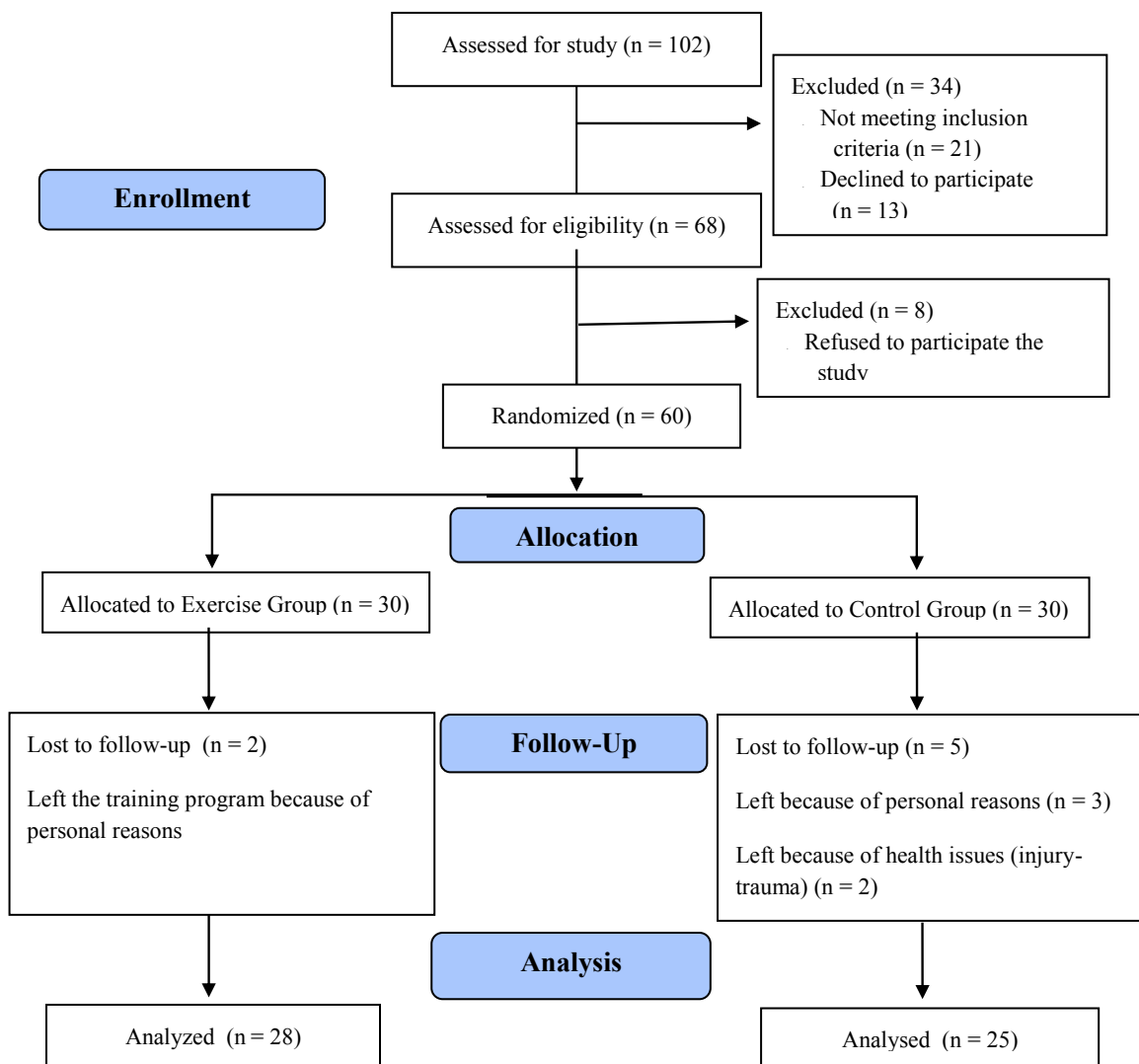


Figure. The flowchart diagram of the study.

Spinal alignment was evaluated using a Spinal Mouse (Idiag, Volkswill, Switzerland), a computer-assisted noninvasive device. The intraclass coefficients for curvature measurement with the Spinal Mouse were reported to be 0.92–0.95 (38). Demographic data of the subjects were recorded using a computer program. The spinal processes of the vertebra from C7 to S3 were marked. The Spinal Mouse device was slid along the spine from top to bottom to complete the measurement. The evaluation was administered while the subjects were standing in upright position, and then in maximum flexion and maximum extension positions. Each angle of thoracic kyphosis (between T1 and T12) and lumbar lordosis (between T12 and S1) was evaluated by the software in degrees.

Postural sway of the participants was evaluated with a Biodex Balance System SD (Biodex Medical Systems, Inc.,

Shirley, NY, USA) in the Postural Stability mode with their eyes open and closed in a bilateral standing position. The subjects were given an overview of the testing procedure, they removed their footwear, and they were positioned on the platform of the system. During the assessment, the subjects stood upright with both feet on the platform. The base was set “12-1” for the dynamic mode. In this system, the base becomes more unstable as the number decreases; thus the mode “1” is the most unstable mode. The participant was asked to stay stable while the platform was tilting. After two or three trials for familiarization, eyes open and eyes closed positions were tested, consecutively (39,40). All subjects completed the following modes: dynamic mode eyes open (DMEO) and dynamic mode eyes closed (DMEC). Each measurement took 32 s. As a result of measurements, an overall stability index was

obtained, where a low value indicated high stability.

McGill's trunk muscle endurance tests were used to assess core endurance (41,42). Previous studies show that all four trunk isometric muscle endurance tests have excellent reliability coefficients: trunk flexor (FLEX), intraclass correlation coefficient (ICC) = 0.97, back extensor (EXT) ICC = 0.97, and right and left lateral trunk musculature (LATr/LATl) ICC = 0.99 (41,42). The subjects were instructed to maintain isometric postures for each test position as long as possible. The length of time that the subjects could maintain the correct position was recorded in seconds (41,42).

### 2.5. Intervention

The exercise group received the Thoracic Spinal Stabilization Exercise program. An experienced physiotherapist (DOK) conducted the program at the university's exercise facility, which was clean and comfortable with enough lighting and materials, such as mirrors, mats, bands, and balls. The temperature was 22–24 °C during exercising. All exercise sessions were composed of 10-min warm-up exercises, 25-min stabilization exercises, 10-min cool-down, and stretching exercises in a group set-up. The program included 3 progression phases throughout the 8-week period where the phases were arranged according to the stages of motor learning and sensory motor integration as static, dynamic, and functional (43).

The static phase aimed to maintain short and quick motor control and kinesthetic awareness. The thoracic bracing technique included postural alignment and, as part of the technique, minimal multifidus muscle activation with scapular orientation was taught (44). Compensations were prevented during the interventions with visual and auditory stimuli. The exercises included workouts of thoracic bracing in neurodevelopment stages (supine, prone, side lying, quadrupedal, and bipedal). The contraction was maintained for 10 s at each position for 3 sets of 10 repetitions. The participants were asked to maintain the positions and contractions during the exercises. Upper and lower extremity range of motion exercises were conducted while maintaining spine stability at the specific positions. All exercise repetitions were increased progressively from 6 to 15. The objective of the dynamic phase was to teach conscious motor control and to maintain a stable spine during extremity motions with elastic resistive bands. It started at week 3 and lasted until the end of week 5. The participants began exercising using a red latex band and a 200-cm-long pre-cut section of Thera-Band (Hygenic Corporation, Akron, OH, USA) with medium tension. They had 3 sets of 10 repetitions, each with a holding time of 6–10 s. When they performed 3 sets of 15 repetitions without significant pain or fatigue, they progressed to the next color resistance band in the sequence of green and blue. The functional phase aimed to

teach unconscious motor control. The exercises included functional training with elastic resistance and exercise balls on unstable surfaces. They had 3 sets 10 repetitions with a holding time of 10–15 s each.

The control group did not receive any exercise program. They were asked not to participate in any kind of exercise or sport during the study period.

### 2.6. Statistical analysis

The G\*Power software package (G\*Power, Version 3.0.10, Franz Faul, Universität Kiel, Germany) was used to determine the sample size. It was calculated that a sample consisting of at least 42 subjects was needed to obtain 80% power with  $d = 0.50$  effect size,  $\alpha = 0.05$  type I error, and  $\beta = 0.20$  type II error.

Data analysis was conducted using IBM SPSS 21.0 (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY, USA). The variables were investigated using visual (histograms, probability plots) and analytical methods (Kolmogorov–Smirnov test) to determine whether or not they were normally distributed. Descriptive analyses were presented using mean and standard deviation (SD) for the normally distributed variables, and tables of frequencies, median, and interquartile range (IQR) for the nonnormally distributed and ordinal variables. Wilcoxon's test was used to compare the measurements obtained at the two time points (baseline and week 8) for postural pain, spinal alignment, postural sway, and core endurance parameters. The Mann–Whitney U test was used to compare the parameters between groups. An overall P-value of less than 0.05 was considered to show a statistically significant result.

### 3. Results

The baseline demographic and physical characteristics of the groups were similar between the groups ( $P > 0.05$ ) and are shown in Table 1.

At the baseline, there were no differences between groups in terms of postural back pain, thoracic and lumbar curvature, DME0 and DMEC overall stability indexes, and core endurance scores (FLEX, EXT, LATr, LATl) ( $P > 0.05$ ). Significant differences were observed for postural back pain, thoracic curvature, lumbar curvature, DMEC overall stability index, FLEX, EXT, LATr, and LATl in the exercise group between the baseline and week 8 ( $P < 0.05$ ), whereas no significant difference was observed for the control group ( $P > 0.05$ ) (Table 2).

The intergroup comparison showed that postural back pain, thoracic curvature, lumbar curvature, and DMEC overall stability index decreased, and FLEX, EXT, LATr, and LATl increased in the exercise group in comparison to the control group ( $P < 0.05$ ) (Table 3).

**Table 1.** Demographic and physical characteristics of the participants.

Demographic and physical characteristics	Exercise group n = 28	Control group n = 25	P values
Age (years, mean $\pm$ SD)	21.00 $\pm$ 1.27	20.36 $\pm$ 1.22	0.069 <sup>a</sup>
Fat mass (kg, mean $\pm$ SD)	11.83 $\pm$ 3.91	11.02 $\pm$ 3,93	0.456 <sup>a</sup>
Lean mass (kg, mean $\pm$ SD)	52.86 $\pm$ 11.40	55.35 $\pm$ 12.61	0.454 <sup>a</sup>
Body mass index (kg/m <sup>2</sup> , mean $\pm$ SD)	22.49 $\pm$ 2.92	22.45 $\pm$ 2.95	0.957 <sup>a</sup>
Waist/hip ratio (mean $\pm$ SD)	0.81 $\pm$ 0.07	0.79 $\pm$ 0.04	0.386 <sup>a</sup>
Sex (n, %)			
Female	15 53.6	12 48.0	0.685 <sup>b</sup>
Male	13 46.4	13 52.0	
Postural back pain (n, %)			
Yes	21 75.0	13 52.0	0.145 <sup>b</sup>
No	7 25.0	12 48.0	
Smoking (n, %)			
Yes	0 0.00	2 8.00	0.127 <sup>b</sup>
No	28 100.0	23 92.00	

\* P < 0.05; X: Mean; SD: Standard Deviation, <sup>a</sup>Independent t test, <sup>b</sup>Chi-square test

#### 4. Discussion

The present study aimed to investigate the effects of thoracic spinal stabilization exercises in university students and the following findings were observed: (i) postural back pain decreased in the exercise group, (ii) the exercise program decreased the thoracic and lumbar curvature in the standing position, whereas no difference was observed for the controls, (iii) the training changed the overall postural sway only in the eyes closed position, (iv) the core endurance improved in the training group.

Spinal curvatures change throughout the life span (45). Changes in the spinal curve cause both physical and psychological distress due to the changes in posture, balance, and self-image, and also because of musculoskeletal pains caused by muscle spasms and the changes in articulation of the apophyseal joints of the vertebrae (46–48). Thoracic stabilization was reported to have a significant role in obtaining and maintaining vertical alignment (12). Musculoskeletal pain disorders in the spine were reported to be related to spinal alignment (7). It was reported that more neutral thoraco-lumbo-pelvic alignment was associated with less back pain (49). Kyphosis, as the natural curve of the thoracic spine, has been reported to be 20° to 40° (50–52). It was reported that a curve more than 40° to 45° in the thoracic spine could be considered abnormal or a spinal deformity. This deformity has been mostly associated with postural problems called round back posture or hunchback. However, more serious problems may be the source of the increased curve, such as healed vertebral fractures,

rheumatoid arthritis, osteoporosis, or Scheuermann's kyphosis (50–53). A number of radiographic studies, but few of which using skin-surface devices, have documented the normal values for the sagittal curvature of the thoracic spine. Similar to the present study, Mannion et al. (52) measured standing kyphosis with the Spinal Mouse. They declared that standing kyphosis was on average 45° for healthy volunteers with a mean age 41  $\pm$  12 years (52). Standing thoracic kyphosis measured by the spinal wheel was reported to be 30° in another study (54). In the present study, thoracic curvature was found to be 44.50 (11.75)° for the study group (mean age 21.00  $\pm$  1.27), which may be considered high for this age group. After the exercise program it was 36.50 (13.25)°, which may be considered an improvement at least for the prevention of round back posture and to decrease pain in these young university students even if it might not be considered clinically meaningful.

Another component of spinal alignment is lumbar lordosis, which was also assessed in this study. Lordosis, as measured with inclinometers, has been reported to be between 23° and 33° (52). It was recorded as 32° in a healthy group using the Spinal Mouse (52). In our study, lumbar curvature was –29.00 (10.00)°. It decreased by 7.00 (19.50)° with the exercise program. A lordosis angle of less than 23° was defined as hypolordosis (55). Therefore, it can be concluded that the exercise regimen caused a flattening in the lumbar region. The exercise regimen seemed to have an impact on the overall spine that, as the thoracic curve decreased, the lumbar curve also decreased. The decrease

**Table 2.** Differences between postural back pain, spinal alignment, postural sway, and core endurance of groups at baseline and 8 weeks.

	Exercise group n = 28 Baseline Median (IQR) Median (IQR)	Z values	P values	Control group n = 25 Baseline Median (IQR) Median (IQR)	Z values	P values
Postural back pain (cm)	0.50 (0.00–2.75) 0.00 (0.00–0.00)	-3.343	0.001* <sup>c</sup>	0.00 (0.00–2.50) 0.00 (0.00–1.10)	-1.893	0.058 <sup>c</sup>
Spinal alignment (°)	Thoracic curvature 44.50 (37.00–48.75) 36.50 (28.25–41.50) Lumbar curvature -29.00 ((-34.00)-(-24.00)) -7.00 ((-17.00)-2.50)	-4.087 -4.470	<0.001* <sup>c</sup> <0.001* <sup>c</sup>	42.00 (34.00–48.00) 42.00 (31.00–48.00) -27.00 ((-31.00)-(-24.50)) -25.00 ((-30.00)-(-22.50))	-0.647 -1.931	0.518 <sup>c</sup> 0.054 <sup>c</sup>
Postural sway	DMEO overall stability index 1.20 (0.90–1.70) 1.25 (0.82–1.75) DMEC overall stability index 3.65 (2.50–5.87) 3.10 (2.10–4.77)	-0.420 -2.383	0.674 <sup>c</sup> 0.017* <sup>c</sup>	1.50 (0.90–1.75) 1.50 (0.90–1.90) 4.40 (3.05–5.80) 4.40 (3.00–5.80)	-1.035 -0.750	0.301 <sup>c</sup> 0.453 <sup>c</sup>
Core endurance (s)	FLEX 28.50 (22.00–39.50) 32.00 (28.25–45.25) EXT 41.50 (27.00–64.25) 55.00 (44.25–78.75) LATr 26.00 (20.50–43.75) 35.50 (24.25–52.25) LATl 25.00 (15.00–30.00) 26.50 (20.00–54.75)	-2.551 -3.988 -2.401 -2.765	0.011* <sup>c</sup> <0.001* <sup>c</sup> 0.016* <sup>c</sup> 0.006* <sup>c</sup>	40.00 (23.00–60.50) 40.00 (22.00–57.00) 39.00 (21.50–68.00) 38.00 (23.00–66.50) 23.00 (16.50–50.50) 24.00 (17.00–51.00) 33.00 (16.00–56.00) 32.00 (16.00–52.00)	-0.032 -0.523 -1.137 -1.531	0.975 <sup>c</sup> 0.601 <sup>c</sup> 0.255 <sup>c</sup> 0.126 <sup>c</sup>

\* P < 0.05; DMEO: Dynamic mode eyes open; DMEC: Dynamic mode eyes closed; FLEX: Trunk flexor musculature; EXT: Back extensor musculature; LATr: Right lateral trunk musculature; LATl: Left lateral trunk musculature; IQR: Interquartile range; <sup>c</sup> Wilcoxon's test

**Table 3.** Differences between groups at baseline and 8 weeks.

Parameters 8th week-baseline differences		Exercise group n = 28 Median (IQR)	Control group n = 25 Median (IQR)	Z values	P values
Postural back pain (cm)		-0.50 ((-2.00)-0.00)	0.00 ((-0.10)-0.00)	-2.574	0.010* <sup>d</sup>
Spinal alignment (°)	Thoracic curvature	-8.00 ((-13.00)-3.75)	0.00 ((-3.00)-0.00)	-3.793	< 0.001* <sup>d</sup>
	Lumbar curvature	22.50 (15.25-29.50)	0.00 ((-1.00)-3.00)	-5.164	< 0.001* <sup>d</sup>
Postural sway	DMEO overall stability index	-0.15 ((-0.30)-0.30)	0.00 (0.00-0.00)	-1.835	0.067 <sup>d</sup>
	DMEC overall stability index	-0.40 ((-1.30)-0.07)	0.00 (0.00-0.00)	-2.729	0.006* <sup>d</sup>
Core endurance (s)	FLEX	8.00 (2.25-17.00)	0.00 ((-0.50)-1.00)	-3.546	< 0.001* <sup>d</sup>
	EXT	11.50 (2.50-18.00)	0.00 ((-2.50)-2.00)	-4.517	< 0.001* <sup>d</sup>
	LATr	5.50 (0.00-12.25)	-1.00 ((-2.50)-1.00)	-3.001	0.003* <sup>d</sup>
	LATl	5.00 (1.75-12.50)	0.00 ((-0.50)-1.00)	-3.155	0.002* <sup>d</sup>

\*P < 0.05; DMEO: Dynamic mode eyes open; DMEC: Dynamic mode eyes closed; FLEX: Trunk flexor musculature; EXT: Back extensor musculature; LATr: Right lateral trunk musculature; LATl: Left lateral trunk musculature; IQR: Interquartile range; <sup>d</sup> Mann-Whitney U test

in thoracic kyphosis might be considered an improvement. However, the decrease in lumbar lordosis may not be relevant for all conditions. It depends on the situation. Therefore, the use of the program should be taken into account based on each patient group's special needs. Moreover, the results indicated both negative and positive outcomes for lumbar lordosis, which resulted in larger standard deviations. These conditions should be taken into account and they might be considered a weakness.

There exist very few reports of prospective studies that evaluated the effects of specific exercises on spinal alignment (26-29,56). In one study, it was found that spinal extension exercises could delay the progression of kyphosis angle (26). Kuo et al. (27) found that a Pilates-based exercise program reduced the thoracic curve in healthy older adults, whereas Greendale et al. (28) reported that yoga decreased kyphosis in senior women and men with adult-onset hyperkyphosis. Another study showed that respiratory-muscle exercises decreased thoracic curve and straightened the spine, leading to good posture control (29). Park et al. (57) investigated the effects of prone trunk extension exercises in their slouched thoracic posture group in comparison to the control group. They declared that during the prone trunk extension exercise, the muscle activity of the thoracic to lumbar erector spine muscles decreased, whereas the angle of kyphosis and lumbar lordosis increased. They concluded that the increased spinal curve and decreased activation of the erector spinae pars thoracis induced during this exercise could have a negative impact on the spine. In contrast to this exercise regimen, our results showed the effectiveness of the thoracic spinal stabilization exercise program proposed

in the present study in reducing postural back pain and thoracic and lumbar curvature, which may further result in better muscle activation. This exercise regimen could be recommended for providing and maintaining more a neutral or better posture.

Ageing and many pathologies are known to affect postural sway and balance (13,58,59). The optimal control of balance in upright posture as well as in postural sway are essential requirements for high level sports activities and for daily life activities, as well as for the prevention of musculoskeletal injury (31). Previous studies claimed that back extensor muscle strength trainings, core stabilization exercises, balance trainings, Pilates programs, tai-chi, and dance exercises are beneficial for postural sway (31,32,60-63). It was also observed in the present study that the Thoracic Spinal Stabilization Exercise program decreased DMEC overall stability score. Therefore, the program improved postural sway and somatosensory reactions especially when the visual feedback was not present at the end of 8 weeks. Consequently, this exercise could be an alternative approach for improving postural stability in patients with spinal disorders, the elderly, and athletes.

Core endurance is achieved through the stabilization of one's torso, thus allowing optimal production, transfer, and control of force and motion to the terminal segment during an integrated kinetic chain activity (64). Mostly the lumbar region was focused on and core training was primarily administered for gaining trunk muscle strength and physical function, preventing musculoskeletal injuries, and especially for reducing LBP (15,30). The thoracic region related to the neck, scapula, and low back could play an important role in the closed kinetic mechanism.

Recently, some studies have demonstrated that the treatment of this region has improved spinal posture and postural stability, reduced the risk of falls, and treated chronic musculoskeletal spinal disorders (26,31,33,65,66). Our results also showed improvement in core endurance. Therefore, the exercise is an alternative intervention for preventing core weakness, musculoskeletal injuries, and LBP.

The current study had some limitations. First, the study was conducted in a group of healthy university students. Thus, the results could not be generalized for individuals with pathologies or different age groups. However, it might be a very good base for further studies in different populations. Second, a nonexercising control group was used. The control group could have included different exercise programs or interventions. However, the aim of the present study was not to compare the differences between kinds of treatment. The study aimed to show the

extent of the differences between nonexercising groups instead of just presenting before and after results for the exercise group. Third, the results of an 8-week program were presented in this study. Long-term effects should be observed with follow-up studies.

In conclusion, the Thoracic Spinal Stabilization Exercise program administered to university students in the present study decreased postural back pain, lumbar and thoracic curves, and postural sway in eyes closed position, and increased the overall core endurance. The exercise program, which focused on the thoracic region of the spine, can be used for postural pain and misalignment of the spine, problems related to core weakness, and balance disorders.

### Acknowledgment

This study was funded by Ahi Evran University Scientific Research Unit (number: 47/2011-05).

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