PIONEER
ACADEMIC PUBLISHING LIMITED

Current Research in Medical Sciences
ISSN 2958-0390
www.pioneerpublisher.com/crms
Volume 3 Number 1 March 2024

Analysis of the Research Progress on the Impact of Lumbosacral Transitional Vertebra on the Lumbopelvic-Hip Complex

Yuxi Luo[1]

[1] Department of Radiology, The First Affiliated Hospital of Chongqing Medical University, Chongqing 400016, China
Correspondence: Yuxi Luo, Department of Radiology, The First Affiliated Hospital of Chongqing Medical University, Chongqing 400016, China.

doi:10.56397/CRMS.2024.03.10

Abstract

The lumbosacral transitional vertebra is a common congenital variation. The presence of LSTV can result in smaller benefits for the population after total hip arthroplasty. Although extensive research has been conducted on the association between LSTV and lumbopelvic-hip complex syndrome in populations undergoing total hip arthroplasty, with convincing evidence suggesting that the presence of LSTV can have a negative impact on the outcomes of total hip arthroplasty, there is currently a lack of exploration into the association between LSTV and hip joint anatomical development, as well as its correlation with lumbopelvic-hip complex syndrome. The lumbopelvic-hip complex (LPHC) is a key structure for maintaining body stability and transmitting forces. Lumbosacral transitional vertebra (LSTV) is one of the most common congenital variations at the lumbosacral junction, which has a certain influence on the line of force transmission to the pelvis and hip joints and plays a role in the occurrence and development of hip and lumbar back pain.

Keywords: lumbosacral transitional vertebrae, hip, lumbo-pelvic-hip complex, hip-spine syndrome

1. Research Progress on Lumbosacral Transitional Vertebra

1.1 Classification and Identification of Lumbosacral Transitional Vertebra

Lumbosacral transitional vertebra (LSTV) is one of the most common congenital variations at the lumbosacral junction and a major cause of lower back pain in young patients. Its prevalence varies in different regions, with reported rates ranging from 2.6% to 35.6% (Apazidis A, Ricart PA, Diefenbach CM & Spivak JM, 2011; Apaydin M, Uluc ME & Sezgin G, 2019; Nakagawa T, Hashimoto K, Tsubakino T, Hoshikawa T, Inawashiro T & Tanaka Y, 2017; Nevalainen MT, McCarthy E, Morrison WB, Zoga AC & Roedl JB, 2018). The wide range of prevalence of LSTV may be due to differences in imaging methods used for its identification. LSTV can be identified using various imaging techniques, with the best method for identifying the lumbar vertebrae being the lateral view and Ferguson X-ray (i.e., X-ray tube tilted 30° cephalad), to better demonstrate the relationship between the

L5 transverse process and the sacrum (Konin GP & Walz DM, 2010). The Ferguson method measurement involves assessing the angle formed by the superior margin of S1 and a horizontal line on the lateral X-ray taken in the standing position.

The sacralization of lumbar vertebrae presents with various morphological features, including a range from enlarged transverse processes to complete fusion with the sacrum. Among these, the most commonly used classification system for LSTV is the Castellvi radiographic classification. In 1984, Castellvi et al. classified sacralized lumbar vertebrae into four types based on their morphological characteristics: Type I primarily shows underdevelopment of the L5 transverse process, with a width of at least greater than 19mm, and can be further divided into two subtypes - Ia (unilateral transverse process underdevelopment) or Ib (bilateral transverse process underdevelopment); Type II exhibits partial sacralization of the lumbar vertebrae, with widened transverse processes and pseudoarthrosis between them and the sacrum, further subdivided into two subtypes - IIa (unilateral pseudoarthrosis formation) or IIb (bilateral pseudoarthrosis formation); Type III: unilateral (IIIa) or bilateral (IIIb) complete lumbar vertebrae sacralization, with L5 transverse process completely fused with the sacrum; Type IV: one side presenting as Type II, where there is pseudoarthrosis formation between the L5 transverse process and the sacrum, while the other side is Type III, with complete bony fusion between the L5 transverse process and the sacrum.

1.2 Lumbosacral Transitional Vertebra and Clinically Relevant Diseases

The association between lumbosacral transitional vertebra (LSTV) and lower back pain is controversial (Konin GP & Walz DM, 2010). The earliest report on symptomatic LSTV was by Bertolotti in 1917. The presence of transitional vertebra leads to biomechanical changes in the corresponding segment, accelerating degeneration of adjacent vertebrae, intervertebral discs, and facet joints, causing persistent lower back pain, sciatica, and other related symptoms. The reasons for this may include: (1) secondary degenerative changes in adjacent upper vertebral discs or posterior column structures due to lumbosacral transitional vertebra; (2) osteoarthritis occurring in the pseudoarthrosis formed by the transverse process of the transitional vertebra (Kanematsu R, Hanakita J, Takahashi T, Minami M, Tomita Y & Honda F, 2020); (3) enlargement of the transverse process leading to narrowing of the extraforaminal area, compressing the corresponding spinal nerve root exit and causing sciatica (Akbar JJ, Weiss KL, Saafir MA & Weiss JL, 2010). Lumbosacral transitional vertebra with accompanying clinical symptoms is relatively common among young people and can be misdiagnosed as lumbar spinal stenosis or lumbar disc herniation, leading to inappropriate surgical treatment. Treatment options for lumbosacral transitional vertebra syndrome include block therapy, radiofrequency ablation, endoscopic resection of enlarged transverse processes, and decompression of nerve root canals, all of which have shown good clinical results in reported cases. Therefore, the presence of transitional vertebra directly affects the choice of clinical treatment plans. Numerous studies currently suggest an association between LSTV and lower back pain, intervertebral disc degeneration, and neuropathy (Apaydin M, Uluc ME & Sezgin G, 2019). However, some authors have reported no association between LSTV and lower back pain (Nakagawa T, Hashimoto K, Tsubakino T, Hoshikawa T, Inawashiro T & Tanaka Y, 2017; Tini PG, Wieser C & Zinn WM, 1977; Luoma K, Vehmas T, Raininko R, Luukkonen R & Riihimäki H, 2004).

2. Research Progress on the Spine-Pelvis-Hip Complex

2.1 The Impact of the Spine-Pelvis-Hip Complex on the Sagittal Plane Balance of the Human Body

The spine-pelvis complex plays an important role in maintaining axial skeletal stability and is one of the core structures of the human body. Sagittal plane balance of the spine is crucial for human health (Thiong JMM, Berthonnaud É, Dimar JR, Betz RR & Labelle H, 2004). The Lumbo-Pelvic-Hip Complex (LPHC) connects the lower limbs and upper limbs, and the stability of the LPHC is defined as the ability to control the position of the trunk on the pelvis to achieve continuous energy transmission and transfer. Clinically, instability of the LPHC can lead to increased hip internal rotation and flexion, ultimately causing external rotation of the knee joint (Ben Kibler W, Press J & Sciascia A, 2006). Currently used clinical parameters for the sagittal plane alignment of the spine-pelvis include pelvic incidence (PI), pelvic tilt (PT), and sacral slope (SS), which are geometrically related as PI = SS + PT. PI refers to the angle between the line connecting the center of the femoral head to the midpoint of the upper endplate of S1 and the vertical line passing through that point; PT is the angle between the line from the center of the femoral head to the midpoint of the upper endplate of S1 and the vertical line; while SS represents the angle between the tangent line of the upper endplate of S1 and the horizontal line.

The classification of sagittal balance of the spine is mainly based on the value of sacral slope (SS), as defined by Berthonnaud and Roussouly et al. (Berthonnaud E, Dimnet JS, Roussouly P & Labelle H, 2005). Scholars have divided the sagittal alignment of the spine into four different types: Type 1, SS < 35°, with almost no lumbar lordosis, low apex position near L5, the main part of the curve is an anterior convexity with a short and small convexity, and a transition to a posterior convexity at the thoracolumbar junction. The thoracic spine's long posterior convexity is incongruent with the short anterior convexity of the lumbar spine. Type 2, SS < 35°, with a small lower curve, long and flat lumbar lordosis close to a straight line. The thoracic spine has a small posterior convexity that is consistent with the anterior convexity of the lumbar spine. Type 3, 35° < SS < 45°, with the apex of the anterior convexity at L4, the transition point between anterior and posterior convexities at the thoracolumbar junction, representing a standard sagittal alignment curve. Type 4, SS > 45°, with a noticeably increased curvature of the lower curve, more vertebral bodies contributing to the lower curve, increased length and curvature of the lumbar lordosis, and a corresponding increase in thoracic posterior convexity, representing an overly curved coordinated state. A normal lumbar-pelvic shape curve helps maintain optimal balance in the body and reduces energy consumption. Once there is a change in the sagittal alignment of the spine-pelvis complex, this balance will be disrupted, causing the lumbar spine to lose balance in the sagittal plane and increasing energy consumption, thereby accelerating degenerative changes in the lumbar spine. Previous studies have shown that patients with spinal deformities and degenerative lumbar diseases exhibit varying degrees of changes in the spine-pelvis sagittal alignment. When transitioning from a standing position to a sitting position, the pelvis tilts backward and the hip joints flex to avoid collision or dislocation of the hip socket in front (Riviere C, Hardijzer A, Lazennec JY, Beaule P, Muirhead-Allwood S & Cobb J, 2017). However, once there is a change in the force line of the spine and pelvis in the sagittal plane, this balance will be disrupted. For example, during the transition from standing to sitting, if the degree of pelvic tilt decreases, the compensatory increase in hip joint flexion angle to maintain balance in the sagittal plane can lead to anterior collision between the femur and hip socket (Chavarria JC, Douleh DG & York PJ, 2021). When the spine loses balance in the sagittal plane, it affects the function of the hip joints. When one anatomical structure is abnormal, another anatomical structure will initiate a vicious compensatory mechanism, referred to as hip-spine syndrome or spine-hip syndrome, depending on whether the anatomical abnormality first appears in the spine-pelvis complex or the hip joint (Riviere C, Lazic S, Dagneaux L, Van der Straeten C, Cobb J & Muirhead-Allwood S, 2018).

Secondary spine-hip syndrome refers to the pathological changes in one area that can lead to or exacerbate pathological changes in another area. In 1983, scholars such as Offerski and MacNab introduced the term "spine-hip syndrome" to describe the clinical manifestations of degenerative diseases occurring simultaneously in the hip joint and spine, suggesting the possible interrelated pathological changes between the spine and hip joint (Offierski CM & MacNab I, 1983). In 2012, Lee and colleagues found that among patients over 50 undergoing spinal surgery, 32.5% experienced concurrent hip joint pathology (Lee BH, Moon SH, Lee HM, Kim TH & Lee SJ, 2012). Saunders conducted a cohort study investigating 75 patients with lower back pain symptoms and found that compared to the control group, these patients were more likely to be diagnosed with hip joint osteoarthritis on imaging (Saunders WA, Gleeson JA, Timlin DM, Preston TD & Brewerton DA, 1979). In recent years, the impact of spine-hip syndrome on total hip arthroplasty has been widely discussed. Research findings indicate that decreased mobility of the spine-pelvic complex increases the risk of prosthetic impingement and dislocation after total hip arthroplasty (Redmond JM, Gupta A, Hammarstedt JE, Stake CE & Domb BG, 2014). This syndrome is applicable to elderly patients with osteoarthritis, and recent studies have also found that young people without osteoarthritis may be affected by it, such as femoroacetabular impingement syndrome, ischiofemoral impingement syndrome, and other diseases that limit hip joint mobility, leading to increased load-bearing capacity and reduced mobility in the lumbosacral spine (Hatem M & Martin HD, 2021). Additionally, scholars have identified hip joint osteoarthritis as a strongly correlated predictive factor for spine osteoarthritis, and conversely, spine osteoarthritis is also a strongly correlated predictive factor for hip joint osteoarthritis (Weinberg DS, Gebhart JJ & Liu RW, 2017). Anatomical/structural changes at the lumbosacral-pelvic junction accelerate the progression of osteoarthritis. In conclusion, when clinically related symptoms appear in either the spine-pelvic complex or the hip joint, both structures should be observed simultaneously rather than considered separately.

2.2 The Impact of LSTV on the Spine-Pelvis-Hip Complex

The curvature of the spine-pelvis complex is more rigid and has a smaller range of motion; correspondingly, there is less posterior pelvic tilt and an increased compensatory angle of hip flexion. In contrast, when the curvature of the spine-pelvis complex is more curved and has a larger range of motion, there is an increased posterior pelvic tilt and a decreased compensatory angle of hip flexion. In elderly patients, due to spinal aging leading to decreased lumbar lordosis, the pelvis tilts backward in the standing position. To achieve sagittal plane balance, the body compensates by flexing the hips and knees. The presence of lumbosacral transition vertebrae has similar effects on load-bearing of the hip joint and physiological changes. When there is a missing vertebral body in the lumbosacral transitional vertebrae (LSTV), causing lumbarization of the sacrum, the spine-pelvis morphological curve becomes straighter, the posterior pelvic tilt decreases, leading to a larger compensatory angle of hip flexion. Conversely, when there is an additional vertebral body in the LSTV, causing sacralization of the lumbar vertebra, the spine-pelvis morphological curve becomes more curved, the posterior pelvic tilt increases, and there is a smaller compensatory angle of hip flexion. Research by Kyrölä et al. found that compared to the normal five lumbar vertebrae group, the radiographic spinal-pelvic parameters of PI (pelvic incidence), PT (pelvic tilt), and LL (lumbar lordosis) were significantly higher in the group with six lumbar vertebrae variations (Kyrola K, Kautiainen H, Ylinen J, Lehtola R, Kiviranta I & Hakkinen A, 2019). Abola et al. found through lateral X-ray screening of cadaveric specimens that the PI was 38.5° for specimens with four lumbar vertebrae, while it was 46.7° and 47.1° for specimens with five and six lumbar vertebrae, respectively (Abola MV, Teplensky JR, Cooperman DR, Bauer JM & Liu RW, 2019). LSTV subtypes can lead to corresponding changes in spinal curvature at the lumbosacral junction to adapt to biomechanical loading capacity and enhance spinal stability, thereby affecting changes in pelvic parameters. A comparison revealed significant anatomical differences in the spinal-pelvic structure between the LSTV group and the normal control group, which may also influence the interaction between the pelvis and lumbar spine. Ifthekar found in their study that the spinal-pelvic parameters of patients with chronic low back pain and spinal abnormalities underwent substantial changes (Ifthekar S, Yadav G, Ahuja K, Mittal S, P Venkata S & Kandwal P, 2022). The progression of degenerative spinal diseases is influenced by the spine-pelvis factors and pelvic shape. In a retrospective analysis of 3855 abdominal CT scans, the presence of LSTV was found to affect the distribution of degenerative segments in the spine (Hanhivaara J, Maatta JH, Niinimaki J & Nevalainen MT, 2020). For example, degeneration is common at the L4/5 level but less common at L5/S1. Furthermore, in patients with Castellvi type II, the prevalence of disc and facet joint degeneration is higher. It can be seen that LSTV not only affects the transitional vertebra but is also related to degeneration in the segments above the lumbar spine. Previous studies have mainly focused on the correlation between lumbar spine degeneration and LSTV, limited to the transitional vertebra and the vertebra above it. This suggests that LSTV may accelerate the degeneration of the vertebra above it, while relatively protecting the transitional vertebra. This is because when a segment of the spine is fixed, the mobility of other segments increases, thereby accelerating their degeneration process. This is similar to the accelerated disc degeneration that occurs after vertebral body shaping surgery. Therefore, when evaluating each segment from L1 to L5, considering their interdependence and indispensable relationship within the entire lumbar spine motion loop is more meaningful.

The latest research explored the influence of Lumbosacral Transitional Vertebrae (LSTV) on patients with Developmental Dysplasia of the Hip (DDH). The results indicated that compared to patients with only DDH, those with both DDH and LSTV had a higher rate of posterior coverage of the femoral head. To avoid insufficient anterior coverage, patients with both DDH and LSTV and a widely tilted acetabulum may adopt a more pronounced forward-leaning posture, which may be accompanied by a significant posterior wall sign (Becker L, Hipfl C, Schoemig F, Perka C, Hardt S, Pumberger M, et al, 2023). Heaps and other scholars proposed that despite sufficient research on the relationship between spinal diseases and the postoperative efficacy of hip arthroplasty, little is known about the impact of spinal pathological changes on the results of hip arthroscopy (HA). Through retrospective analysis and the collection of reports from 62 LSTV patients who underwent total hip arthroplasty, the results were compared with a control group, revealing that the benefits of total hip arthroplasty in LSTV patients were more limited compared to patients without LSTV. Therefore, it is recommended to conduct a detailed evaluation of transitional vertebral anomalies in LSTV patients when considering surgical consultation and management expectations to provide guidance.

Becker and others were the first to study the segmental distribution of lumbar spine activity in LSTV patients using flexion and extension X-rays. Compared to the L5/S1 segment of the control group, LSTV patients exhibited significantly reduced motion in the transitional segment but a significantly increased distribution of motion in the adjacent upper segments (Becker L, Schoennagel L, Mihalache TV, Haffer H, Schoemig F, Schmidt H, et al, 2022). These changes may be attributed to anatomical differences in the iliolumbar ligament and compensatory relative motion increase due to decreased activity in LSTV. Additionally, the overall range of lumbar spine activity may also affect this effect. Verhaegen and other scholars measured pelvic-spinal-related parameters, hip flexion range, and lumbar spine activity in sitting and standing positions through X-ray imaging of LSTV patients and healthy volunteers. The study results showed that degenerative changes in adjacent lumbar spine segments in LSTV patients were more likely due to increased lumbar lordosis in the standing position, rather than compensatory movements within these segments (Verhaegen JCF, Alves Batista N, Horton I, Rakhra K, Beaule PE, Michielsen J, et al, 2023). Furthermore, when stiffness occurred at the L5-S1 segment, compensation mainly occurred at the L1-L2 segment rather than the L4-L5 segment. Individuals with LSTV had a greater standing lumbar lordosis, and compensatory mechanisms existed at the upper vertebral level, which may make these individuals more prone to degenerative changes at that level. The presence of LSTV had no effect on pelvic and hip joint movement, and compensatory mechanisms existed in the remaining lumbar spine motion segments to maintain normal range of motion.

3. Conclusion

After comprehensive analysis, variation in lumbosacral transitional vertebrae (LSTV) may lead to changes in pelvic-related parameters, thereby affecting the stability and function of the hip joint and potentially increasing the risk of hip joint diseases. LSTV may have a more significant impact on younger individuals, however, as age and weight load increase, it may cause irreversible damage to the hip joint. Therefore, we propose this study to explore the connection between lumbosacral transitional vertebrae and early hip joint pathological changes, and to further enhance awareness of related diseases for early intervention and treatment. However, further in-depth exploration of the mechanisms and clinical impact of lumbosacral transitional vertebrae variation on the hip joint is still needed in clinical practice.

References

Abola MV, Teplensky JR, Cooperman DR, Bauer JM, Liu RW. (2019). Pelvic Incidence in Spines With 4 and 6 Lumbar Vertebrae. *Global Spine Journal, 9*(7), 708-12.

Akbar JJ, Weiss KL, Saafir MA, Weiss JL. (2010). Rapid MRI Detection of Vertebral Numeric Variation. *American Journal of Roentgenology, 195*(2), 465-6.

Apaydin M, Uluc ME, Sezgin G. (2019). Lumbosacral transitional vertebra in the young men population with low back pain:

anatomical considerations and degenerations (transitional vertebra types in the young men population with low back pain). *Radiologia Medica, 124*(5), 375-81.

Apazidis A, Ricart PA, Diefenbach CM, Spivak JM. (2011). The prevalence of transitional vertebrae in the lumbar spine. *Spine Journal, 11*(9), 858-62.

Becker L, Hipfl C, Schoemig F, Perka C, Hardt S, Pumberger M, et al. (2023). The influence of lumbo-sacral transitional vertebrae in developmental dysplasia of the hip: a matched pair analysis. *Scientific Reports, 13*(1).

Becker L, Schoennagel L, Mihalache TV, Haffer H, Schoemig F, Schmidt H, et al. (2022). Lumbosacral transitional vertebrae alter the distribution of lumbar mobility-Preliminary results of a radiographic evaluation. *Plos One, 17*(9).

Ben Kibler W, Press J, Sciascia A. (2006). The role of core stability in athletic function. *Sports Medicine, 36*(3), 189-98.

Berthonnaud E, Dimnet JS, Roussouly P, Labelle H. (2005). Analysis of the sagittal balance of the spine and pelvis using shape and orientation parameters. *Journal of Spinal Disorders & Techniques, 18*(1), 40-7.

Chavarria JC, Douleh DG, York PJ. (2021). The Hip-Spine Challenge. *Journal of Bone and Joint Surgery-American Volume, 103*(19), 1852-60.

Hanhivaara J, Maatta JH, Niinimaki J, Nevalainen MT. (2020). Lumbosacral transitional vertebrae are associated with lumbar degeneration: retrospective evaluation of 3855 consecutive abdominal CT scans. *European Radiology, 30*(6), 3409-16.

Hatem M, Martin HD. (2021). Low Back Pain Improves After Surgery for Lesser Trochanteric-Ischial Impingement. *Arthroscopy-the Journal of Arthroscopic and Related Surgery, 37*(5), 1503-9.

Ifthekar S, Yadav G, Ahuja K, Mittal S, P Venkata S, Kandwal P. (2022). Correlation of spinopelvic parameters with functional outcomes in surgically managed cases of lumbar spinal tuberculosis — A retrospective study. *Journal of clinical orthopaedics and trauma, 26*, 101788.

Kanematsu R, Hanakita J, Takahashi T, Minami M, Tomita Y, Honda F. (2020). Extraforaminal entrapment of the fifth lumbar spinal nerve by nearthrosis in patients with lumbosacral transitional vertebrae. *European Spine Journal, 29*(9), 2215-21.

Konin GP, Walz DM. (2010). Lumbosacral Transitional Vertebrae: Classification, Imaging Findings, and Clinical Relevance. *American Journal of Neuroradiology, 31*(10), 1778-86.

Kyrola K, Kautiainen H, Ylinen J, Lehtola R, Kiviranta I, Hakkinen A. (2019). Spinopelvic Parameters and Sagittal Alignment of Symptomatic Degenerative Adult Spinal Disorder Patients With 6 Lumbar Vertebrae. *Clinical Spine Surgery, 32*(1), E43-E9.

Lee BH, Moon SH, Lee HM, Kim TH, Lee SJ. (2012). Prevalence of hip pathology in patients over age 50 with spinal conditions requiring surgery. *Indian Journal of Orthopaedics, 46*(3), 291-6.

Luoma K, Vehmas T, Raininko R, Luukkonen R, Riihimäki H. (2004). Lumbosacral transitional vertebra: Relation to disc degeneration and low back pain. *Spine, 29*(2), 200-5.

Nakagawa T, Hashimoto K, Tsubakino T, Hoshikawa T, Inawashiro T, Tanaka Y. (2017). Lumbosacral Transitional Vertebrae Cause Spinal Level Misconception in Surgeries for Degenerative Lumbar Spine Disorders. *Tohoku Journal of Experimental Medicine, 242*(3), 223-8.

Nevalainen MT, McCarthy E, Morrison WB, Zoga AC, Roedl JB. (2018). Lumbosacral transitional vertebrae: significance of local bone marrow edema at the transverse processes. *Skeletal Radiology, 47*(8), 1145-9.

Offierski CM, MacNab I. (1983). Hip-spine syndrome. *Spine, 8*(3), 316-21.

Redmond JM, Gupta A, Hammarstedt JE, Stake CE, Domb BG. (2014). The Hip-Spine Syndrome: How Does Back Pain Impact the Indications and Outcomes of Hip Arthroscopy? *Arthroscopy — The Journal of Arthroscopic and Related Surgery, 30*(7), 872-81.

Riviere C, Hardijzer A, Lazennec JY, Beaule P, Muirhead-Allwood S, Cobb J. (2017). Spine-hip relations add understandings to the pathophysiology of femoro-acetabular impingement: A systematic review. *Orthopaedics & Traumatology-Surgery & Research, 103*(4), 549-57.

Riviere C, Lazic S, Dagneaux L, Van der Straeten C, Cobb J, Muirhead-Allwood S. (2018). Spine-hip relations in patients with hip osteoarthritis. *Efort Open Reviews, 3*(2), 39-44.

Saunders WA, Gleeson JA, Timlin DM, Preston TD, Brewerton DA. (1979). Degenerative joint disease in the hip and spine. *Rheumatology and rehabilitation, 18*(3), 137-41.

Thiong JMM, Berthonnaud É, Dimar JR, Betz RR, Labelle H. (2004). Sagittal alignment of the spine and pelvis during growth. *Spine, 29*(15), 1642-7.

Tini PG, Wieser C, Zinn WM. (1977). The transitional vertebra of the lumbosacral spine: its radiological classification, incidence, prevalence, and clinical significance. *Rheumatology and rehabilitation, 16*(3), 180-5.

Verhaegen JCF, Alves Batista N, Horton I, Rakhra K, Beaule PE, Michielsen J, et al. (2023). Prevalence of Lumbosacral Transitional Vertebral Anomalies Among Healthy Volunteers and Patients with Hip Pathology: Association with Spinopelvic Characteristics. *JB & JS open access, 8*(1).

Weinberg DS, Gebhart JJ, Liu RW. (2017). Hip-spine syndrome: A cadaveric analysis between osteoarthritis of the lumbar spine and hip joints. *Orthopaedics & Traumatology-Surgery & Research, 103*(5), 651-6.