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Original Article

Clinical characteristics of early-stage lumbar spondylolysis detected by magnetic resonance imaging in male adolescent baseball players

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A B S T R A C T

Background: Many adolescent athletes experience low back pain; the most common cause is lumbar spondylolysis. Although early identification of lumbar spondylolysis in adolescent athletes is critical, few studies have focused on identifying the early stages of spondylolysis in baseball players. This study aimed to investigate the clinical characteristics of early-stage spondylolysis in male adolescent baseball players.
Methods: The participants comprised male junior and high school baseball players. Before magnetic resonance imaging, we recorded their demographic data, low back pain characteristics, and physical findings (lumbar flexion, extension, Kemp's test and the provocative tenderness of a spinous process). After the imaging evaluation, the association among low back pain characteristics, physical findings and the final diagnosis (early-stage spondylolysis or not) were investigated using univariate and multivariable analyses.
Results: A total of 171 players were included in this study. Univariate analyses indicated that the characteristics associated with early-stage spondylolysis were longer duration of low back pain ($P = 0.0085$), low back pain-related interference while running ($P = 0.0022$), low back pain starting with laterality ($P = 0.0001$), lumbar extension ($P = 0.022$), positive Kemp's test ($P = 0.020$), and the tenderness of a spinous process ($P = 0.0003$). After adjusting for confounding factors (age and position), we found that early-stage spondylolysis was significantly associated with low back pain duration ≥4 weeks (odds ratio 3.13, 95% confidence interval 1.42–6.92; $P = 0.0048$), low back pain-related interference while running (odds ratio 2.89, 95% confidence interval 1.30–6.46; $P = 0.0094$), low back pain starting with laterality (odds ratio 2.78, 95% confidence interval 1.24–6.27; $P = 0.0133$), and the tenderness of a spinous process (odds ratio 3.00, 95% confidence interval 1.36–6.57; $P = 0.0062$).
Conclusions: Male adolescent baseball players with early-stage spondylolysis might have low back pain duration of more than four weeks, low back pain-related interference while running, and a history of low back pain starting with laterality. The tenderness of a spinous process might be helpful in the diagnosis of early-stage spondylolysis in male adolescent baseball players.

1. Introduction

Low back pain (LBP) is widespread and increasing in prevalence among adolescents [1]. Adolescents show a 1-year prevalence of about 30% and a lifetime prevalence of 40% for LBP [1,2]. Adolescent athletes and non-athletes show comparable frequencies of LBP, although athletes in some sports show greater risk [3,4]. The most prevalent recognized cause of LBP among adolescent athletes is lumbar spondylolysis [5,6], a fatigue fracture of the pars interarticularis resulting from repeated minor traumas due to loading [7]. Adolescent lumbar spondylolysis is categorized into early, progressive, or terminal stages [8]. These stages are defined by the lesion imaging appearance (not the duration of the damage) [8,9]. The best outcome for adolescents with lumbar spondylolysis is

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bone union. Given the considerable links between the stage of lumbar spondylolysis and the likelihood of achieving bone union shown in previous research [7–10], early identification of lumbar spondylolysis is critical to achieve bone union with conservative management in adolescent athletes.

Early-stage spondylolysis (ESS) is challenging to diagnose from routine plain radiographs alone; magnetic resonance imaging (MRI) is more effective for the early detection of spondylolysis [11]. Recent studies have advocated MRI over single-photon emission computed tomography (CT) for detecting spondylolysis [8,11,12]. MRI is also considered safer than conventional radiography and CT, which require radiation exposure. However, due to the high cost of MRI, this option is not available for every adolescent with LBP.

The clinical characteristics of ESS previously documented in the literature, such as pain during the one-legged hyperextension test or LBP that worsens with hyperextension activities, may distinguish ESS from other causes of LBP [5,13,14]. Several investigations, however, have cast doubt on the effectiveness of the one-legged hyperextension test for detecting ESS [15,16]. Sugiura et al. concluded that the hyperextension test was ineffective in detecting ESS and that lateral bending was the most characteristic motion for provoking LBP in patients with ESS [17]. Therriault et al. identified three diagnostic variables most associated with ESS diagnoses: male sex, pain on extension, and the difference between active and resting pain [18]. The clinical characteristics of adolescent athletes best suited for detecting ESS thus remain unclear.

Baseball is a popular sport among adolescents and is reported to show higher incidence of lumbar spondylolysis than other sports [3,6,15]. Previous studies investigating the clinical characteristics of ESS have included adolescent athletes participating in various sports [15–17]; such studies can be generalized, but studies focusing on one sport are more useful in providing specific suggestions. Clarification of specific clinical characteristics of ESS in adolescent baseball players can help diagnose ESS before imaging. This study aimed to investigate the clinical characteristics of ESS in male adolescent baseball players.

2. Methods

2.1. Participants

We prospectively collected clinical and radiological data from male adolescent baseball players (aged 13–18 years) who visited our hospitals and clinics between January 2018 and April 2022 with complaints of LBP. We included consecutive players who underwent MRI to assess LBP. We excluded those with neurological symptoms or findings such as muscle weakness, sensory disturbances, and positive supine straight-leg raising test with reproduction of pain into the lower leg. We also excluded those with a history of lumbar surgery. We also obtained data from medical checkups for male adolescent baseball players to evaluate LBP between January 2021 and January 2022. These medical checkups were open to “students who engaged in a baseball club with formal practice at least twice a week.” The same exclusion criteria were established. All the parents/guardians and participants enrolled between January 2021 and April 2022 provided written informed consent prior to enrolment. Informed consent was obtained by an opt-out option on the website between January 2018 and December 2020. The Research Ethics Committee of our institute approved our study protocol.

2.2. Characteristics of participants

We collected variables including age, school year, playing position, and dominant throwing and hitting sides. Players who had practiced and played as pitchers were considered pitchers, even if they also played other positions.

2.3. Evaluation of ESS on MRI

Each participant underwent MRI. At least four images were acquired for each patient using the following MRI sequences and views of the lumbar spine: (1) sagittal T2-weighted images, (2) sagittal short tau inversion recovery (STIR) images, (3) axial T2-weighted images, and (4) axial STIR images. Participants were divided into two groups based on the MRI findings: ESS or non-ESS. ESS was diagnosed when sagittal and axial STIR imaging revealed signal hyperintensity in the lumbar spine pedicle, as reported previously [8] (Fig. 1). A systematic review recommended that MRI should be used in early diagnosis of pediatric lumbar spondylolysis, and the average sensitivity and kappa value of MRI with CT as the gold standard was 81.4% and 0.83, respectively [19]. Signal hyperintensity in the lumbar spine pedicle on MRI might be positive in elite junior athletes, even asymptomatic; specificity of MRI was reported as 0.54 [20]. To assess intra/inter-observer reliability, two board-certified orthopedic surgeons (the first and third authors) conducted independent assessments twice one week apart [21]. Thirty participants were randomly chosen for kappa value analysis. Intra- and inter-observer reliabilities for the evaluation of ESS were 1.00 and 0.97, respectively, and were considered excellent. Finally, one board-certified orthopedic surgeon (the third author) examined all MRI images while being blinded to participant information, including symptoms. Patients who had clear end-stage spondylolysis or spondylolisthesis detected by lumbar plain radiography or CT were excluded from the non-ESS group.

2.4. Evaluation of LBP characteristics

Previous and present LBP episodes were measured using a review of the medical record or the self-completed questionnaire in medical checkups. Previous episodes of LBP were assessed using the following question: “Have you ever felt pain in your low back?” (0 = “no”; 1 = “yes”). Present episodes of LBP were assessed using the following question: “Do you currently feel pain in your lower back?” (0 = “not at all”; 1 = “I felt low back pain for less than 1 week”; 2 = “I felt low back pain for 1–4 weeks; 3 = “I felt low back pain for more than 4 weeks”). LBP-related interference with playing baseball was assessed using the following question: “Have you felt pain or discomfort in your low back while playing baseball? Please select all applicable answers.” (1 = “With hitting”; 2 = “With throwing”; 3 = “With fielding”; 4 = “With running”). The location of LBP was assessed using the following questions: “On which side did your low back pain start?” (1 = “My low back pain started on the left side”; 2 = “My low back pain started on the right side”; 3 = “My low back pain started on both sides”). We measured the same variables for those who underwent medical checkups and those who visited the hospitals and clinics in the questionnaire.

2.5. Evaluation of physical findings

Physical findings of LBP were evaluated before MRI on the same day. To assess the characteristics of present LBP, pain during lumbar flexion, extension, and combination of lateral bending and extension (Kemp's test) was evaluated (Fig. 2) [15,22]. Participants were asked to stand in a relaxed position with the feet shoulder width apart and perform maximal flexion of the lumbar spine, followed by maximum extension of the lumbar spine with the legs straight. If a participant complained of pain localized between the costal margins and superior gluteal folds during that test, LBP was

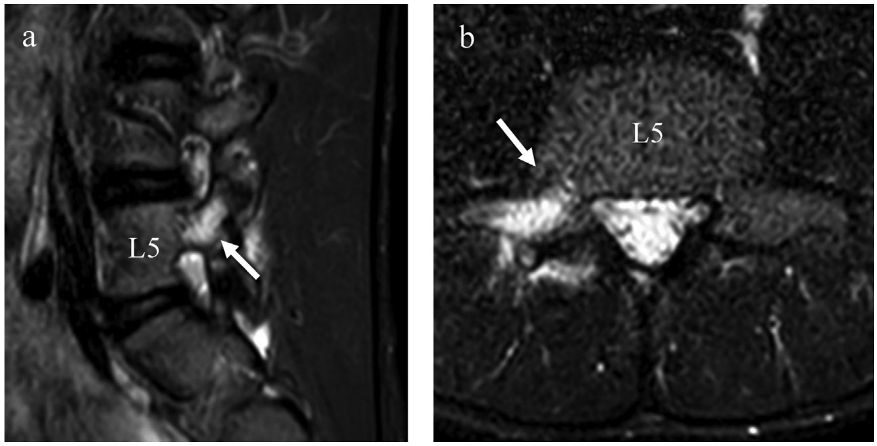

Fig. 1. STIR-MRI of early-stage spondylolysis. Sagittal (a) and axial (b) STIR-MRI images of a 16-year-old baseball player showing a high signal change at the right L5 pedicle adjacent to the pars interarticularis (arrows).

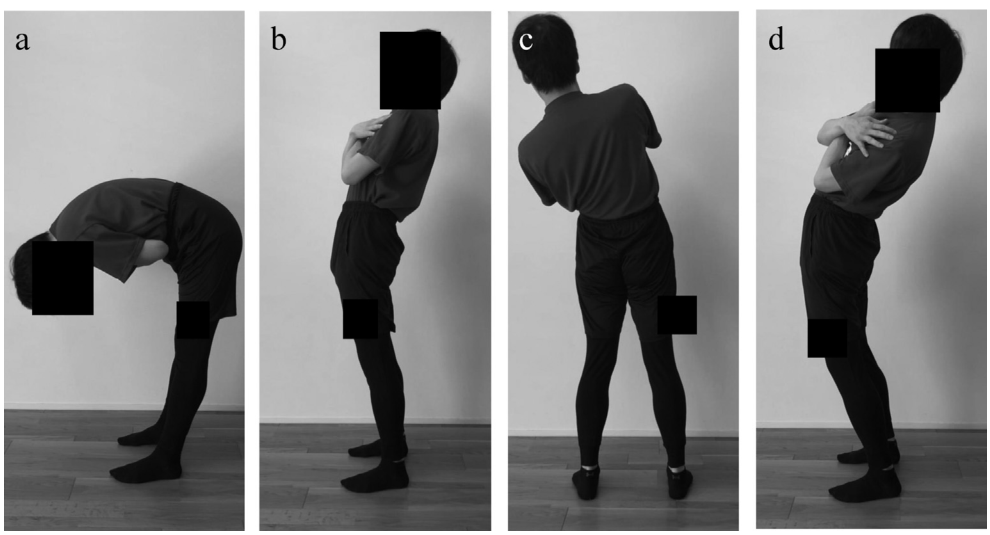

Fig. 2. Spinal signs. Lumbar flexion (a). Lumbar extension (b). Kemp's test (left) (c, d). The Kemp's test was evaluated on both sides.

recorded as positive. The Kemp's test was recorded as positive when the participant complained of LBP on the side of lateral bending and extension of the trunk while standing erect on both legs [15]. We performed each test twice and considered the test to be positive if the patient had similar pain both times.

The provocative tenderness at a vertebral spinous process was also evaluated (Fig. 3). The participant lay prone on an examination table and the examiner first palpated each vertebral spinous process with the thumbs (Fig. 2a, d), and then placed the hypothenar eminence on that spinous process (Fig. 2b, e) and slowly pressed inferiorly to produce localized extension of the lumbar spine (Fig. 2f, e). The test was considered positive if the participant complained of LBP during pressing. We performed this test to assess stress on the spondylolysis region during localized segmental lumbar spine movement in the prone position, and therefore defined a test as negative if the participant complained of pain from the vertebral spinous process itself. All physical examinations in this study were performed by the first author, a board-certified orthopedic and spine surgeon. The same physical examinations were used for all participants in this study.

2.6. Statistical analyses

Participants with complete data were included in the primary analysis. Descriptive statistics were calculated for participant characteristics. Continuous data are summarized as means and standard deviations, while dichotomous or categorical data are provided as proportions. First, we compared the participants between the ESS and non-ESS groups using univariate analyses. Thereafter, a multivariable logistic regression analysis was performed, and odds ratios (ORs) and 95% confidence intervals (CIs) were calculated. The number of potential variables in the multivariable analysis was determined based on 10 outcome events per explanatory variable; therefore, any potential variable with a P-value of <0.01 in the univariate analysis was included in the regression model. Age (greater than the median of this study population) and position (pitcher) were considered as potential confounders and included as covariates in the multivariable logistic regression analysis. All statistical analyses were conducted using JMP version 15.0.0 software (SAS Institute, Cary, NC). All tests used were two-sided, and values of $P < 0.05$ were considered statistically significant.

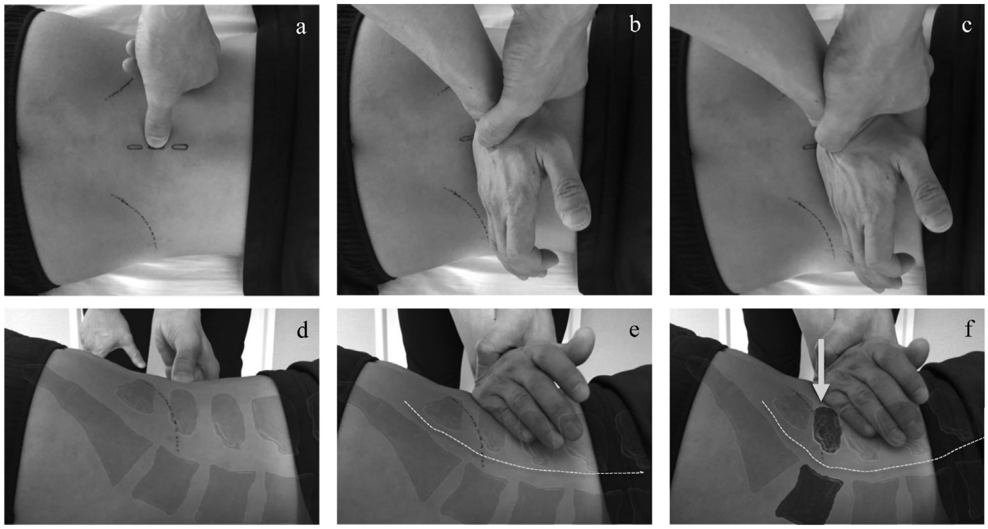

Fig. 3. The tenderness of the vertebral spinous process. The examiner palpates each spinous process with the thumbs (a, d), places the hypothenar on that process (b, e), and presses inferiorly to produce extension movement of the lumbar spine (f, e).

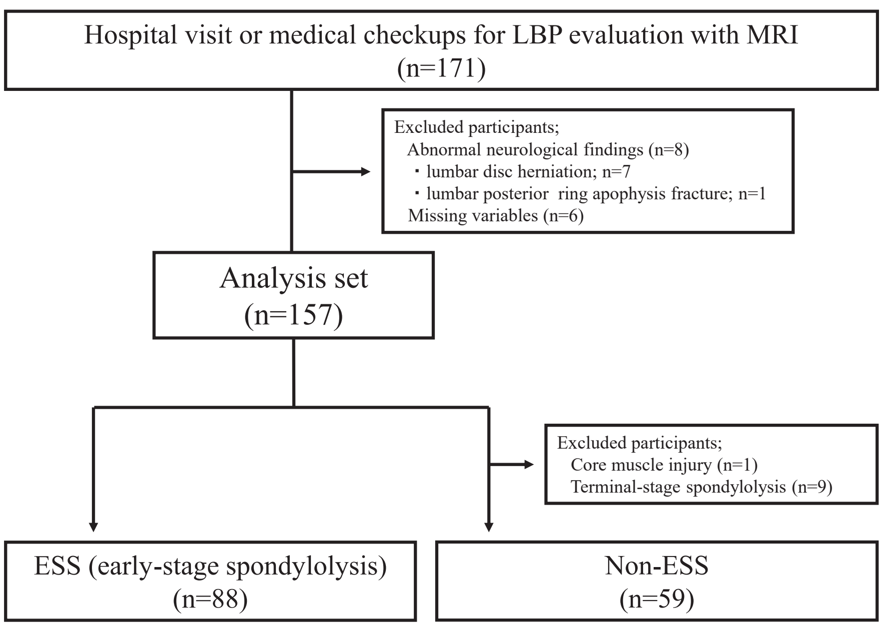

Fig. 4. Study flowchart.

3. Results

One hundred and seventy-one adolescent baseball players with a complaint of LBP were included in this study (Fig. 4). Eight participants who had neurological symptoms or deficits and six participants for whom data were missing were excluded. After evaluating both physical findings and MRI, 88 of the 157 participants were diagnosed with ESS, and 69 were diagnosed with non-ESS. One participant who showed specific lesions on MRI (core muscle injury at its junction with the thoracolumbar fascia), and 9 participants who showed terminal-stage spondylolysis on plain radiography or CT were excluded from the non-ESS group. Participant characteristics are presented in Table 1. All players were male, aged between 13 and 18 years. The most frequent school year in the ESS group was the first year of high school.

The affected vertebral levels were L1, L3, L4, L5, and L6 (transitional vertebra) in 1, 12, 27, 45, and 1 patient, respectively. We found bilateral active spondylolysis on MRI in 20 patients and unilateral active spondylolysis in 68 patients. Of the unilateral lesions, 26 were on the right side and 43 were on the left side (2 patients had multiple-level unilateral spondylolysis at left L2 and left L3, and at left L4 and right L5) (Table 2). Right-handed throw and right-side hitting players had the most frequent unilateral active left-side spondylolysis, and Left-handed throw and left-side hitting players had the most frequent unilateral active right-side spondylolysis (Table 3).

The LBP duration of the ESS and non-ESS groups was as follows: <1 week in 8 and 9 players, 1–4 weeks in 18 and 23 players, and ≥4 weeks in 62 and 27 players, respectively. LBP duration was significantly longer in the ESS than in the non-ESS group ($P = 0.0085$).

Table 1
Summary of demographic data.

Characteristics		Total (n = 147)	ESS (n = 88)	non-ESS (n = 59)
Age	mean ± SD, years	15.6 ± 1.3	15.5 ± 1.3	15.8 ± 1.2
School grade level, junior high	1st year, n (%)	12 (8.2)	7 (8.0)	5 (8.5)
	2nd year, n (%)	21 (14.3)	18 (20.5)	3 (5.1)
	3rd year, n (%)	13 (8.8)	6 (6.8)	7 (11.9)
School grade level, high	1st year, n (%)	65 (44.2)	36 (40.9)	29 (49.2)
	2nd year, n (%)	28 (19.0)	17 (19.3)	11 (18.6)
	3rd year, n (%)	8 (5.4)	4 (4.5)	4 (6.8)
Pitchers	n (%)	43 (29.3)	28 (31.8)	15 (25.4)
Dominant throw/hitting sides	Right/right, n (%)	111 (75.5)	69 (78.4)	42 (71.2)
	Right/left, n (%)	22 (15.0)	10 (11.4)	12 (20.3)
	Right/both, n (%)	2 (1.4)	0 (0)	2 (3.4)
	Left/left, n (%)	12 (8.2)	9 (10.2)	3 (5.1)

ESS, early-stage spondylolysis. Data are presented as mean ± standard deviation (SD) or number and percentage.

Table 2
Vertebral levels affected in cases with early-stage spondylolysis.

Vertebral Level	Total	Bilateral	Unilateral, Total (Right side/Left side)
L1	1	1	0 (0/0)
L3	12	3	9 (2/7)
L4	27	7	20 (8/12)
L5	45	9	36 (15/21)
L6 (transitional vertebra)	1	0	1 (0/1)
L2 and L3	1	0	1 (0/L2 left, L3 left)
L4 and L5	1	0	1 (L5 right/L4 left)
Total	88	20	68 (25/44)

Table 3
Dominant throw/hitting sides and lesion laterality in cases with early-stage spondylolysis.

		Dominant throw/hitting sides								
		All players (n = 88)			Pitchers (n = 28)			Fielders (n = 60)		
		Right/right (n = 69)	Right/left (n = 10)	Left/left (n = 9)	Right/right (n = 18)	Right/left (n = 2)	Left/left (n = 8)	Right/right (n = 51)	Right/left (n = 8)	Left/left (n = 1)
Lesion laterality	Unilateral, Right side n (%)	17 (24.6)	3 (30.0)	5 (55.6)	5 (27.8)	0 (0.0)	5 (62.5)	12 (23.5)	3 (37.5)	0 (0.0)
	Unilateral, Left side n (%)	33 (47.8)	6 (60.0)	3 (33.3)	10 (55.6)	2 (100.0)	3 (37.5)	23 (45.1)	4 (50.0)	0 (0.0)
	Bilateral n (%)	19 (27.5)	1 (10.0)	1 (11.1)	3 (16.7)	0 (0.0)	0 (0.0)	16 (31.4)	1 (12.5)	1 (100.0)

"Right/Right" indicates right-handed throw and right-side hitting players. Data are presented as number and percentage.

LBP-related interference with playing baseball was recorded while running in 94 (63.9%) players and was significantly more frequent in the ESS group (65 of 88 players, 73.9%) than in the non-ESS group (29 of 59 players, 49.2%; P = 0.0022). LBP starting on the unilateral paraspinal side was significantly more frequent in the ESS group (69 of 88 players, 78.4%) than in the non-ESS group (28 of 59

Table 4
Univariate analysis for the association of LBP characteristics, physical findings and early-stage spondylolysis.

		ESS (n = 88)	non-ESS (n = 59)	P-value
LBP characteristics				
Previous episodes, n (%)		45 (51.1)	22 (37.3)	0.10
Low back pain duration, n (%)	<1 week	8 (9.1)	9 (15.3)	0.0085*
	1–4 weeks	18 (20.5)	23 (39.0)	
	≥4 weeks	62 (70.5)	27 (45.8)	
LBP-related interference with playing baseball	Hitting	47 (53.4)	30 (50.9)	0.76
	Throwing	43 (48.9)	21 (35.6)	0.11
	Fielding	27 (30.7)	26 (44.1)	0.10
	Running	65 (73.9)	29 (49.2)	0.0022*
Starting LBP with laterality, n (%)		69 (78.4)	28 (47.5)	0.0001*
Physical findings				
Lumbar flexion		31 (35.2)	25 (42.4)	0.38
Lumbar extension		75 (85.2)	41 (69.5)	0.022*
Kemp's test (positive of either side)		74 (84.1)	40 (67.8)	0.020*
Tenderness of spinous process		55 (62.5)	19 (32.2)	0.0003*

ESS, early-stage spondylolysis. Data are presented as number and percentage. Data comparing ESS with non-ESS. *P < 0.05.

players, 47.5%; P = 0.0001) (Table 4). According to the univariate analysis, significant associations in the ESS group compared with the non-ESS group were identified in lumbar extension, Kemp's test, and the tenderness of a spinous process (P = 0.022, P = 0.020, P = 0.0003, respectively; Table 4). The numbers of players in LBP characteristics and physical findings stratified in pitchers and fielders are in Supplemental table 1.

After adjusting for confounding factors (age and position), we found significant associations between ESS and LBP duration of more than 4 weeks (OR 3.13, 95% CI 1.42–6.92; P = 0.0048), LBP-related interference while running (OR 2.89, 95% CI 1.30–6.46; P = 0.0094), LBP starting with laterality (OR 2.78, 95% CI 1.24–6.27; P = 0.0133), and the tenderness of a spinous process (OR 3.00, 95% CI 1.36–6.57; P = 0.0062) (Table 5).

4. Discussion

Early diagnosis of ESS is critical for effective conservative treatment. MRI can aid in the early detection of ESS, but differentiating ESS from other low back pathologies is difficult without imaging evaluation. Our study identified LBP duration of more than 4 weeks, LBP-related interference while running, and start of LBP on the unilateral paraspinal side as characteristics associated with ESS in male adolescent baseball players. Tenderness of a spinous process of the vertebrae might also be useful for diagnosing ESS.

LBP duration was significantly longer in the players with ESS than in the players with non-ESS. Kaneko et al. conducted a retrospective study of 312 patients (under 18 years of age) with sports-related LBP lasting 7 days who underwent MRI; 33% of these individuals had lumbar stress injuries [23]. In addition, Nitta et al. reported that 45.5% of elementary, 45.1% of junior high, and 31.5% of high school patients with LBP persisting for longer than 2 weeks who consulted for primary care clinic might have lumbar spondylolysis [24]. They thus recommended obtaining MRI images for confirmation in pediatric patients with LBP persisting for longer than 2 weeks and with a history of athletic activity. In our study, 62 (approximately 70%) of the 89 players with LBP persisting for longer than 4 weeks had ESS. Therefore, a longer duration of LBP might be predictive of ESS, and the LBP duration of more than 4 weeks may be a reference number for care providers caring for male adolescent baseball players with LBP to suspect ESS.

LBP-related interference with running was detected in around 75% of players with ESS (compared with approximately 50% of players with non-ESS), and may be an indicator of ESS in male adolescent baseball players. LBP online questionnaire surveys of university baseball players (aged 21 ± 2 years) found that baseball motions that induced LBP were running (25%), hitting (29.4%), throwing (24.1%), and catching a ground ball (14.9%) [25]. However, these online surveys did not investigate LBP pathophysiology. One cross-sectional study in university athletes (aged 18–23 years) revealed that the proportion of participants with disc degeneration was higher in the baseball players than in the non-athletes (odds ratio, 3.23) [26]. In another study comparing adolescent and adult athletes with LBP, spondylolysis was identified in 47% of young athletes, while 48% of adult LBP was disc-related [5]. Given the contrasts between our results and those of these previous studies, our findings indicate that LBP-related interference while running may be associated with ESS in adolescent baseball players. Moreover, recent motion analysis experiments have pointed out that running (particularly sprinting) could increase hip extension angles, spine rotation angles, and hip flexion moments, and could thus be a risk factor for lumbar spondylolysis [27].

LBP starting on the unilateral paraspinal side was associated with ESS in adolescent baseball players. The primary symptom of lumbar spondylolysis might be LBP during activities, particularly those involving lumbar extension/rotation, and the pain may be central or on one side of the low back [3,9,28]. Lumbar spondylolysis has been found to occur exclusively on one side in less than half of athletes [28,29]. A retrospective comparative study on MRI detection of ESS reported that baseball players have single, unilateral lesions (40 of 49 players; 81.6%) more frequently than soccer players (13 of 33 players; 39.4%) [30]. This could be caused by asymmetrical movement, such as throwing and batting, in baseball players [22,25,31]. The dominance of the hand resulted in an asymmetrical movement that altered the lumbar spine's rotational direction [30,31]. In addition, pitching or batting with the dominant-side hand would be associated with contralateral-side lesions in adolescent baseball players with lumbar spondylolysis [30]. Our study did not statistically analyze this association because of insufficient power, but similar findings were observed (e.g., right-handed throw and right-sided hitting players had the most frequent unilateral active left-side spondylolysis). Although unilateral LBP might be expected in baseball players of all ages regardless of lumbar spondylolysis [31,32], our results suggest unilateral LBP might be more prevalent in adolescent baseball players with ESS.

The tenderness of a vertebral spinous process might be useful for diagnosing ESS. Physical examination to identify ESS is required to determine the necessity of MRI, but which physical examinations are effective remains unclear. According to previous studies, the one-leg hyperextension test and lumbar hyperextension might be useful [13,14]. However, other studies concluded that hyperextension, hyperflexion, and the Kemp's test were not clinically useful for diagnosing ESS [15–17]. In our study, we assessed the tenderness of vertebral spinous processes. Kobayashi et al. concluded that the percussion in the vertebral spinous process test was not clinically useful for diagnosing ESS [15]. However, they did not describe the detailed method of the percussion such as patient positioning and whether the physician's fist was closed. The palpation of the vertebral spinous process for clinical tests is best performed with the patient in the prone position, and pain provocation responses are more reliable than other palpation methods [33,34]. In our study, the tenderness of a vertebral spinous process was used as a provocative pain response, intended to assess sensitivity of the spondylolysis region during segmental lumbar movement with the absence of axial loading.

Several limitations to this study should be acknowledged. Since the LBP characteristics such as duration and pain location in the present study relied on self-reports from participants, who had an average age of 15 years, the self-reported data might have been affected by recall bias. Second, the physical findings of participants were evaluated before MRI on the same day by the examiner, a board-certified orthopedic and spine surgeon. Although the examiner recorded the physical findings with blinded MRI results in this study, the examiner performed a medical interview with the participants prior to performing the physical examination. The information from the interview might have influenced the physical examination results. Third, the present study only included male

Table 5
Multivariable analysis for the association of ESS and predictive variables.

	OR (95%CI)	P-value
LBP duration, ≥4 weeks	3.13 (1.42–6.92)	0.0048*
LBP-related interference while running	2.89 (1.30–6.46)	0.0094*
Starting LBP with laterality	2.78 (1.24–6.27)	0.0133*
Tenderness of a spinous process	3.00 (1.36–6.57)	0.0062*

ESS, early-stage spondylolysis; LBP, low back pain; OR, odds ratio; CI, confidence interval. *P < 0.05. Models are adjusted for age and position (pitcher).

adolescent baseball players. The results thus may not be generalizable to other sports activities, different ages, or female athletes.

In conclusion, we found that LBP duration of more than 4 weeks, LBP-related interference while running, LBP starting on the unilateral paraspinal side, and tenderness of the vertebral spinous process may lead to the diagnosis of ESS in male adolescent baseball players. Male adolescent baseball players in whom LBP with these four findings might be good candidates to be considered for advanced imaging examination such as MRI.

Ethical statement

The Research Ethics Committee of Fukushima Medical University approved our study protocol (identification numbers 2063, 2064, 242). Informed consent was obtained by an opt-out option on the website between January 2018 and December 2020. All the parents/guardians and participants enrolled between January 2021 and April 2022 provided written informed consent prior to enrolment.

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Declaration of competing interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jos.2022.10.014.

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