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Three-dimensional evaluation of pelvic posture in adolescents with and without a history of low back pain*

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Background/aim: This study aimed to evaluate the three-dimensional (3D) profile of pelvic posture and postural displacements of the pelvis in adolescents with and without a history of low back pain (LBP).

Materials and methods: Thirty-two adolescents participated in this study. Participants were asked if they had ever suffered LBP at some point in their lives. Participants were divided into two groups: with a history of LBP (LBP group) and without a history of LBP (control group). For 3D evaluation of pelvic posture, the PosturePrint system was used. Three digital photographs were obtained in an upright stance (anteroposterior, left-right lateral) and analyzed. Postural displacements of the pelvis were calculated as rotations in degrees and translations in millimeters. The posture index, which is the total postural displacements score, was recorded.

Results: Overall, 40.6% of the participants reported a history of LBP, while 59.4% of the participants did not. Although the 3D profile of pelvic posture, postural displacements of pelvis, and posture index score were similar between groups, the majority of participants in both groups had altered pelvic and total body posture.

Conclusion: The findings suggest that adolescents with LBP have a profile of pelvic posture similar to those of healthy adolescents without a history of LBP.

Key words: Three-dimensional, posture, pelvis, low back pain, adolescent

1. Introduction

Low back pain (LBP) is one of the most frequent reasons of disability in the adult population and has become a significant public health problem worldwide (1). Although the data for lifetime prevalence of LBP vary, it is reported to be as high as 80% in adults (2). Epidemiological studies reported a similar prevalence in adolescents (3); the prevalence of LBP rises significantly between the ages of 12 and 18 (4). LBP in adolescence has been reported as a risk factor for developing LBP in adults (5). Prevention of this problem at younger ages may help prevent LBP in adulthood. Therefore, it is important to identify the risk factors for the development of LBP.

A number of studies have investigated the potential predictors of LBP in adolescents, including smoking habit, age, sex, high physical activity level, time spent watching television, inappropriate home postural habits, and carrying a heavy backpack (6–10). While postural alteration has been considered as a possible risk factor for adolescent LBP (8), the literature regarding this topic is scarce.

The pelvis plays an essential role in optimal body alignment; isolated analysis of the pelvis has marked importance (11). Asymmetrical alignment of the pelvis has been thought to alter body mechanics and put increased strain on some regions of the body contributing to musculoskeletal pain (12). More specifically, lower extremity problems and LBP have been associated with postural abnormalities of the pelvis (13,14).

Earlier investigations revealed that the sagittal and frontal planes are the most investigated planes regarding postural alterations in low back problems (13–18). It is claimed that loss or flattening of the normal lumbar lordosis is a significant clinical sign of low back disorders and a risk factor for LBP (13,14). Smith et al. proposed that more neutral standing thoraco-lumbo-pelvic postures in

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the adolescent spine are related to less back pain, which was consistent with other findings (15). However, controversy exists on these findings and potential associations with respect to the literature (5,16–18). A cross-sectional study that was carried out among schoolchildren and adolescents concluded that lordosis did not correlate with either LBP or dorsal pain (16). In a study conducted with 1196 adolescents, Dolphens et al. reported that spinopelvic sagittal alignment parameters could not be identified as a factor associated with LBP (17). Similar results were found in another study by Dolphens et al.; according to these results spinal pain measures did not differ between groups of lumbopelvic subclassification in adolescent boys (18).

There are conflicting results in the literature, but there has been a growing interest among researchers and clinicians in the role of abnormal asymmetrical posture in relation to LBP. Although postural abnormality is suggested to be associated with LBP in adolescents, and, in turn, three-dimensional (3D) pelvic posture, this is still a current issue in the teenage population that requires further research.

The aim of this study was to evaluate the 3D profile of pelvic posture and postural displacements of the pelvis from a neutral upright stance in adolescents with and without a history of LBP.

2. Materials and methods

2.1. Participants

This school-based study was designed as a cross-sectional work conducted over a 1-year period. The study population was randomly selected from public elementary and high schools in Balçova and Narlıdere. A list of schools was obtained from the İzmir Provincial Directorate for National Education. By using a method of cluster sampling, schools were clustered according to level of education (elementary and high schools). From each cluster two schools were randomly selected out of a total of 25 schools (8 elementary schools and 17 high schools) in Balçova and Narlıdere. In total, four schools were included in the study. Students aged between 12 and 17 years were included in the study. Exclusion criteria included a history of any spinal fracture or violent back trauma, spinal surgery, skeletal disorders (leg length discrepancy, spondylolisthesis, scoliosis), neurologic conditions, rheumatic disorders, symptomatic complaints of upper and lower extremity musculoskeletal pain, metabolic or endocrine diseases, and LBP radiating to legs. In order to avoid negative effects of acute pain on posture we also excluded students who had experienced LBP in the preceding 3 months or reported LBP at the time of the assessments.

The study was reviewed and approved by the ethics committee of Dokuz Eylül University. All procedures were explained to each subject and written informed consent was obtained from all students and their parents or guardians prior to assessments. Students were removed from the study if they requested to withdraw.

2.2. Assessment procedures and data collection

Assessment procedures were completed in two separate stages. In the first stage, students were asked to complete a questionnaire at their schools. In the second stage, students were invited to the School of Physical Therapy and Rehabilitation, Dokuz Eylül University, for the 3D evaluation of pelvic posture.

2.3. Questionnaire on LBP complaints

The questionnaire was developed by the researchers based on data in the literature about LBP. Information regarding LBP was obtained with the low-back part of the Nordic questionnaire (19), which included a drawing of the low back. The Nordic questionnaire used in the current study was a slightly modified version. LBP was defined as aching, pain, or discomfort in the low back not related to trauma or menstrual pain. To evaluate the complaints of musculoskeletal pain in different parts of the body, an additional body diagram was used. It was also asked if the LBP radiated to the legs or stayed only in the low back region.

Questions relevant to the history of LBP included an inquiry about lifetime prevalence. Three-month prevalence was also asked to identify that exclusion criterion. Students were asked if they had ever suffered LBP at some point in their lives to determine the history of LBP. According to their answers, students were divided into two groups: with a history of LBP (if the answer was "yes", LBP group) and without a history of LBP (if the answer was "no", control group).

2.4. Three-dimensional evaluation of pelvic posture

Students attended the data collection sessions for 3D evaluation of pelvic posture at the School of Physical Therapy and Rehabilitation, Dokuz Eylül University. Posture analysis was performed with the web-based PosturePrint system (Biotonix, Montreal, Canada), which is a reliable tool for clinical use (20) and sufficiently accurate for evaluation of 3D standing pelvic posture (21). The setting up of the system and the assessment procedures were done according to the manufacturer's instructions (22). A digital camera was placed 84 cm above the floor and 3.4 m from a calibrated wall grid. The camera (Panasonic DMC-FZ20, 5.0-megapixel resolution) was fixed on a tripod (Velbon, Tokyo, Japan). Calibration was based on 4 calibration markers that were at known locations on the wall grid.

Students were requested to wear tight-fitting clothes (boys did not wear shirts) to make it easy for the examiner to palpate and find body surface landmarks. Palpation and marker placement of landmarks were performed by a trained examiner (a physiotherapist). Fourteen reflective markers were placed on the anatomical landmarks of students before taking the photographs. Students were instructed to stand barefoot 61 cm in front of a calibrated wall grid in a normally comfortable posture. Three digital photographs (anteroposterior, left lateral, and right lateral) of each subject were obtained with a digital camera. On the photographs, 16 additional "click-on" markers were placed with the computer mouse and then the digital photographs were analyzed through the PosturePrint web-based system. The PosturePrint report of each subject was generated by the PosturePrint web-based system. Figure 1 shows the anatomical locations of the markers.

Although the PosturePrint system assesses the posture of the head, rib cage, and pelvis, only the pelvic posture was of primary interest in this study. Postural displacements of the pelvis from a neutral upright posture were calculated as rotations (Rx, Ry, Rz) in degrees and translations (Tx, Tz) in millimeters using (x, y)-coordinates and (y, z)-coordinates from the markers on the digital photographs. As seen in Figure 2, there are 6 rotations and 6 translations for the posture of the pelvis. Since vertical translation (Ty) of the pelvis is impossible to determine without dynamics, the system does not attempt to measure that degree of freedom. The classifications of pelvic postural displacements according to the PosturePrint system are:

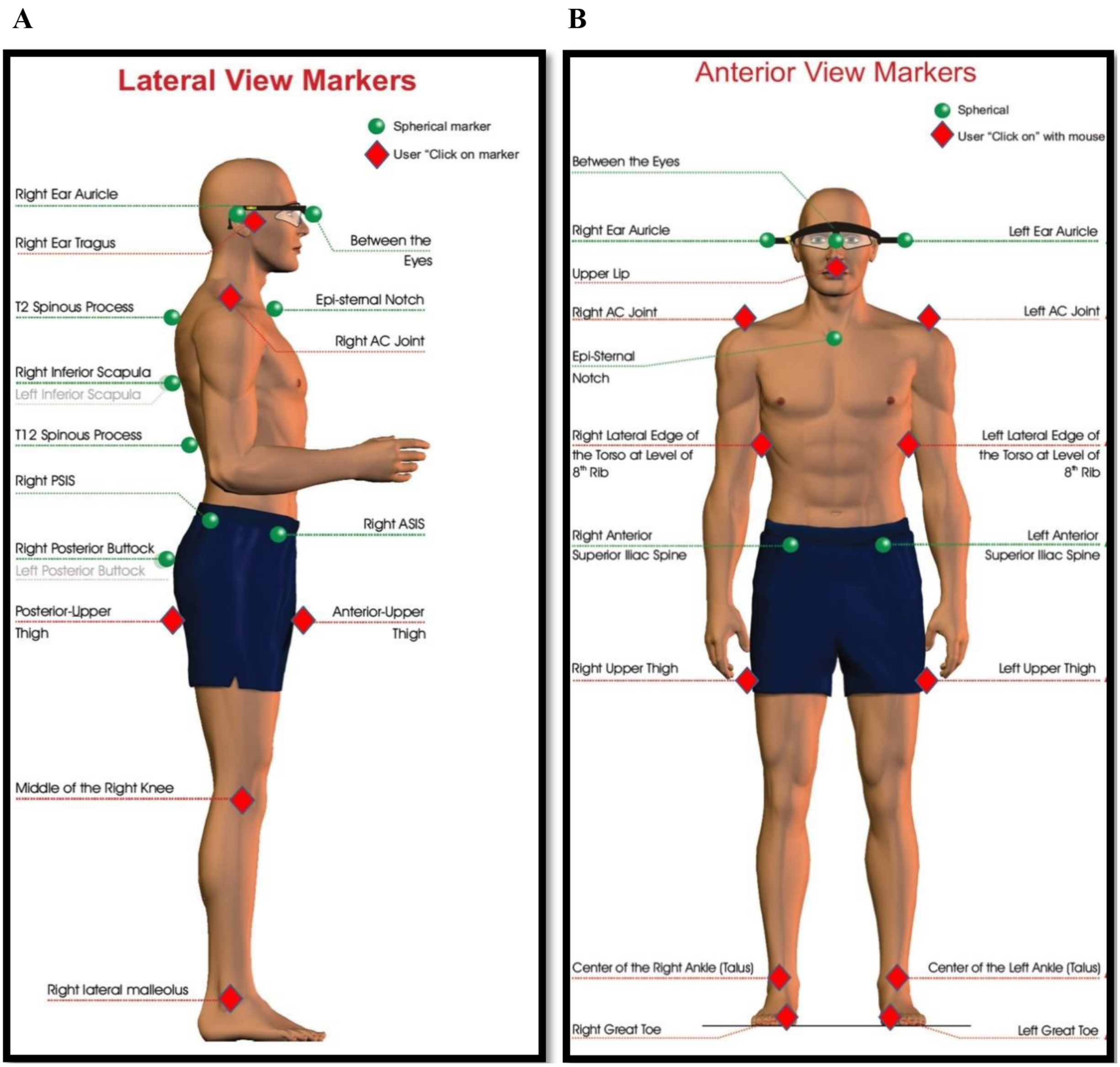

Figure 1. Anatomic location of markers for anteroposterior (A) and lateral (B) view. Reprinted with permission from Biotonix, Montreal, Quebec, Canada.

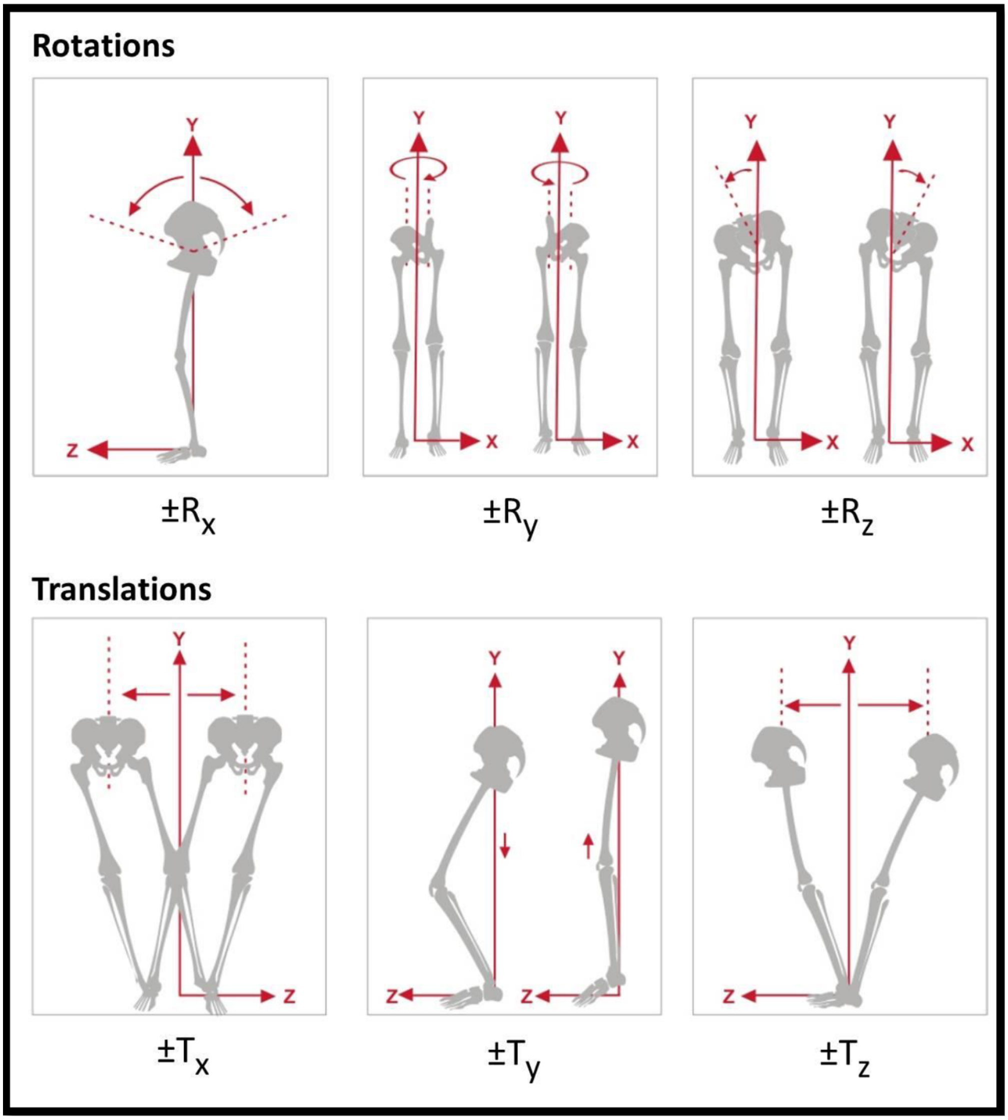

Figure 2. 3D assessment of postural rotations (Rx, Ry, Rz) and translations (Tx, Ty, Tz) of pelvis. Using a right-handed Cartesian coordinate system with x-axis positive to the left, y-axis positive vertically, and z-axis positive to the anterior. Reprinted with permission from Biotonix, Montreal, Quebec, Canada.

1. Lateral view
   a. Rotation x-axis, degree (flexion or extension)
   b. Translation z-axis, mm (forward or backward)
2. Anterior view
   a. Translation x-axis, mm (left- or right-side shift)
   b. Rotation y-axis, degree (left or right turning)
   c. Rotation z-axis, degree (left or right lateral bending)

Besides the postural displacements of the pelvis, the total postural abnormality of a student was evaluated using the posture index. This index is a simple scientific approach to categorizing total postural abnormality. The total score is 96 points. Higher posture index score indicates a more severely displaced posture. The following categories represent the severity of postural displacements: slight = 1–10, significant = 11–20, moderate = 21–30, serious = 31–40, severe = 41–96.

2.5. Statistical analysis

Statistical analyses were performed using SPSS 20.0 (IBM Corp., Armonk, NY, USA). All continuous variables were evaluated for normality using the Shapiro–Wilk test. The results of the Shapiro–Wilk test showed that most of the variables were not normally distributed ($P < 0.05$). Therefore, nonparametric tests were deemed more adequate for analysis. Medians and interquartile ranges (25th–75th percentile) were used for descriptive analyses of quantitative variables due to the skewness of most variables. The Mann–Whitney U test was performed to compare the demographics and postural displacements between the groups. The chi-square test or Fisher's exact test were used to compare proportions in different groups. The level of significance was set at $P < 0.05$.

3. Results

3.1. Participants and LBP questionnaire

One hundred fifty-eight adolescent students completed the questionnaire in the first stage of the study. Of these 158 students, 35 were excluded due to various exclusion criteria [reporting LBP at the time of the assessment (n = 15), pain in different parts of the body (n = 15), trauma to low back (n = 4), and leg length discrepancy (n = 1)]. Hence, 123 students were invited to participate in 3D evaluation of pelvic posture in the second stage of the study. Eight-eight students withdrew from the study because the students or their parents did not consent to participate in postural evaluation. Only 35 students agreed to participate in the postural evaluation. Three students had corrupted data regarding digital photographs. Finally, data of 32 students were analyzed.

As a result of the questionnaire, there were 13 students (40.6%) with a history of LBP (5 males and 8 females) and 19 students (59.4%) without a history of LBP (7 males and 12 females) who participated in this study. The demographic characteristics of the participants were not significantly different between groups (Table 1). When data were analyzed from 158 students' questionnaires (original population), 65 students (41.1%) reported a history of LBP. No differences in demographic characteristics and lifetime prevalence of LBP were found between the original population (median age = 13.5 years, median BMI = 20.5 kg/m^2, sex = 48.7% female, lifetime prevalence of LBP = 41.1%) and the 32 students (median age = 14 years, median BMI = 19.95 kg/m^2, sex = 62.5% female, lifetime prevalence of LBP = 40.6%) who participated in the postural evaluation (P-value for age = 0.855, BMI = 0.616, sex = 0.155, and prevalence of LBP = 0.957). These results indicate that the 32 analyzed students were representative of the original population of 158 adolescents in terms of demographic characteristics and proportion of LBP.

3.2. Three-dimensional profile of pelvic posture

Table 2 presents the postural alignment profile of the pelvis in the LBP and control groups. No significant differences were found for the 3D profile of pelvic posture between groups in anterior and lateral views ($P > 0.05$). Although there was no difference between the groups, the majority of participants had nonoptimal pelvic posture in the lateral view (for Rx and Tz) and anterior view (for Tx).

Similarly, the results showed that there were no significant differences in postural displacements of pelvis between the groups ($P > 0.05$) (Table 3).

Results of the total body postural evaluation of all participants showed that 12.5% of the adolescents had "slight", 68.8% had "significant", and 18.7% had "moderate" displacements in their posture. Total postural abnormality profile and posture index scores were similar between the groups ($P > 0.05$). This score represented the "significantly displaced posture" category for the posture index (Table 4).

4. Discussion

To better appreciate the pelvis position in adolescents with LBP, this study evaluated the 3D pelvic posture in adolescent students with and without a history of LBP. The main findings of our study showed that the 3D profile of pelvic posture and postural displacements of the pelvis from a neutral upright stance were similar in both groups. Although there was no difference between groups, the study revealed that pelvic posture was altered in the majority of students.

It is important to study postural evaluation in adolescents because adolescence is a critical period due to rapid skeletal growth in the vertebral column (23). The adolescent spine is less able to withstand stresses than the adult spine, and therefore it is more vulnerable to musculoskeletal problems and spinal pain (24). Postural

Table 1. Demographic characteristics of participants.

	LBP group n = 13	Control group n = 19	P-value
Sex (n) Age (years)	8 females, 5 males 14 (12.5–16)	12 females, 7 males 13 (12–15)	1.000 0.326
Height (cm)	164 (160–172)	163 (157–171)	0.631
Weight (kg)	52 (45–64)	55 (46–65)	0.985
BMI (kg/m^2)	19.67 (16.75–23.15)	20.98 (18.37–23.92)	0.478

Values are expressed as median (interquartile ranges). BMI = Body mass index.

Table 2. Postural alignment profile of pelvis in participants with and without a history of LBP.

	LBP group - n (%) n = 13	Control group - n (%) n = 19	P-value
Lateral view			
Rotation x-axis, degree (flexion or extension) Optimal Flexed Extended	6 (46.2%) 4 (30.8%) 3 (23.1%)	4 (21.1%) 7 (36.8%) 8 (42.1%)	0.293
Translation z-axis, mm (forward or backward) Optimal Forward Backward	--- 12 (92.3%) 1 (7.7%)	--- 19 (100%) ---	0.406
Anterior view			
Translation x-axis, mm (left- or right-side shift) Optimal Right Left	5 (38.5%) 3 (23.1%) 5 (38.5%)	6 (31.6%) 8 (42.1%) 5 (26.3%)	0.526
Rotation y-axis, degree (left or right turning) Optimal Right Left	10 (76.9%) 2 (15.4%) 1 (7.7%)	13 (68.4%) 3 (15.8%) 3 (15.8%)	0.785
Rotation z-axis, degree (left or right lateral bending) Optimal Right Left	12 (92.3%) 1 (7.7%) ---	17 (89.5%) 1 (5.3%) 1 (5.3%)	0.683

Values are expressed as median (interquartile ranges).
--- = Not available

deviations have been found to be associated with several different types of pain and dysfunction (25). When all these scientific findings are taken into account, we believe that the 3D postural evaluation that was used in this study is one of the most useful assessment methods for clinical practice in a teenage population that has a high prevalence of LBP.

According to the results of the LBP questionnaire, 40.6% of students reported a history of LBP. The high prevalence of LBP in the present study is remarkable and this condition may lead to chronic pain and disability later in life. The lifetime prevalence of LBP was almost the same as in the study of Jeffries et al. (3). The high prevalence of LBP might be of clinical relevance, since Harreby et al. suggested that subjects who had LBP in adolescence may be candidates for LBP as adults (5).

The literature has established a connection between postural problems and LBP (8,14). It is known that neutral posture is related to minimum strain on the active and passive spinal structures (26). Neutral spinal alignment is also believed to reduce the symptom of musculoskeletal pain. Therefore, it is essential to identify the postural deviations from neutral posture. In 2014, Rosario summarized the assessment methods of human posture and it was shown that there are different kinds of methods, such as photographic analysis, X-ray, inclinometer, etc. Photography of posture in the sagittal and frontal planes is a popular method in recent studies (25). Another review indicated that photography is one of the most widely used postural evaluation methods among others (27). We chose the same method as most of the other studies because Fortin et al. suggested that photograph acquisition is easy, cheap, and fast. Furthermore, you can obtain objective data, such as angle or distance (28).

It is important to emphasize that a key aspect in this study method was the assessment of pelvic posture through

Table 3. Comparison of absolute values for pelvic postural displacements between groups.

	LBP group n = 13	Control group n = 19	P-value
Lateral view			
Rotation x-axis, degree (flexion or extension)	4.9 (0–12.2)	5 (3.2–7.6)	0.922
Translation z-axis, mm (forward or backward)	54.5 (35.35–65.70)	51.2 (36.7–76.8)	0.409
Anterior view			
Translation x-axis, mm (left- or right-side shift)	4.1 (0–7.05)	4.3 (0–6.1)	0.769
Rotation y-axis, degree (left or right turning)	0 (0–1.8)	0 (0–4.6)	0.646
Rotation z-axis, degree (left or right lateral bending)	0 (0–0)	0 (0–0)	0.791

Values are expressed as median (interquartile ranges).

Table 4. Total postural abnormality profile and posture index score of participants.

	LBP group n = 13	Control group n = 19	P-value
Grades for posture index, n (%) Slightly displaced posture Significantly displaced posture Moderately displaced posture	 2 (15.4%) 9 (69.2%) 2 (15.4%)	 2 (10.5%) 13 (68.4%) 4 (21.1%)	0.870
Posture index score, points	16 (13–19)	16 (13–19)	0.893

Posture index scores are expressed as median (interquartile ranges).

a 3D evaluation system, calculated electronically from 2D digital photographs. Generally, the photography method assesses the body posture both in sagittal (lateral view) and frontal (anterior and posterior view) planes and obtains 2D information of a position of body segments. According to the literature, the PosturePrint system measures the head, rib cage, and pelvic posture as rotations (Rx, Ry, Rz) and translations (Tx, Tz) in 3D (20,21). In contrast to radiological evaluation, this system is a noninvasive method. The 3D whole-body scanner is a new tool for evaluation of 3D posture but it is large and expensive and it requires skilled operation when compared with the PosturePrint system (29).

Panjabi et al. stated that pelvis has 6 degrees of freedom: three translating motions along the x, y, and z axes and three rotation motions around the x, y, and z axes, respectively (30). Using the 1974 Cartesian coordinate system of Panjabi et al. (Figure 2), pelvic postures were categorized as rotations and translations in our study. Most of the studies involving the pelvis have mainly investigated the flexion/extension (Rx) or lateral flexion (Rz). There has been an omission of pelvic translations in the literature. However, pelvic translations (left-right, forward-backward) were also evaluated in our study. The current study showed that all participants in both groups had an abnormal pelvic posture of Tz. Although no significant differences were observed for Tz values between the groups, 92.3% of participants had forward pelvic posture in the LBP group and 100% of participants had forward pelvic posture in the control group. To the best of our knowledge, there is only one study that measured forward pelvic posture in children (aged 4–12 years) in mm (31). Our findings are similar to the study by Lafond et al. They also found significant associations with age for forward pelvis translation and reported that postural evolution during childhood is characterized by an increase in forward translation displacement of pelvis in the sagittal plane.

Rotation values (Ry, Rz) in anterior view are essential parameters to assess the pelvic posture. Rotation in Rz is a frontal plane asymmetry commonly known as lateral pelvic tilt or pelvic obliquity, in which the anterior superior iliac spine (ASIS) and posterior superior iliac spine (PSIS) on one side were higher than on the other side (32). It is the most common compensatory mechanism in leg length discrepancy. Rotation in Ry is a sagittal plane asymmetry known as iliac rotation asymmetry, in which one innominate bone rotates anteriorly or posteriorly relative to the other innominate (32). In our study, most of the students in both groups had optimal pelvic posture for Rz and Ry. These findings were expected because none of the students had scoliosis or leg length discrepancy. A line through each PSIS-ASIS in the lateral view was used to evaluate the flexion-extension (Rx) movement of the pelvis. To our knowledge, the pelvic posture of Rx is one of the most studied postures in the literature and normative data on lordosis are scarce (21). Flexed, extended, and optimal pelvic postures were identified in our study, but no significant differences were found between the groups.

Students who had experienced LBP in the preceding 3 months or reported LBP at the time of the assessments were excluded in our study. The major reason for this was to eliminate the compensatory effects of acute pain on pelvic posture because we aimed to evaluate the habitual posture of participants. We think that postural adaptations that have developed over the years may cause the LBP.

The LBP and control groups exhibited similar 3D postural profiles and alterations in the pelvis. The findings of our study concur in part with Dolphens et al., who reported that LBP was not significantly different between groups of lumbopelvic posture subtypes in adolescent boys (18). In another study by Dolphens et al., only the sagittal standing postures of adolescent boys and girls were examined using digital images and direct body measurements (17). They calculated the pelvic displacement angle in degrees from digital photographs. A positive value of this angle represents a forward carriage of the pelvis relative to the base of support as measured at the ankle, whereas a negative value indicates a backward carriage of the pelvis. Parallel to our study, they found that all subjects had positive pelvic displacement angle (forward translation of the pelvis). They reported that boys were found to have a significantly bigger pelvic displacement angle than girls. According to their findings, none of the spinopelvic parameters could be identified as a factor associated with lifetime prevalence of LBP in all subjects. On the contrary, forward translation of the pelvis was found to be associated with higher odds of lifetime prevalence LBP in boys. However, in our study pelvis translation was calculated in mm. Unfortunately, we did not do sex-specific analysis for the parameters of 3D pelvic posture because of the small sample size.

Although this study set out to assess pelvic posture, total postural abnormality was also evaluated using the posture index. The results revealed that not only pelvic posture but also total body posture was altered in students.

The results of the current study should be interpreted with certain limitations. The small number of participants in the groups was a major limitation of the study because the majority of the students were not willing to participate in photographic evaluation. Nonsignificant differences between the groups might be related to the small sample size. Another problem was the lack of sex-specific analysis due to the small sample size. The last possible limitation of the study was the use of photographic measurements to assess posture because palpation and marker placement external to the body can affect the results. This was reported as the main problem of the photography technique in the literature (25,27). While the current study has some limitations, the results provide useful clinical information upon which further research in 3D postural evaluation of the pelvis and its relationship with LBP in adolescent students can be based.

Overall, 40.6% of the students reported a history of LBP. Although adolescents with LBP have a profile of pelvic posture similar to those of healthy adolescents without a history of LBP, most of the students in both groups had altered pelvic and total body posture in upright stance. Regardless of LBP history, altered pelvic and total body posture may be a serious health problem in adolescents.

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