



**Table 1.** Characteristics of the Patients.

Number	Age (years)	Sex	Sporting level	Sporting discipline	Vertebral level	Pathological stage	Bone union	Treatment period (days)
1	18	Male	Professional athlete	Soccer	L5	Early/Progressive	Non-union	N/A
2	22	Male	Professional athlete	Soccer	L4	Early/Pre-lysis	Union	77
3	18	Male	Amateur student	Soccer	L4	Pre-lysis	Union	51
4	21	Male	Amateur student	Soccer	L5	Progressive	Union	41
5	18	Male	Amateur student	Track and field	L3	Early/Early	Non-union	N/A
6	18	Male	Amateur student	Track and field	L5	Early/Early	Union	91
7	19	Male	Amateur student	Track and field	L4	Early	Union	108
8	21	Male	Amateur student	Track and field	L4	Progressive/Early	Union	95
9	20	Female	Amateur student	Basketball	L4	Progressive	Union	121

The slash separating pathological stages indicates bilateral lesions with right/left. The treatment period was analyzed for lesions for which bone union was achieved.

tients aged 18 or older who visited our institute during 2013-2021. Their chief complaint was lower back pain, and both MRI and computed tomography (CT) imaging were performed to achieve a diagnosis. Among these patients, those who achieved complete bone maturation and who could be followed until the end of treatment were included in this study. Patients presenting with pseudarthrosis lesions, which did not show bone marrow edema on MRI, at the first visit were excluded. The age at diagnosis, sex, competitive sporting level (e.g., amateur/professional), and competitive sporting discipline were investigated in each patient. Additionally, the following parameters were analyzed in each lesion: the level of the affected vertebra, pathological stage, bone union, and treatment period. Note that bilateral spondylolysis in one vertebral arch was counted as two lesions.

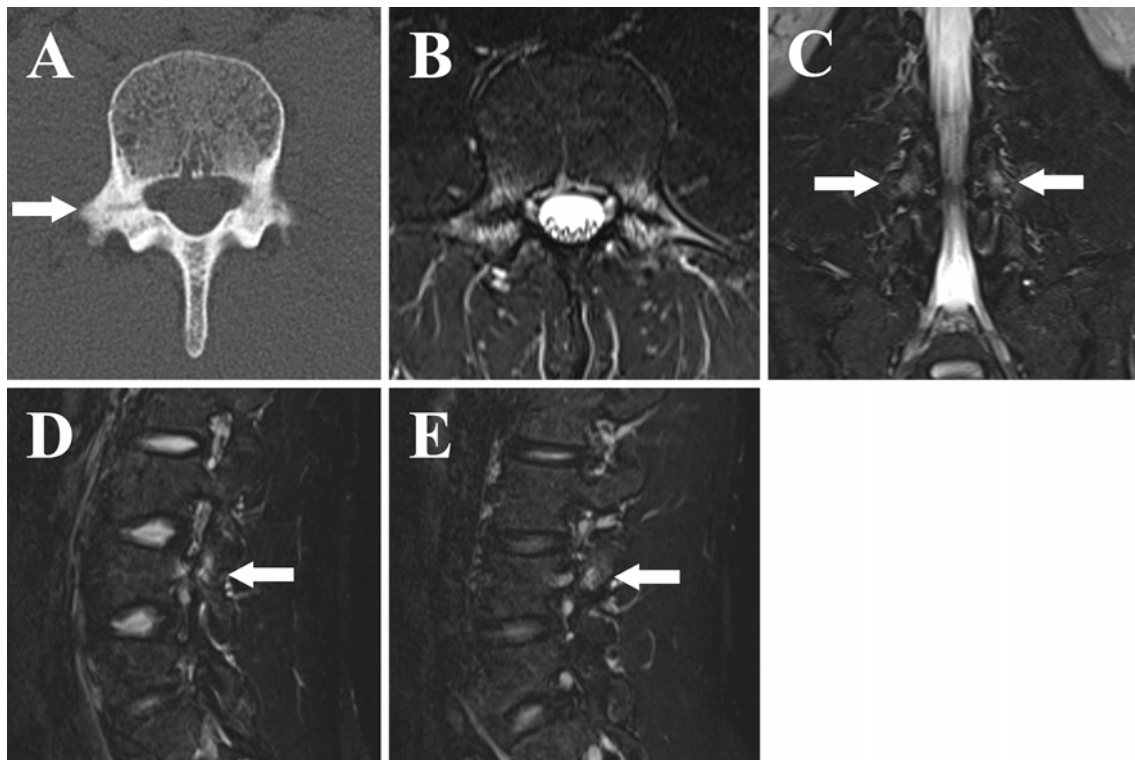
Lumbar spondylolysis was defined as the presence of bone marrow edema in the pars interarticularis on MRI short tau inversion recovery (STIR) imaging, or the presence of a fracture line between the articular processes on CT. Bone age was investigated with plain lateral X-ray of the third lumbar vertebra using the classification described by Sairyo et al.<sup>1)</sup> and plain anteroposterior X-ray of the pelvis using the United States Risser classification<sup>7)</sup>. The treatment protocol was exercise prohibition and the use of a semi-rigid lumbosacral brace until the bone marrow edema disappeared on MRI. MRI was performed once a month to evaluate bone marrow edema. Additionally, physiotherapy was performed once a week from the beginning of the treatment, until the patients were able to resume their sporting activities. The pathological stages of the lesion were determined by axial slice classification using CT and MRI<sup>3)</sup>. Bone union was defined in cases where bone marrow edema had disappeared on MRI and bone union had been confirmed on CT. The treatment period was defined as the number of days from the date of diagnosis to the date of bone union and analyzed for lesions in which bone union had been achieved.

## Results

Fourteen acute lesions involving lumbar spondylolysis were detected in nine patients aged 18 to 22 years, including five patients with bilateral spondylolysis. The average age at diagnosis was 19.4 years and the patients included eight males and one female. All patients had achieved complete bone maturation and were in the epiphyseal stage based on the plain lateral X-ray and in stage 5 based on the Risser classification. The duration of the lower back pain between the onset and the first visit ranged from 2 weeks to 7 months. Two patients were professional athletes, while the others were college or high school students. The athletic career started in elementary school in six patients and junior high school in two. Although the details about the athletic career were unknown in one patient, most of the remaining patients were highly skilled athletes who had begun their athletic careers at a young age. In terms of the sporting disciplines of the patients, it was soccer in four patients, track and field in four, and basketball in one. Regarding the affected vertebral level, it was L3 in two lesions (14.3%), L4 in seven lesions (50.0%), and L5 in five lesions (35.7%). The findings on the pathological stages of the lesions were as follows: pre-lysis stage in two lesions, early stage in eight lesions, and progressive stage in four lesions. Finally, in 10 lesions in seven patients, bone union was achieved with conservative therapy, and the average treatment period was 84.7 days (Table 1). Seven of the nine patients returned to sports activities within 5 months. Two patients could not be able followed until they restarted their sports activities.

### Representative case

A 22-year-old male professional soccer player visited our institute with the chief complaint of lower back pain persisting for 7 months. MRI STIR imaging revealed bilateral bone marrow edema in the pars interarticularis in L4, while CT showed the fracture line on the right side (Fig. 1). The patient was diagnosed with right side early stage and left side pre-lysis-stage lumbar spondylolysis, for which conservative therapy was performed. The patient was prohibited



**Figure 1.** CT and MRI imaging of the representative case at the first visit.

A, Axial CT slice. The white arrow indicates the fracture line. The right side was diagnosed as early stage and the left side was diagnosed as pre-lysis stage.

B, Axial MRI STIR slice. Bilateral bone marrow edema is apparent.

C, Coronal MRI STIR slice.

D, E, Sagittal MRI STIR slice of the right (D) and left (E) sides.

CT, computed tomography; MRI, magnetic resonance imaging; STIR, short tau inversion recovery

from playing soccer, wore a knight-type hard brace, and underwent physiotherapy during the treatment period. After 77 days, MRI STIR imaging showed that the bone marrow edema had disappeared, and bone union was confirmed on CT (Fig. 2). The patient was able to resume sporting activities in 4 weeks and, at the time of writing, is playing for a professional soccer team.

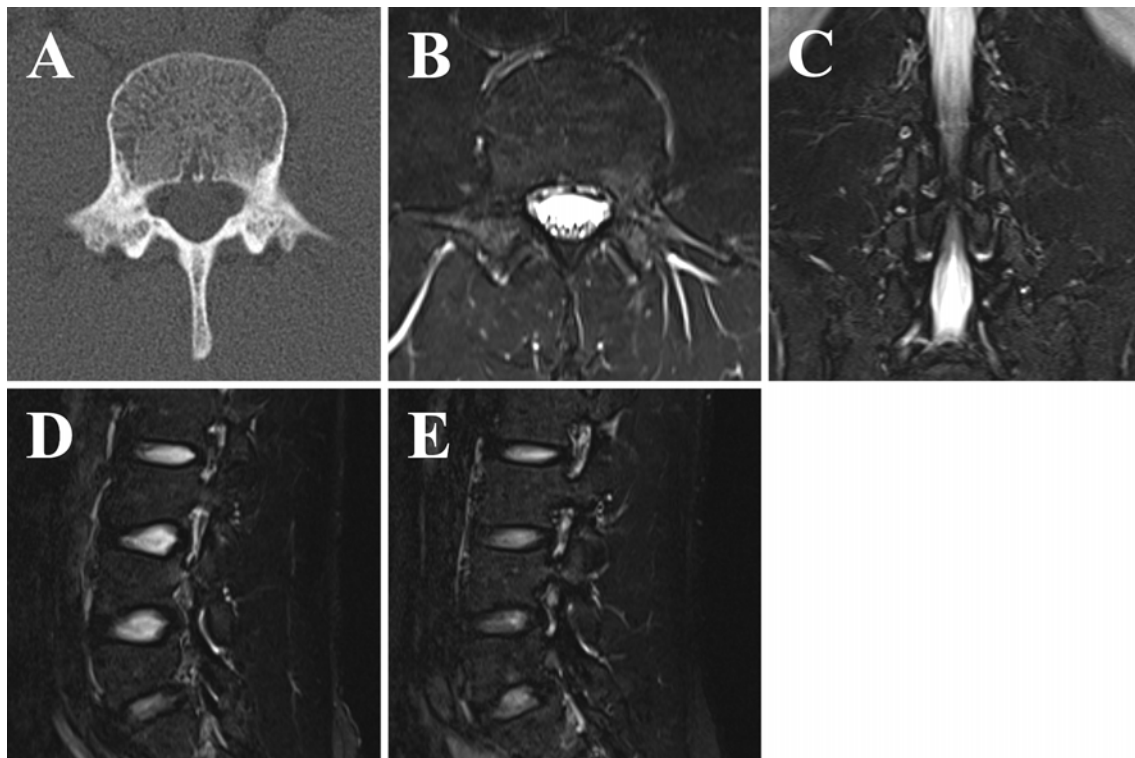
## Discussion

Lumbar spondylolysis predominantly occurs during adolescence and is considered rare among adults who have undergone complete bone maturation<sup>1,2</sup>. However, some studies have reported adult lumbar spondylolysis cases<sup>4,5</sup>, and only one case series reported adult-onset lumbar spondylolysis with bone marrow edema on MRI<sup>6</sup>. This study aimed to investigate the characteristics of patients and lesions with adult-onset acute lumbar spondylolysis that were treated conservatively.

The adult patients with acute lumbar spondylolysis included in this study were young, up to their early 20s, which matches the findings in the previous case series<sup>6</sup>. The incidence of lumbar spondylolysis is reported to be higher in males than in females and in athletes than in the general population<sup>8,9</sup>, which corresponds to the findings in our study.

Lumbar spondylolysis is common during adolescence due to increased bone metabolism and increased physical activity<sup>1,2</sup>, while it is less likely to occur after bone maturation because of increased mechanical strength of the vertebra. In the current study, although the patients were relatively young adults, all had achieved bone maturation. The evaluation of vertebral bone age, described by Sairyó et al.<sup>1</sup>, was used in the previous case series of adult-onset acute lumbar spondylolysis by Tezuka et al.<sup>6</sup>. The Sairyó classification evaluates the appearance of a secondary ossification center in plain lateral X-ray of the third lumbar vertebra. The vertebral bone age was in the epiphyseal stage, with fully matured vertebrae, in all study patients<sup>1</sup>. The Risser classification, which is widely used to evaluate skeletal maturity, utilizes the development of iliac crest apophysis as an indicator. All patients were in Risser stage 5 in which the fusion of the apophysis to the iliac wing is complete, representing bone maturation<sup>7</sup>. Therefore, if high mechanical stress is placed on the pars interarticularis, lumbar spondylolysis can occur even after bone maturation. Of note, mechanical stress placed on the pars interarticularis may differ depending on the sporting discipline.

The sporting prowess of the patients included in this study was high. Two patients were professional soccer players, while the others, although amateur students, included



**Figure 2.** CT and MRI imaging of the representative case after 77 days of conservative therapy.

- A, Axial CT slice. Fracture line is unclear.  
 B, Axial MRI STIR slice. Bone marrow edema has disappeared.  
 C, Coronal MRI STIR slice.  
 D, E, Sagittal MRI STIR slice of the right (D) and left (E) sides.

representatives of national teams who played their sport almost every day, especially during the on-season. The most common sporting disciplines among the patients were soccer and track and field, with four patients each. This corresponds to a previous study in which soccer and track and field players had higher incidences of lumbar spondylolysis (8.7% and 12.0%, respectively) than the general population (5.9%)<sup>10</sup>. Moreover, an even higher incidence of lumbar spondylolysis was found in soccer players playing at a professional level (38.1%)<sup>10</sup>, suggesting that elite sport and the high intensity of exercise that it entails increase the risk of developing lumbar spondylolysis.

The affected vertebral level varied from L3 to L5 in this study, with L4 being the most common. Meanwhile, L5 was the dominant vertebral level in studies on patients with lumbar spondylolysis both in the general population and among adolescent athletes<sup>8,9,11</sup>; however, more mid-lumbar lesions are reported in adult-onset spondylolysis. Only about half of the lesions occurred in L5 and many were L2-L4 mid-lumbar lesions in the previous case series<sup>6</sup>. In studies on adult-onset spondylolysis in athletes using CT, only L3 and L4 lesions were reported<sup>12</sup>. The high incidence of mid-lumbar lesions in the present study might be related to the sports discipline practiced by the patients. However, L5 is the most affected vertebral level reported in soccer<sup>13,14</sup> and track and field<sup>15</sup>. Therefore, the sports discipline is less likely to explain this finding. Regarding spinal alignment,

one study reported that lumbar lordosis increased with age<sup>16</sup>. Larger lumbar lordosis may increase the mechanical stress to mid-lumbar lesions and contribute to the observed trend. Therefore, it can be hypothesized that adult-onset spondylolysis is more likely to occur in the mid-lumbar area, while this trend differs from that in adolescent patients. However, since few cases of adult-onset acute lumbar spondylolysis occur and few related reports have been published, further research is needed.

In this study, we investigated adult patients with acute lumbar spondylolysis with bone marrow edema and found that bone union was achieved in 10/14 lesions (71%). The average treatment period until bone union was slightly less than 3 months. On the other hand, patients with acute lumbar spondylolysis of high school age or younger undergoing conservative therapy were reported to achieve bone union in 76% of the lesions, and the average treatment period was 106 days<sup>16</sup>. Considering that bone metabolism increases during the growth period<sup>2</sup>, it is thought that bone union can more readily occur in young patients, which leads to a higher bone union rate and a shorter treatment period. However, in our study, the bone union rate and the treatment period did not differ so much between adolescents and adults. In a previous study<sup>16</sup>, patients with bilateral acute spondylolysis were excluded, and some patients exhibited pseudarthrosis lesions on the contralateral side, which negatively impacts bone union<sup>17-19</sup>; these factors prevent simple com-

parisons between these studies. Nonetheless, for adult-onset acute spondylolysis with bone edema, conservative therapy is probably as effective as during adolescence with regard to achievement of bone union.

Considering that lumbar spondylolysis forces sportsmen and -women to stop playing their sport during the treatment period, prevention is important, even after bone maturation. For athletes at a professional or elite level and those involved in high risk sports, caution should be taken because such sports subject the lumbar spine to repetitive high stress. In the previous case series by Tezuka et al.<sup>6)</sup>, the pain-free return to competition as soon as possible was prioritized; thus, the bone union rate was as low as 23.1%. However, some patients exhibited terminal-stage spondylolysis on the contralateral side, so the background factors of the patients differed from those in our study. When lumbar spondylolysis lesions progress to the terminal-stage, chronic pain may occur or spondylolisthesis may develop, causing neurological symptoms<sup>11,20)</sup>; therefore, if there is a high possibility of bone union, it is better to prioritize conservative therapy. In patients with acute lumbar spondylolysis without terminal-stage lesions on the contralateral side or other vertebrae, it is worthwhile performing conservative therapy.

A limitation of this study is its small sample size. We were able to investigate only nine adult-onset acute lumbar spondylolysis patients who visited our institute during the years 2013-2021. Since lumbar spondylolysis is rare in adulthood, a multi-centered study should be conducted to investigate a larger sample. Additionally, we excluded patients presenting with pseudarthrosis lesions; therefore, conservative therapy cannot be simply applied to all patients with lumbar spondylolysis.

## Conclusion

This study showed that patients with acute lumbar spondylolysis after bone maturation tend to be in their early 20s and to have a high level of sporting prowess. Intense repetitive mechanical stress on the pars interarticularis can potentially lead to lumbar spondylolysis, even after bone maturation. Soccer and track and field were common as sporting disciplines of those affected by lumbar spondylolysis, in line with findings in previous studies. L4 was the most commonly affected vertebral level, and most of the lesions achieved bone union with conservative therapy.

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

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**Author Contributions:** M.T. conceived and designed the study. R.A. drafted the manuscript. M.T., S.O., H.G., T.F., and A.H. treated the patients. M.Y. revised the draft manuscript. All the authors approved the final version submitted for publication.

**Ethical Approval:** The study's protocol was reviewed and approved by the Institutional Review Board of Tsukuba University Hospital Mito Clinical Education and Training Center/Mito Kyodo General Hospital (IRB No. 21-11).

**Informed Consent:** Oral informed consents were obtained from all the patients.

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