# Utility of Physical Examination Findings for Predicting Low-Back Pain in Adolescent Patients with Early-Stage Spondylolysis: A Retrospective Comparative Cohort Study

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**Abstract:**

**Introduction:** This study aimed to elucidate low-back pain (LBP) characteristics, i.e., its qualities, extent, and location, in patients with early-stage spondylolysis (ESS).

**Methods:** We recruited patients (≤18 years old) who presented with acute LBP lasting up to 1 month. Patients were divided into ESS and nonspecific LBP (NS-LBP) groups based on their magnetic resonance imaging findings; patients showing no pathological findings that might explain the cause of LBP were classified as NS-LBP. All patients were evaluated using the following tests: hyperextension and hyperflexion (pain provocation tests in a standing position), pain quality (sharp/dull), pain extent (fingertip-sized area/palm-sized area), and pain location (left and/or right pain in side [side]/central pain [center]). We have also compared outcomes between the ESS and NS-LBP groups in terms of gender and physical symptoms.

**Results:** Of 101 patients, 53 were determined to have ESS (ESS group: mean age: 14.3 years old; 43 males/10 females), whereas 48 had no pathological findings explaining the LBP origin [NS-LBP group (mean age, 14.4 years old; 31 males/17 females)]. Chi-squared test has identified gender (male), a negative result on hyperflexion test, pain extent (fingertip-sized area), and pain location (side) to be significantly associated with ESS. Among these, regression analysis revealed that male gender and LBP located on the side were significantly associated with ESS ($p<0.05$).

**Conclusions:** Although the hyperextension test is generally considered useful for ESS, we demonstrated that its association is not deemed significant. Our results indicate that male gender, a negative result of the hyperflexion test, fingertip-sized pain area, and LBP on the side may be specific characteristics of ESS. Of these physical signs, male gender and LBP located on the side are characteristic factors suggesting ESS presence.

**Keywords:**
Early-stage spondylolysis, early diagnosis, physical examination, magnetic resonance imaging, acute low-back pain

Spine Surg Relat Res 2021; 5(6): 412-417
dx.doi.org/10.22603/ssrr.2020-0199

## Introduction

Low-back pain (LBP) has been found to be common among children and adolescents[1)]. As with most other athletic injuries, those involving the LBP can occur due to trauma or overuse. Fatigue fractures of the pars interarticularis often result from repetitive hyperextension in active young people[2)]. The pathogenesis of spondylolysis is considered to be fatigue fractures as per clinical observations[3-6)]. Kobayashi et al. reported that stress fractures in this context constitute early-stage spondylolysis (ESS)[7)].

The progression of ESS to non-union has been associated with an increased incidence of spondylolisthesis and degeneration of the lumbar discs[8,9)]. There have been several re-

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Received: November 1, 2020, Accepted: January 27, 2021, Advance Publication: March 10, 2021

ports indicating that young athletes with spondylolysis or spondylolisthesis are at a higher risk of LBP than those with no abnormal radiographic findings[10-12]. Early recognition of ESS is associated with improved fracture healing[13-15], and patients with ESS are good candidates for conservative treatment with a hard brace[16].

Sairyo et al. reported that if ESS is treated in the early stage, the healing rate can be significantly high. However, it has been reported that over 70% of patients with bilateral spondylolysis experience some degree of forward slippage, which may require surgical treatment[17].

Diagnosing ESS has been deemed difficult using plain radiography alone[18,19], even when the oblique view is examined. Recent studies have reported bone scintigraphy, single-photon emission computed tomography, and magnetic resonance imaging (MRI) to be useful for the early diagnosis of ESS[13,15,20-23]. Among these imaging modalities, MRI offer a number of advantages including reduced radiation exposure, which is important because ESS mainly occurs during growth periods[24,25]. However, because of its high cost, MRI is not available for all adolescent patients who present with LBP. In addition, most patients with ESS have previously engaged in sporting activities; therefore, a doctor is not always consulted immediately.

For these reasons, determining validated physical signs of ESS would enable diagnosis of ESS with the requirement for imaging examinations. The differential diagnosis of back pain can be complex in athletically active children or adolescents. Previously, we have reported that adolescent patients with ESS exhibited significantly greater pain intensity while in motion compared with standing or sitting, using the visual analog scale[26,27].

Clinical features of ESS that have been previously described in the literature do not enable differentiation of this condition from other causes of LBP[12,28]; currently, there are no validated examination findings for ESS[29,30]. The only reported pathognomonic finding is reproduction of pain through the one-legged hyperextension test[31,32], in which the pain upon hyperextension is most pronounced unilaterally in the paraspinous area. However, a study by Masci et al. has denied the usefulness of the one-legged hyperextension test[23].

Clinically, we have observed that patients with both ESS and nonspecific LBP (NS-LBP) experience LBP, but patients with ESS experience localized, sharp LBP on the side upon lumbar spine hyperextension in a standing position. However, there has been no data published to date supporting this observation. Thus, in this study, we hypothesize that these physical signs might be important indicators in differentiating between ESS and NS-LBP adolescent patients. The aim of this study was to evaluate the clinical features of ESS in terms of gender and its physical symptoms, i.e., the quality, extent, and location of LBP.

## Materials and Methods

For this present study, we recruited adolescent patients aged ≤18 years who presented at our clinic for rehabilitation between September 2012 and September 2013 within 1 month of acute LBP but had no pathological findings detected by plain radiography. Exclusion criteria were as follows: lower extremity symptoms (to exclude the possibility of radicular back pain), clear spondylolysis or spondylolisthesis based on plain radiography findings, and other spinal disorders based on MRI findings (detailed below). All patients provided informed consent. The study protocol was approved by the Institutional Review Board.

All patients underwent MRI examination. Six images were recorded for each patient with the following MRI sequence: sagittal view of the lumbar spine with (1) T2-weighted images and (2) T1-weighted images; coronal view with (3) fat-saturation T2-weighted images; axial view with (4) T2-weighted images, (5) T1-weighted images, and (6) fat-saturation T2-weighted images. This protocol enabled diagnosis of ESS as well as other spinal disorders such as herniation, disc degeneration (grade IV or above according to Pfirrmann classification), vertebral fractures, tumors, and infectious diseases. The diagnosis of ESS was made when the lumbar spine pedicle showed high signal intensity on fat-saturation T2-weighted images and low signal intensity on T 1-weighted images, according to a previous study (Fig. 1)[15].

Patients were then classified into two groups on the basis of MRI results: the ESS group and the NS-LBP group.

### *Evaluation of LBP*

We evaluated LBP on the following five factors: (1) presence or absence of LBP during lumbar spine extension in a standing position (the hyperextension test), (2) presence or absence of LBP during lumbar spine flexion in a standing position (the hyperflexion test), (3) pain quality (sharp or dull), (4) pain extent (categorized as a fingertip-sized or palm-sized area), and (5) pain location (pain on the left and/or right side or central pain center). The pain location was considered as "side" for those patients who experienced LBP on both sides without central LBP. The physical therapist at our clinic created a checklist with the abovementioned test items and evaluated patients according to these items. In addition, a lecture on the testing method was then conducted, and the evaluation method was standardized among physical therapists.

### *Statistical analysis*

Data are presented as mean (range) or number (%). We tested the sensitivity and specificity of gender and each finding of the physical examination. The chi-squared test was used to compare data in terms of gender, participation in sports activities, and each physical examination findings between the ESS and NS-LBP groups; $p<0.05$ was regarded as statistically significant. Logistic regression analysis was performed as well. All statistical analyses were performed using

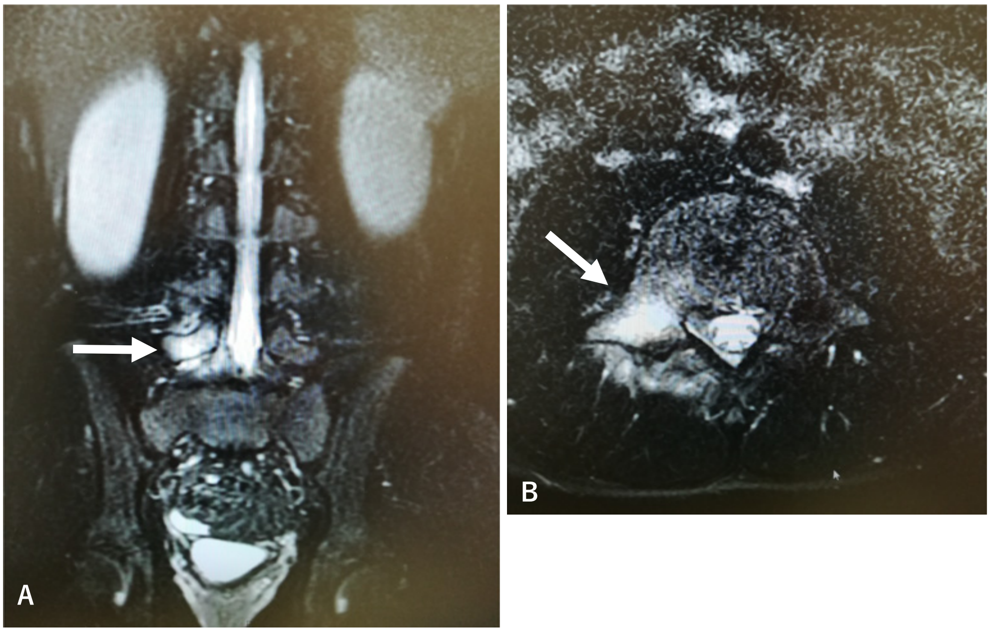


**Figure 1.** Fat-saturation T2-weighted magnetic resonance image of the lumbar spine of a 13-year-old male athlete. (A) Coronal view shows high signal intensity in the right L5 pedicle (arrow). (B) Axial slice shows high signal intensity in the right pedicle (arrow). The high signal intensity areas are indicative of early-stage spondylolysis.

IBM SPSS software version 23.

***Role of the funding source***

The funders played no role in the design, conduct, or reporting of this study.

## Results

In total, 101 patients with a mean age of 14.4 (10-18) years were enrolled for analysis (74 males/27 females). As per the MRI findings, 53 patients (52.5%) were categorized into the ESS group, with a mean age of 14.3 years. The mean age of the NS-LBP group was 14.4 years.

The sensitivity and specificity for ESS were determined to be as follows: gender (male), 81% and 35%; hyperextension test (positive), 79% and 9%; hyperflexion test (negative), 51% and 79%; pain quality (sharp), 73% and 47%; pain extent (fingertip-sized), 58% and 72%; and pain location (side), 89% and 63%, respectively (Table 1).

The chi-squared test showed gender (male), results of the hyperflexion test (negative), pain extent (fingertip-sized area), and pain location (side) to be significantly different between the two groups (Table 2). Logistic regression analysis revealed only male gender and pain location were found to be significantly associated with ESS (Table 3).

The affected vertebral levels were L2, L3, L4, L5, and both L3 and L5 in 1, 5, 19, 27, and 1 patients, respectively. As per our MRI findings, bilateral active spondylolysis was detected in 15 patients, while unilateral active spondylolysis was determined in 38 patients. Among the unilateral lesions, 16 and 22 were found on the left and right sides, respectively (one patient had multiple-level unilateral spondylolysis at L3 and L5).

**Table 1.** Sensitivity and Specificity of Each Factor in Diagnosing Early Stage Spondylolysis.

| | Sensitivity | Specificity |
|---|---|---|
| Gender (male) | 0.81 | 0.35 |
| *Hyperextension (positive) | 0.79 | 0.09 |
| *Hyperflexion (positive) | 0.49 | 0.21 |
| *Pain quality (sharp) | 0.73 | 0.47 |
| *Pain extent (fingertip sized) | 0.58 | 0.72 |
| *Pain location (side) | 0.89 | 0.63 |

*There were several patients with missing data.

## Discussion

ESS has been identified to be a common cause of LBP in adolescent athletes[33]. On the basis of clinical appearances, the pathogenesis of lumbar spondylolysis is considered to be a stress fracture[3,34,35]. Therefore, early diagnosis of ESS is essential in order for conservative treatment to be successful[35]. It has been reported that MRI can provide important information for the early detection of ESS[13,36]; however, it is difficult to differentiate ESS from other low-back disorders without radiological examination[7,15].

This present study investigated the physical signs which might be predictive of ESS without the need for MRI examination. Jackson et al. reported that typical young athletes with ESS exhibit aching, usually unilateral, LBP, which is exacerbated by motion such as hyperextension[31]. Our results were consistent with their findings, in that unilateral LBP was observed in the patients with ESS in this study. How-

**Table 2.** Comparison of Characteristics Associated with Early Stage Spondylolysis and Nonspecific Low-back Pain.

| | ESS (n=53) | NS-LBP (n=48) | p value |
|---|---|---|---|
| Gender (male/female) | 43/10 | 31/17 | p=0.061 |
| *Participation in sports activities (participation/no participation) | 53/0 | 45/2 | n.s. |
| *Hyperextension (positive/negative) | 41/11 | 43/4 | n.s. |
| *Hyperflexion (positive/negative) | 25/26 | 37/10 | p<0.01 |
| *Pain quality (sharp/dull) | 32/12 | 20/18 | p=0.06 |
| *Pain extent (fingertip/palm) | 29/21 | 13/33 | p<0.01 |
| *Pain location (side/center) | 47/6 | 17/29 | p<0.01 |

Data are shown as number.
Abbreviations: ESS, early stage spondylolysis; NS-LBP, nonspecific low-back pain; n.s., not significant
p values were calculated using the Chi-square test.
*There were several patients with missing data.

**Table 3.** Multivariate Logistic Regression Analysis for Predictors of Clinically Relevant in Early Stage Spondylolysis.

| Variable | Odds Ratio | 95% CI | p value |
|---|---|---|---|
| Gender (male/female) | 4.053 | 1.056–15.554 | p<0.05 |
| Pain quality (sharp/dull) | 2.047 | 0.549–7.639 | n.s. |
| Pain extent (fingertip/palm) | 2.99 | 0.901–9.921 | n.s. |
| Pain location (side/center) | 7.9 | 2.205–28.309 | p<0.01 |
| Hyperflexion test (positive/negative) | 2.574 | 0.777–8.525 | n.s. |
| Hyperextension (positive/negative) | 2.451 | 0.392–15.324 | n.s. |

Abbreviations: CI, Confidence interval; n.s., no significant difference

ever, we found that hyperextension test tended to be positive in NS-LBP patients as well as in ESS patients. Kobayashi et al. suggested that the hyperextension, hyperflexion, Kemp, and percussion of the vertebral spinous process tests were not clinically useful for the diagnosis for ESS[7]. In addition, Jackson et al. reported that the one-legged hyperextension test usually provokes LBP on the ipsilateral side and is useful as a diagnostic tool for spondylolysis[31].

Previous studies have not examined the validity of the one-legged hyperextension test, although Masci et al. reported this test to have insufficient sensitivity and specificity for the diagnosis of ESS[23]. For these reasons, in combination with the results of this present study, we suggest that the hyperextension test is not useful for the differential diagnosis of ESS. Therefore, to evaluate LBP, we believe it is important to consider not only the hyperextension test but also other physical findings.

We found a negative association of the flexion test with ESS in this present study. Tonosu et al. reported that LBP experienced while washing one's face and while in a standing position with flexion are useful characteristics for the diagnosis of discogenic LBP associated with degenerative disc disease[37]. This may explain why the flexion test was negative in patients with ESS in this study, which further suggests that the diagnosis of ESS should be considered when the flexion test is negative.

It is interesting to note that, in this present study, patients in the ESS group had LBP on the side covering a fingertip-sized area. Joseph et al. reported that the one-finger test could be an accurate clinical diagnostic test for sacroiliac joint dysfunction[38], while Jackson et al. reported that localized pain over 2-3-cm diameter area was experienced by patients with ESS[31]. However, there has been no formal study validating pain area as a diagnostic tool. Smart KM et al. reported that pain localized to the area of injury/dysfunction is associated with the clinical classification of nociceptive pain[39]. The results of these studies, and the fact that ESS comprises fatigue fracture of the pars interarticularis as a result of repeated trauma[6], may explain why patients with ESS in this present study reported fingertip-sized pain areas.

We identified gender as a significant factor of ESS, consistent with the study of Kobayashi et al., who reported that significantly more adolescent boys developed ESS than adolescent girls[7]. These boys participated in baseball and soccer, which require repetitive extension or rotation motion of the lumbar spine; thus, the authors suggested that the reason for the increase prevalence of ESS among boys compared with girls was due to the difference in sporting activities.

There are various limitations in this study. First, because this was a retrospective study, we could not examine asymptomatic subjects. Because ESS is fatigue fracture of pars, there is a possibility of asymptomatic patients in the early stage. Second, we could not confirm the patients' psychosocial status in this study. Third, this current study did not assess inter-examiner reliability for back pain assessment. To confirm these factors, further prospective investigation is needed.

In conclusion, our study demonstrates that adolescent patients with ESS are more likely to be male, have a negative result on the hyperflexion test, and experience side LBP over a fingertip-sized area. In addition, among these physical signs, male gender and LBP on the side are characteristic factors that suggest the presence of ESS by logistic regression analysis. In contrast, patients with NS-LBP are more likely to experience central LBP covering a palm-sized area and have a positive result on the hyperflexion test. Patients with both ESS and NS-LBP may show a positive hyperextension test, which suggests that this test does not provide characteristic results for patients with ESS. Because early diagnosis is essential for the successful treatment of lumbar spondylolysis, MRI examination is recommended for adolescent patients presenting with side LBP covering a fingertip-sized area who have a negative result on the hyperflexion test.

**Conflicts of Interest:** The authors declares that there are no relevant conflicts of interest.

**Sources of Funding:** None

**Ethical Approval:** The study protocol was approved by the Institutional Review Board (Eastern Chiba Medical Center, Chiba, Japan, Approval number 48). All patients provided informed consent.

## References

1. Burton AK, Clarke RD, McClune TD, et al. The natural history of low back pain in adolescents. Spine. 1996;21(20):2323-8.
2. Blanda J, Bethem D, Moats W, et al. Defects of pars interarticularis in athletes: a protocol for nonoperative treatment. J Spinal Disord. 1993;6(5):406-11.
3. Cyron BM, Hutton WC. The fatigue strength of the lumbar neural arch in spondylolysis. J Bone Joint Surg Br. 1978;60-B(2):234-8.
4. Sairyo K, Katoh S, Sakamaki T, et al. Three successive stress fractures at the same vertebral level in an adolescent baseball player. Am J Sports Med. 2003;31(4):606-10.
5. Sairyo K, Katoh S, Sasa T, et al. Athletes with unilateral spondylolysis are at risk of stress fracture at the contralateral pedicle and pars interarticularis: a clinical and biomechanical study. Am J Sports Med. 2005;33(4):583-90.
6. Wiltse LL, Widell EH Jr, Jackson DW. Fatigue fracture: the basic lesion is inthmic spondylolisthesis. J Bone Joint Surg. 1975;57(1):17-22.
7. Kobayashi A, Kobayashi T, Kato K, et al. Diagnosis of radiographically occult lumbar spondylolysis in young athletes by magnetic resonance imaging. Am J Sports Med. 2013;41(1):169-76.
8. Frennered AK, Danielson BI, Nachemson AL. Natural history of symptomatic isthmic low-grade spondylolisthesis in children and adolescents: a seven-year follow-up study. J Pediatr Orthop. 1991;11(2):209-13.
9. Muschik M, Hähnel H, Robinson PN, et al. Competitive sports and the progression of spondylolisthesis. J Pediatr Orthop. 1996;16(3):364-9.
10. Iwamoto J, Abe H, Tsukimura Y, et al. Relationship between radiographic abnormalities of lumbar spine and incidence of low back pain in high school and college football players: a prospective study. Am J Sports Med. 2004;32(3):781-6.
11. Iwamoto J, Abe H, Tsukimura Y, et al. Relationship between radiographic abnormalities of lumbar spine and incidence of low back pain in high school rugby players: a prospective study. Scand J Med Sci Sports. 2005;15(3):163-8.
12. Micheli LJ, Wood R. Back pain in young athletes. Significant differences from adults in causes and patterns. Arch Pediatr Adolesc Med. 1995;149(1):15-8.
13. Fujii K, Katoh S, Sairyo K, et al. Union of defects in the pars interarticularis of the lumbar spine in children and adolescents. The radiological outcome after conservative treatment. J Bone Joint Surg Br. 2004;86(2):225-31.
14. Leone A, Cianfoni A, Cerase A, et al. Lumbar spondylolysis: a review. Skelet Radiol. 2011;40(6):683-700.
15. Sairyo K, Katoh S, Takata Y, et al. MRI signal changes of the pedicle as an indicator for early diagnosis of spondylolysis in children and adolescents: a clinical and biomechanical study. Spine. 2006;31(2):206-11.
16. Sairyo K, Sakai T, Yasui N, et al. Conservative treatment for pediatric lumbar spondylolysis to achieve bone healing using a hard brace: what type and how long?: clinical article. J Neurosurg Spine. 2012;16(6):610-4.
17. Harvey CJ, Richenberg JL, Saifuddin A, et al. The radiological investigation of lumbar spondylolysis. Clin Rad. 1998;53(10):723-8.
18. Papanicolaou N, Wilkinson RH, Emans JB, et al. Bone scintigraphy and radiography in young athletes with low back pain. AJR Am J Roentgenol. 1985;145(5):1039-44.
19. Bhatia NN, Chow G, Timon SJ, et al. Diagnostic modalities for the evaluation of pediatric back pain: a prospective study. J Pediatr Orthop. 2008;28(2):230-3.
20. Campbell RS, Grainger AJ, Hide IG, et al. Juvenile spondylolysis: a comparative analysis of CT, SPECT and MRI. Skelet Radiol. 2005;34(2):63-73.
21. Elliott S, Hutson MA, Wastie ML. Bone scintigraphy in the assessment of spondylolysis in patients attending a sports injury clinic. Clin Rad. 1988;39(3):269-72.
22. Itoh K, Hashimoto T, Shigenobu K, et al. Bone SPET of symptomatic lumbar spondylolysis. Nucl Med Commun. 1996;17(5):389-96.
23. Masci L, Pike J, Malara F, et al. Use of the one-legged hyperextension test and magnetic resonance imaging in the diagnosis of active spondylolysis. Br J Sports Med. 2006;40(11):940-6; discussion 946.
24. Brooks BK, Southam SL, Mlady GW, et al. Lumbar spine spondylolysis in the adult population: using computed tomography to evaluate the possibility of adult onset lumbar spondylosis as a cause of back pain. Skelet Radiol. 2010;39(7):669-73.
25. Fredrickson BE, Baker D, McHolick WJ, et al. The natural history of spondylolysis and spondylolisthesis. Bone Joint Surg Am. 1984;66(5):699-707.
26. Aoki Y, Sugiura S, Nakagawa K, et al. Evaluation of nonspecific low back pain using a new detailed visual analogue scale for patients in motion, standing, and sitting: characterizing nonspecific low back pain in elderly patients. Pain Res Treat. 2012;2012:680496.
27. Sugiura S, Aoki Y, Toyooka T, et al. Characteristics of low back pain in adolescent patients with early-stage spondylolysis evaluated using a detailed visual analogue scale. Spine. 2015;40(1):E29-34.
28. Ciullo JV, Jackson DW. Pars interarticularis stress reaction, spon-

dylolysis, and spondylolisthesis in gymnasts. Clin Sports Med. 1985;4(1):95-110.

**29.** d'Hemecourt PA, Zurakowski D, Kriemler S, et al. Spondylolysis: returning the athlete to sports participation with brace treatment. Orthopedics. 2002;25(6):653-7.

**30.** Weber MD, Woodall WR. Spondylogenic disorders in gymnasts. J Orthop Sports Phys Ther. 1991;14(1):6-13.

**31.** Jackson DW, Wiltse LL, Dingeman RD, et al. Stress reactions involving the pars interarticularis in young athletes. Am J Sports Med. 1981;9(5):304-12.

**32.** Kraft DE. Low back pain in the adolescent athlete. Pediatr Clin North Am. 2002;49(3):643-53.

**33.** Hollenberg GM, Beattie PF, Meyers SP, et al. Stress reactions of the lumbar pars interarticularis: the development of a new MRI classification system. Spine. 2002;27(2):181-6.

**34.** Letts M, Smallman T, Afanasiev R, et al. Fracture of the pars interarticularis in adolescent athletes: a clinical-biomechanical analysis. J Pediatr Orthop. 1986;6:40-6.

**35.** Morita T, Ikata T, Katoh S, et al. Lumbar spondylolysis in children and adolescents. J Bone Joint Surg Br. 1995;77(4):620-5.

**36.** Yamane T, Yoshida T, Mimatsu K. Early diagnosis of lumbar spondylolysis by MRI. J Bone Joint Surg Br. 1993;75(5):764-8.

**37.** Tonosu J, Inanami H, Oka H, et al. Diagnosing discogenic low back pain associated with degenerative disc disease using a medical interview. Plos One. 2016;11(11):e0166031.

**38.** Fortin JD, Falco FJ. The Fortin finger test: an indicator of sacroiliac pain. Am J Orthop Belle Mead NJ. 1997;26(7):477-80.

**39.** Smart KM, Blake C, Staines A, et al. Mechanisms-based classifications of musculoskeletal pain: Part 2 of 3: symptoms and signs of peripheral neuropathic pain in patients with low back (± leg) pain. Man Ther. 2012;17(4):345-51.