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Prevalence of Lumbosacral Transitional Vertebral Anomalies Among Healthy Volunteers and Patients with Hip Pathology

Association with Spinopelvic Characteristics

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Background: A lumbosacral transitional vertebra (LSTV) has been reported to be prevalent among patients with hip dysplasia. The aims of this study were to determine the (1) prevalence of an LSTV in young patients presenting with hip pain and a group of asymptomatic volunteers, (2) effect of an LSTV on spinopelvic characteristics, and (3) presence of low back pain among patients with an LSTV.

Methods: This cross-sectional study included 102 patients with hip pathology and 51 asymptomatic volunteers (mean age, 33.9 ± 7.3 years; mean body mass index, 26.0 ± 5.0 kg/m^2; 57.5% female). Participants underwent radiographic assessment of the lumbar spine and pelvis in standing and deep-seated positions. LSTV occurrence was classified according to the Castellvi system. Spinopelvic characteristics included lumbar lordosis (including segmental lumbar angles), pelvic tilt, and hip flexion (pelvic-femoral angle). Differences between standing and deep-seated values were calculated. Low back pain was assessed using the Oswestry Disability Index.

Results: The prevalence of LSTV type ≥II was 8.5%, with no difference between patients and volunteers ($p = 0.386$). Individuals with an LSTV had a greater standing L1-L5 angle (mean, 51.6° ± 11.7° versus 38.9° ± 9.3°; $p < 0.001$). The overall spinal flexion (change in L1-S1 angle between the standing and deep-seated positions) in individuals with an LSTV was similar to that in individuals without an LSTV; restricted L5-S1 mobility was compensated for at L1-L2 (10.2° ± 5.8° in those with versus 8.4° ± 4.1° in those without an LSTV; $p = 0.070$). No significant difference in the presence of low back pain was found ($p = 0.250$).

Conclusions: An LSTV was found in 8.5% of young adults, with no difference between patients with hip pathology and controls. Individuals with an LSTV have greater standing lumbar lordosis, with altered mechanics at the cephalad adjacent level, which may predispose these individuals to degenerative changes at this level.

Level of Evidence: Prognostic Level II. See Instructions for Authors for a complete description of levels of evidence.

A lumbosacral transitional vertebra (LSTV) is a congenital anatomical abnormality in which the transverse process of the fifth lumbar vertebral body engages the sacral ala, resulting in a pseudoarticulation or even a fused segment[1] (Fig. 1). Reported LSTV prevalences vary greatly (3% to 40%) among studies reporting on populations with various characteristics[2-5]. The presence of an LSTV might affect sagittal balance, which is the result of an optimal lordotic positioning of the vertebrae above a correctly orientated pelvis[6]. Anatomical factors that reduce motion in the lumbosacral junction can cause increased degeneration of the cephalad adjacent segment as the body attempts to maintain sagittal balance[4], but may also lead to abnormal sagittal characteristics of the pelvis in relation to the femur (its distal adjacent segment).

Disclosure: The **Disclosure of Potential Conflicts of Interest** forms are provided with the online version of the article (http://links.lww.com/JBJSOA/A480).

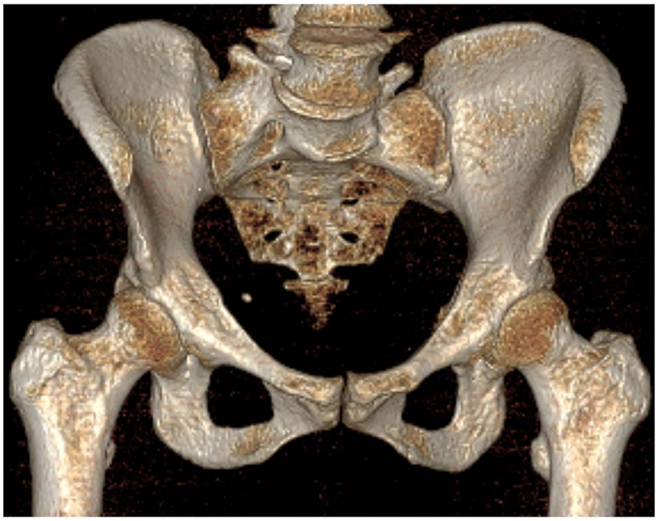

Fig. 1

Three-dimensional CT reconstruction of a pelvis with a Castellvi IIIA lumbosacral transitional vertebra. The fifth lumbar vertebral body engages with the sacrum in a fused segment on the right side, while there is a normal transverse process on the left.

A high LSTV prevalence in patients with hip dysplasia has been reported (40%), and it has been hypothesized that such anomalies are more prevalent in young adults presenting with hip pain[7]. Spinopelvic characteristics have been associated with the pathomechanics of hip pathologies, including both dysplasia and impingement, and have also been implicated as a risk factor for the development of osteoarthritis. To date, only a few studies have reported on the influence of LSTVs on static spinopelvic characteristics[8], and data on the influence of LSTVs on dynamic characteristics are lacking. Furthermore, whether LSTVs are more prevalent among patients with hip pathology compared with asymptomatic healthy volunteers is unknown. Patients with hip pathology present an ideal cohort for the study of dynamic spinopelvic characteristics, as it has been shown that reduced femoroacetabular flexion due to hip pathology leads to increased lumbar flexion and uncouples compensatory spinal mechanisms[9,10].

The aims of this study were to determine the (1) LSTV prevalence in young patients presenting with hip pain in comparison with a group of asymptomatic volunteers, (2) effect of LSTVs on static and dynamic spinopelvic characteristics, and (3) presence of low back pain (LBP) among young adult patients with hip pain with an LSTV.

Materials and Methods

Study Design

This was a prospective, cross-sectional, case-cohort study from a single, tertiary referral, academic center for the treatment of hip and spinal pathology. The study was conducted at The Ottawa Hospital in Canada and approved by the institutional review board. Patients who presented to our hip preservation specialty clinic with hip pain secondary to a labral tear between June 2020 and December 2021 were recruited. These patients were compared with a control group of asymptomatic volunteers (Oxford hip score of ≥45 on a scale of 0 [worst] to 48 [best]) consisting of the hospital's health-care workers and patients presenting to the fracture clinic with upper-limb injuries. The exclusion criteria were an age of <18 or ≥50 years, signs of hip osteoarthritis (Tönnis grade of ≥2), pediatric deformity (hip dislocation or previous femoral or acetabular osteotomy), osteonecrosis, history of a neuromuscular disorder, spinal pathology (history of spinal surgery or Oswestry Disability Index (ODI) of >15 on a scale of 0 [none] to 50 [maximal disability]), or radiographs of insufficient quality. These exclusion criteria were applied because they have been shown to influence spinopelvic characteristics[10-12]. An a priori

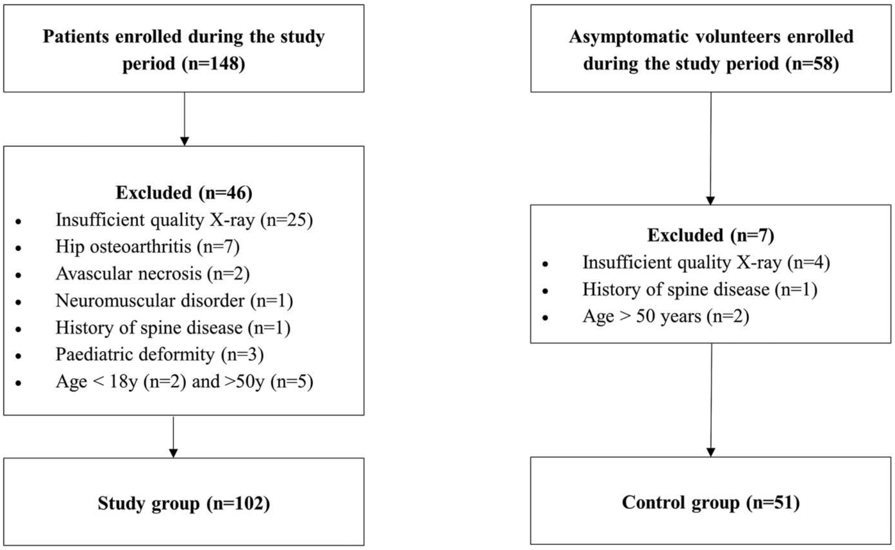

Fig. 2

Flowchart illustrating the inclusion process for the study.

TABLE I Demographics of the Cohort

	Whole Cohort (N = 153)	Patients (N = 102)	Asymptomatic Volunteers (N = 51)	P Value
Age* *(yr)*	33.9 ± 7.3 (18.5-48.3)	34.8 ± 7.5 (18.5-48.3)	32.1 ± 6.6 (23.1-47.2)	0.023†
Sex *(no. [%])*				0.001‡
Male	65 (42.5)	34 (33.3)	31 (60.8)	
Female	88 (57.5)	68 (66.7)	20 (39.2)	
BMI* *(kg/m^2)*	26.0 ± 5.0 (18.7-44.4)	26.2 ± 5.3 (18.7-44.4)	24.4 ± 1.9 (22.1-26.5)	0.568†
Smoking *(no. [%])*	20 (13.1)	20 (19.6)	0 (0.0)	<0.001‡
History of pregnancy *(no. [% of women])*	56 (63.6)	48 (70.6)	8 (40.0)	0.010‡

*The values are given as the mean and standard deviation, with the range in parentheses. †Mann-Whitney U test. ‡Chi-square test.

sample size calculation based on the reported difference in LSTV prevalence documented between young adults with hip pathology (40%)[7] and controls (15%)[5] was performed in IBM SPSS (version 27). This indicated that a minimum of 49 patients per group would be necessary to achieve sufficient power (with $1 - \beta = 0.80$, $\alpha = 0.05$). To increase the power, we included a 2:1 ratio of patients to volunteers. The inclusion process is outlined in Figure 2. All participants signed an informed consent form. After applying the exclusion criteria, 102 patients and 51 volunteers were included in the study. Sixty-five (42.5%) were male and 88 (57.5%) were female. The mean age (and standard deviation) was 33.9 ± 7.3 years (range, 18.5 to 48.3 years), and the mean body mass index (BMI) was 26.0 ± 5.0 kg/m^2 (range, 18.7 to 44.4 kg/m^2) (Table I).

Radiographic Assessment

Patient Positioning

Patients and volunteers underwent radiographic assessment that included standing and supine anteroposterior radiographs of the pelvis and lateral views of the lumbar spine, pelvis, and femur in standing and “deep-seated” positions. In the deep-seated position, the subject sits on a height-adjustable chair with their femora parallel to the floor and their trunk leaning as far forward as is comfortable without abducting or rotating the femora[10,13,14]. This position was chosen because it is associated with maximal sagittal flexion of the kinetic chain, is the position at greatest risk for impingement on a torn acetabular labrum[15], and has been shown to better identify spinal compensatory mechanisms[13,16,17].

Radiographic Assessment of Spinal and Other Parameters

The presence of an LSTV was evaluated on anteroposterior pelvic radiographs. Traditional radiographs have well-documented utility in diagnosing and classifying LSTVs[4,5,7,18]. The Castellvi classification system was used to classify LSTVs on the basis of the degree of either unilateral or bilateral articulation between the transverse processes of L5 and the sacrum[19] (Table II, Fig. 3). Because a type-I LSTV involves neither an articulation nor a fusion of the transverse process to the sacrum, only types II, III, and IV were considered abnormal, in line with previous literature[8].

Leg-length discrepancy (LLD) was measured on an anteroposterior pelvic radiograph[20]. The following measurements were made on the lateral radiographs of the lumbar spine, pelvis, and proximal femur in the standing and deep-seated positions: lumbar lordosis (LL), sacral slope (SS), pelvic incidence (PI), pelvic tilt (PT), and pelvic-femoral angle (PFA)[6,9,13,14,21], as well as segmental measurements at L1-L2, L2-L3, L3-L4, L4-L5, and L5-S1[10]. Spinopelvic motions were calculated as the difference between the standing and deep-seated positions for LL, SS, PI, PT, and PFA[10]. (For example, ΔLL would be $LL_{standing} - LL_{deep\text{-}seated}$.) The sagittal flexion arc (SFA), representing the motion performed by the entire kinetic chain, was calculated as the sum of ΔLL and ΔPFA[10].

The spinopelvic balance of each patient was measured as the difference between PI and LL in the standing position and

TABLE II Castellvi Classification[19]

Type	Description	Anatomical Features
I	Dysplastic transverse process(es)	Unilateral (A) or bilateral (B) enlarged transverse process(es) (>19 mm)
II	Incomplete lumbarization or sacralization	Enlarged transverse process(es) with unilateral (A) or bilateral (B) pseudarthrosis with the sacral ala
III	Complete lumbarization or sacralization	Enlarged transverse process(es) with unilateral (A) or bilateral (B) complete fusion with the sacral ala
IV	Mixed	Type II on one side and III on the other

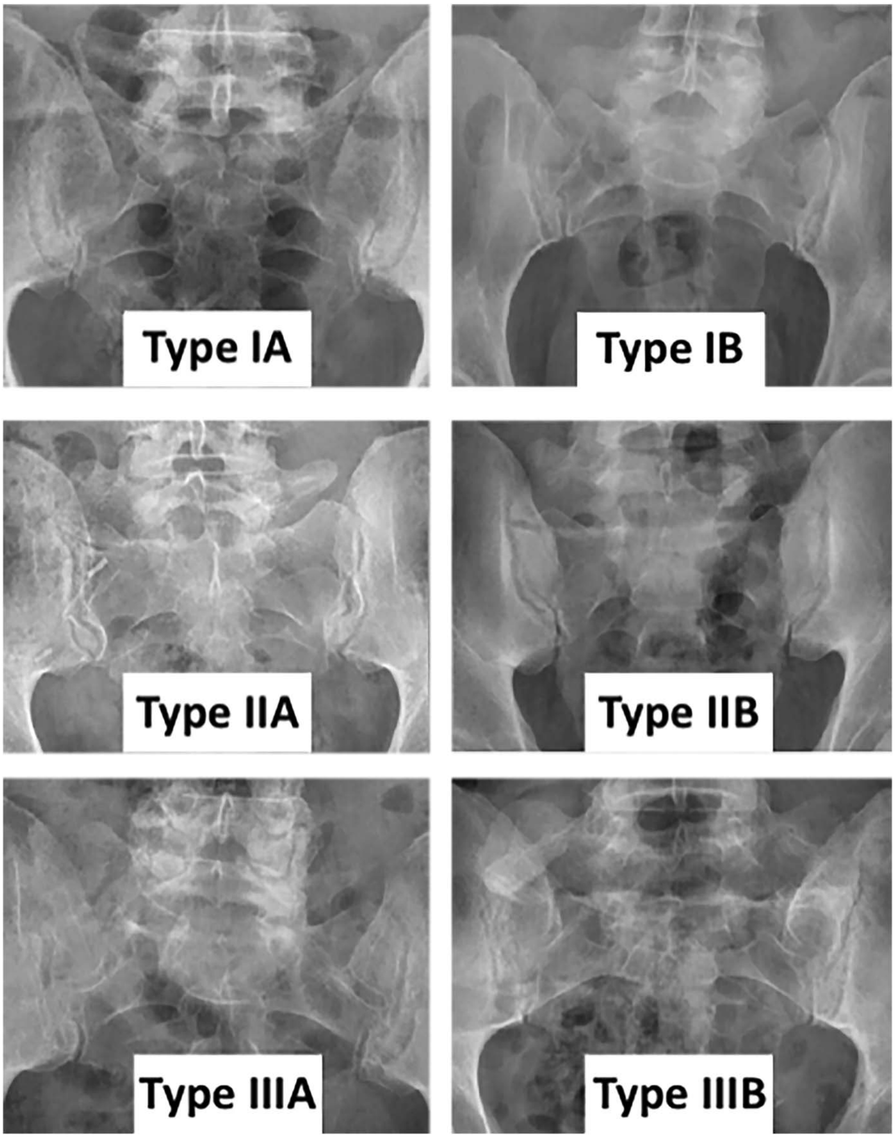

Fig. 3

Closeups of anteroposterior pelvic radiographs focusing on the lumbosacral junction show examples of each type of lumbosacral transitional vertebra according to the Castellvi classification. In the type-IA example, an enlarged transverse process is visible on the left. In type IB, bilateral enlarged transverse processes are visible. In type IIA, the enlarged transverse process forms a pseudarthrosis with the sacrum on the right. In type IIB, the enlarged transverse processes form pseudarthroses with the sacrum bilaterally. In type IIIA, the transverse process is fused with the sacrum on the right. In type IIIB, the transverse processes are fused with the sacrum bilaterally.

was classified as flatback (PI – LL, >10°), normal (PI – LL, −10° to 10°), or hyperlordotic (PI – LL, <−10°)[12,22-24].

The hip user index quantifies the percentage of sagittal femoroacetabular flexion (ΔPFA) relative to the overall SFA when moving from a standing to a deep-seated position:

$$Hip\ user\ index = \frac{\Delta PFA}{SFA} \times 100$$

A high hip user index means that the hip contributes more to sagittal motion, whereas a low hip user index means that the motion takes place primarily in the lumbar spine[10,17]. Patients with a hip user index of ≥80% were defined as hip users[17].

The radiographic measurements were made by a fellowship-trained spine surgeon (N.A.B.). Measurements were repeated 2 weeks later for 30 randomly selected data sets (20%) in a blinded fashion by 2 reviewers (J.C.F.V. and N.A.B.). Interobserver and intraobserver reliability were calculated by means of the intraclass correlation coefficient, using a 2-way mixed model, and showed excellent agreement (Table III).

TABLE III Reliability of Radiographic Measurements of Spinopelvic Parameters*

	Interobserver Reliability		Intraobserver Reliability	
	ICC	95% CI	ICC	95% CI
$LL_{standing}$	0.938	0.750-0.985	0.940	0.758-0.985
$LL_{deep\text{-}seated}$	0.986	0.931-0.997	0.969	0.876-0.992
$SS_{standing}$	0.965	0.861-0.991	0.964	0.855-0.991
$SS_{deep\text{-}seated}$	0.935	0.739-0.984	0.990	0.960-0.998
$PT_{standing}$	0.992	0.967-0.998	0.980	0.921-0.995
$PT_{deep\text{-}seated}$	0.829	0.671-0.980	0.985	0.938-0.996
$PFA_{standing}$	0.930	0.720-0.983	0.927	0.706-0.982
$PFA_{deep\text{-}seated}$	0.939	0.752-0.985	0.939	0.754-0.985

*ICC = intraclass correlation coefficient, and CI = confidence interval.

Clinical Assessment

The presence of LBP was assessed using the ODI[25]. Patients were categorized as without LBP if the ODI was <15 (indicating no [ODI of 0 to 4] or mild [ODI of 5 to 14] disability) and with LBP if the ODI was ≥15 (moderate [ODI of 15 to 24] or severe [ODI of 25 to 34] disability or disabled [ODI of 35 to 50]).

Other patient-reported outcome measures (PROMs) included the International Hip Outcome Tool-12 (iHOT-12)[26]; the Patient-Reported Outcomes Measurement Information System (PROMIS)[27], which allows assessment of mental health and physical activity status; and the EuroQol-5 Dimensions (EQ-5D) questionnaire[28].

Statistical Analysis

Because the data were not normally distributed according to the Kolmogorov-Smirnov test, nonparametric tests were used. The Mann-Whitney U test was used to compare spinopelvic measurements and continuous demographic variables, and the chi-square test was used to compare categorical demographic variables. Statistical analysis was performed using IBM SPSS (version 27). A value of <0.05 was considered significant.

Source of Funding

This study was funded by a Physicians Services Incorporated (PSI) Resident Research Grant.

Results

LSTV Prevalence

The LSTV prevalence in the whole cohort was 12.4% (19 of 153). The most common type was IIA (Fig. 4). The prevalence of LSTV type ≥II was 8.5% (13 of 153). The term LSTV in the subsequent text will refer specifically to type ≥II LSTV. There was no difference in prevalence between the patients with hip pain (11 of 102; 10.8%) and asymptomatic volunteers (8 of 51; 15.7%) ($p = 0.386$).

Influence of LSTVs on Static Spinopelvic Characteristics

In the standing position, individuals with an LSTV had a greater L1-L5 angle (mean, 51.6° ± 11.7° versus 38.9° ± 9.3°; $p < 0.001$) compared with those without LSTV. LL was also greater at all segments in individuals with an LSTV (Table IV), while the L5-S1 angle was significantly smaller (14.0° ± 6.9° versus 22.7° ± 6.3°; $p < 0.001$). SS was greater in individuals with an LSTV as well (43.8° ± 8.4° versus 39.0° ± 7.6°; $p = 0.036$) (Table V).

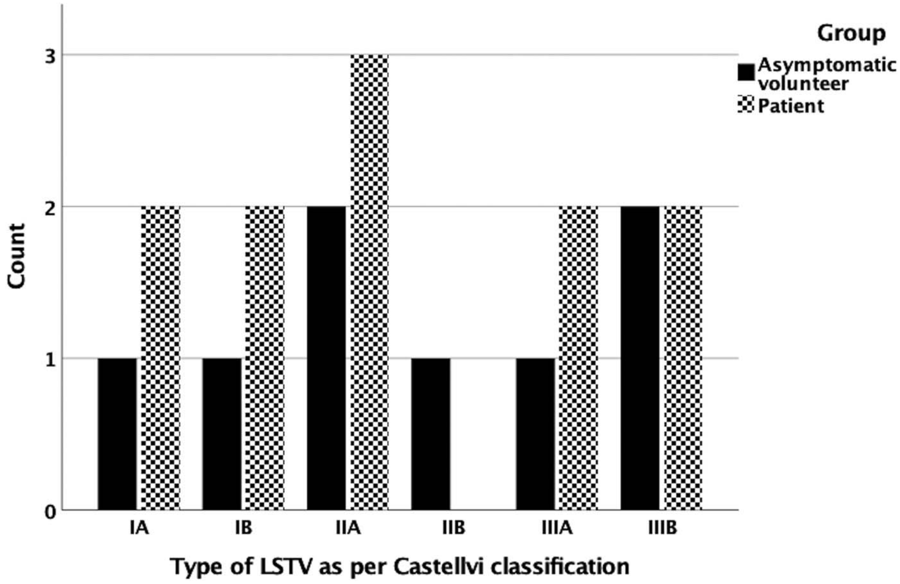

Fig. 4

Distribution of lumbosacral transitional vertebrae by type among patients and asymptomatic volunteers.

TABLE IV Lumbar Segmental Angles in Individuals with and without LSTV Type ≥II)*

	Whole Cohort (N = 153)	Individuals without LSTV (N = 140)	Individuals with LSTV (N = 13)	P Value†
$LL_{standing}$ *(deg)*				
L1-L2	3.4 ± 3.8	3.1 ± 3.6	7.5 ± 4.4	<0.001‡
L2-L3	8.0 ± 4.1	7.7 ± 3.7	11.1 ± 6.4	0.027‡
L3-L4	11.5 ± 3.3	11.4 ± 3.3	12.7 ± 3.1	0.194
L4-L5	17.1 ± 4.8	16.8 ± 4.7	20.3 ± 5.1	0.015‡
L5-S1	22.0 ± 6.8	22.7 ± 6.3	14.0 ± 6.9	<0.001‡
$L1\text{-}L5_{standing}$ *(deg)*	40.0 ± 10.1	38.9 ± 9.3	51.6 ± 11.7	<0.001‡
$L1\text{-}S1_{standing}$ *(deg)*	61.9 ± 10.5	61.6 ± 10.5	65.6 ± 9.9	0.126
$LL_{deep\text{-}seated}$ *(deg)*				
L1-L2	−5.1 ± 3.3	−5.3 ± 3.2	−2.8 ± 3.6	0.019‡
L2-L3	−3.2 ± 3.3	−3.4 ± 3.2	−1.3 ± 3.5	0.030‡
L3-L4	−1.3 ± 3.0	−1.5 ± 3.0	0.8 ± 3.0	0.012‡
L4-L5	1.2 ± 3.6	0.9 ± 3.2	4.4 ± 5.4	0.019‡
L5-S1	10.3 ± 4.6	10.4 ± 4.7	8.9 ± 3.7	0.240
$L1\text{-}L5_{deep\text{-}seated}$ *(deg)*	−8.3 ± 9.2	−9.2 ± 8.5	1.1 ± 11.7	<0.001‡
$L1\text{-}S1_{deep\text{-}seated}$ *(deg)*	1.9 ± 10.5	1.2 ± 9.9	10.0 ± 13.2	0.012‡
$\Delta LL_{standing/deep\text{-}seated}$ *(deg)*				
ΔL1-L2	8.5 ± 4.2	8.4 ± 4.1	10.2 ± 5.8	0.070
ΔL2-L3	11.2 ± 3.8	11.0 ± 3.7	12.4 ± 4.2	0.363
ΔL3-L4	12.8 ± 3.1	12.9 ± 2.9	12.0 ± 4.1	0.480
ΔL4-L5	15.8 ± 4.4	15.8 ± 4.1	15.9 ± 7.3	0.434
ΔL5-S1	11.7 ± 7.0	12.3 ± 6.5	5.1 ± 8.3	0.002‡
$\Delta L1\text{-}L5_{standing/deep\text{-}seated}$ *(deg)*	48.3 ± 8.9	48.1 ± 8.4	50.5 ± 13.8	0.248
$\Delta L1\text{-}S1_{standing/deep\text{-}seated}$ *(deg)*	60.0 ± 10.2	60.4 ± 9.5	55.6 ± 16.1	0.351

*The values are given as the mean and standard deviation. †Mann-Whitney U test comparing spinopelvic characteristics between individuals without and with LSTV. ‡Significant ($p < 0.05$).

Influence of LSTVs on Dynamic Spinopelvic Characteristics

There were no differences between individuals with and without LSTV in hip flexion (ΔPFA: 99.3° ± 14.0° versus 99.9° ± 15.3°; p = 0.950), pelvic motion (ΔPT: 7.7° ± 12.1° versus 11.1° ± 14.5°; p = 0.484), or spinal flexion (ΔL1-S1: 55.6° ± 16.1° versus 60.4° ± 9.5°; p = 0.351) when moving from the standing to the deep-seated position (Table V).

Although overall spinal flexion (ΔL1-S1) was similar between individuals with and without LSTV, there was significantly less lumbar flexion in the L5-S1 segment in individuals with an LSTV (5.1° ± 8.3° versus 12.3° ± 6.5°; p = 0.002). This restriction in mobility was somewhat compensated for at the L1-L2 level by a greater segmental angle (10.2° ± 5.8° versus 8.4° ± 4.1°; p = 0.070) (Table IV).

Clinical Assessment

Among the patients with hip symptoms, 36.8% (35) of the 95 without LSTV and 57.1% (4) of the 7 with an LSTV had LBP (p = 0.250). The mean ODI of those with an LSTV was higher, but not significantly so, compared with those without LSTV (17.3 ± 10.0 versus 12.0 ± 10.3; p = 0.234). Similarly, other PROM scores were not significantly different between patients with and without LSTV (Table VI). The ODI was not correlated with the iHOT-12 (p = 0.691). Patients with LBP did not have higher rates of smoking (p = 0.740) or of a history of pregnancy (p = 0.224).

Discussion

An LSTV reduces motion at the lumbosacral junction, as the fifth lumbar transverse process is fused or has formed a pseudoarticulation with the sacrum. Some studies have suggested a higher prevalence among young patients with hip pain[7]. In the present cross-sectional study, we found an LSTV prevalence of 8.5%, with no significant difference between young patients presenting with hip pain (10.8%) and asymptomatic volunteers (15.7%). LSTVs have been associated with LBP and inferior outcomes after hip arthroscopy, although the pathophysiologic mechanism is unclear because of the paucity of studies investigating the influence of LSTVs on dynamic spinopelvic characteristics[4,5,29,30]. Furthermore, it has been suggested that LSTVs

TABLE V Spinopelvic Parameters in Individuals with and without LSTV*

	Whole Cohort (N = 153)	Individuals without LSTV (N = 140)	Individuals with LSTV (N = 13)	P Value†
L1-S1$_{\text{standing}}$ *(deg)*	61.9 ± 10.5	61.6 ± 10.5	65.6 ± 9.9	0.126
L1-S1$_{\text{deep-seated}}$ *(deg)*	1.9 ± 10.5	1.2 ± 9.9	10.0 ± 13.2	0.012‡
ΔL1-S1$_{\text{standing/deep-seated}}$ *(deg)*	60.0 ± 10.2	60.4 ± 9.5	55.6 ± 16.1	0.351
SS$_{\text{standing}}$ *(deg)*	39.4 ± 7.8	39.0 ± 7.6	43.8 ± 8.4	0.036‡
SS$_{\text{deep-seated}}$ *(deg)*	50.8 ± 15.0	50.5 ± 15.4	54.2 ± 10.2	0.351
ΔSS$_{\text{standing/deep-seated}}$ *(deg)*	−11.4 ± 14.2	−11.4 ± 14.2	−10.4 ± 14.4	0.896
PT$_{\text{standing}}$ *(deg)*	12.8 ± 6.6	12.8 ± 6.4	13.7 ± 9.3	0.801
PT$_{\text{deep-seated}}$ *(deg)*	2.1 ± 15.5	1.7 ± 15.3	6.0 ± 17.1	0.511
ΔPT$_{\text{standing/deep-seated}}$ *(deg)*	10.8 ± 14.3	11.1 ± 14.5	7.7 ± 12.1	0.484
PFA$_{\text{standing}}$ *(deg)*	192.8 ± 6.9	192.6 ± 6.6	195.0 ± 9.9	0.332
PFA$_{\text{deep-seated}}$ *(deg)*	93.0 ± 15.4	92.7 ± 15.0	95.7 ± 19.2	0.852
ΔPFA$_{\text{standing/deep-seated}}$ *(deg)*	99.9 ± 15.2	99.9 ± 15.3	99.3 ± 14.0	0.950
SFA *(deg)*	159.8 ± 17.1	160.2 ± 17.0	154.8 ± 18.0	0.414
PI$_{\text{standing}}$ *(deg)*	52.3 ± 10.7	51.8 ± 10.0	57.8 ± 15.2	0.086
PI-LL mismatch *(deg)*	−9.6 ± 10.2	−9.8 ± 9.7	−7.7 ± 15.1	0.507
Hip user index *(%)*	62.3 ± 6.1	62.1 ± 5.7	64.4 ± 9.3	0.815
Leg-length difference *(mm)*	2.9 ± 3.8	2.9 ± 3.9	2.6 ± 2.4	0.727

*The values are given as the mean and standard deviation. †Mann-Whitney U test comparing spinopelvic characteristics between individuals without and with LSTV. ‡Significant ($p < 0.05$).

can also influence the development of hip symptoms in young adults with hip dysplasia[7] or femoroacetabular impingement (FAI)[1] by altering spinopelvic dynamics. To our knowledge, our study is the first to investigate how LSTVs influence static and dynamic spinopelvic characteristics. Individuals with an LSTV had a higher standing LL in the cephalad segments (between L1 and L5). Compensation for the stiff L5-S1 segment occurred mostly in the L1-L2 segment. These findings suggest that the higher rate of degenerative changes previously seen in the segment cephalad to an LSTV[31,32] is most likely due to increased loading on the lumbar spine in the standing position, as no significantly increased motion was seen at the lower lumbar levels in our analysis of dynamic spinopelvic parameters.

LSTV prevalences ranging from 3% to 40% have been reported in the general population[2-5]. Reported prevalences have generally been higher in studies of patients with LBP than in community-based studies[4,5]. Luo et al. found an LSTV prevalence of 13.9% in a population of patients undergoing hip arthroscopy, but included no asymptomatic volunteers or patients with hip dysplasia[1]. In a recent study, Sun et al. found a high LSTV prevalence (39% to 43%) among patients with dysplasia[7], and they reported Castellvi type IIIB to be the most common type among these patients, suggesting an increased LSTV type in patients with severe dysplasia[7]. In the present study, the LSTV prevalence was higher among the asymptomatic volunteers (15.7%) than the patients with hip pain (10.8%), although this difference was not

TABLE VI Patient-Reported Outcome Scores at Time of Presentation Among Young Adult Patients with Hip Pain, with and without an LSTV

	All Patients (N = 70)	Patients without LSTV (N = 64)	Patients with LSTV (N = 6)	P Value*
ODI	12.5 ± 10.3	12.0 ± 10.3	17.3 ± 10.0	0.234
iHOT-12	34.9 ± 18.9	35.2 ± 19.4	31.5 ± 13.6	0.890
PROMIS global	30.9 ± 6.9	31.3 ± 7.1	27.5 ± 4.4	0.165
PROMIS mental health	12.5 ± 3.1	12.7 ± 3.1	10.8 ± 3.0	0.256
PROMIS physical health	12.1 ± 3.0	12.2 ± 3.1	11.0 ± 0.1	0.273
EQ-5D	0.615 ± 0.101	0.622 ± 0.103	0.549 ± 0.028	0.091

*Mann-Whitney U test comparing patient-reported outcome measures between individuals without and with an LSTV.

significant. Spinopelvic characteristics play an important role in the development of hip symptoms[10,33,34] and in the outcome of hip surgery[22,30,35]. It has been hypothesized that conditions such as LSTV can reduce motion at the lumbosacral junction and help explain why some individuals with dysplasia or FAI morphology become symptomatic[1,7]. The reduced motion due to an LSTV did not affect changes in PT and hip flexion, and compensation primarily took place in the most cephalad lumbar segments.

Some authors have suggested an association between LBP and the presence of an LSTV[4,5,29]. Although we found no difference in the prevalence of LBP between individuals with and without LSTV, several PROMs, including the ODI, PROMIS mental and physical health, and EQ-5D, were worse among patients with an LSTV. The lack of significance may be attributed to the small number of patients with an LSTV (lack of adequate power) or the young age of the cohort, who may be more likely to develop symptoms during aging. The pathophysiologic mechanism of LBP in patients with an LSTV has been attributed to increased motion at the segment cephalad to the LSTV, based on magnetic resonance imaging (MRI) findings of more advanced disc degeneration and extraforaminal stenosis cephalad to the LSTV[4,31,32,36], although studies on dynamic spinopelvic characteristics are lacking. We believe that our study is the first to compare static and dynamic spinopelvic characteristics in patients with and without an LSTV. In the standing position, the PT was similar between patients with and without an LSTV, illustrating similarly adequate sagittal balance. However, individuals with an LSTV demonstrated increased LL between L1 and L5 and increased SS compared with individuals without an LSTV; the latter was predominantly due to a reduced lordosis angle at the L5-S1 segment. The reduced lordosis between L5 and S1 due to the LSTV was compensated for by an increase in lordosis between L1 and L5. The increased lordosis was more prominent throughout all levels in the static standing assessments. This increased lordosis may predispose these individuals to facet degeneration and degenerative spondylolisthesis[37]. Overall spinal flexion (ΔL1-S1) between the standing and deep-seated positions did not differ significantly between individuals with and without an LSTV, but the L5-S1 segment was significantly less mobile in individuals with an LSTV. Although one would expect that the decreased motion at the LSTV segment is compensated for at the adjacent cephalad segments, the compensatory motion was most pronounced at the L1-L2 level. Such ability of the upper lumbar segments to increase their motion when the sagittal movement arc is reduced has also been described in patients with hip osteoarthritis[10]. The static and dynamic findings in the present study suggest that the degenerative changes of the adjacent lumbar segment seen in patients with an LSTV are more likely the consequence of increased lordosis in the standing position, rather than of the compensatory motion within these segments.

This study has some limitations. First, MRI, which has a higher reliability than standard radiographs, would have been a superior method for the detection and classification of LSTVs[38]. The standard for identification of an LSTV on radiographs is the Ferguson view, an anteroposterior radiograph centered at the sacrum with 30° of cranial angulation[18,39]. Although 3-dimensional computed tomography (CT) imaging was available for some patients as part of their diagnostic work-up, the presence of an LSTV in the majority of patients was established on the basis of anteroposterior pelvic radiographs. Other studies have also used anteroposterior pelvic radiographs[5,29], or kidney-urinary bladder (KUB) radiographs[4], to study the prevalence of LSTVs. Second, because MRI was not available and the radiographs did not include the whole spine, it is possible that abnormalities existed higher in the spine, or that some patients had early degenerative changes of cartilage or intervertebral discs that could influence lumbar and spinopelvic characteristics as well as LBP. Third, the number of patients with an LSTV was small and we only included young patients with hip pathology. Therefore, while an LSTV may influence the occurrence of LBP, our data did not allow us to establish a causative relationship between differences in spinopelvic characteristics and the presence of LBP in patients with an LSTV. Furthermore, longitudinal follow-up was lacking, so LBP could still develop in these patients in the future. Fourth, the small size of the LSTV subgroups did not allow a comparative statistical analysis among individual subgroups. Finally, our patient cohort included young adults with symptomatic labral pathology due to a large variety of causes, creating heterogeneity. Patients presented with labral pathology due to various degrees of dysplasia, types of FAI, and/or rotational abnormalities of the femur and/or acetabulum. Each of these morphotypes influences spinopelvic characteristics in its own way. The numbers of LSTVs in these subgroups were too small to allow assessment of the influence of an LSTV on spinopelvic characteristics within these separate morphotypes.

In conclusion, LSTVs were found in 8.5% of young adults, with no significant difference between symptomatic patients and controls. Individuals with an LSTV had greater standing LL, with altered mechanics at the cephalad level, which may predispose these individuals to degenerative changes at that level. There was no influence of LSTV presence on pelvic and hip motion, and compensatory mechanisms were present in the remaining lumbar motion segments to maintain normal range of motion. ■

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