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Literature Review

Return to play after conservative and surgical treatment in athletes with spondylolysis: A systematic review

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ABSTRACT

Purpose: Analyze the return to sports rate and timing after conservative and surgical treatment in athletes with spondylolysis.
Methods: Comprehensive search using Pubmed, Cochrane Library and SPORTDiscus databases to identify English language studies that assessed the return to sports after conservative or surgical treatment of symptomatic spondylolysis in athletes. The main outcome of interest was the return to sports rate and timing, as well as, the follow-up clinical and functional outcomes.
Results: A total of 14 trials (592 participants) were included. Eight and seven studies reported the outcomes of conservative and surgical approach, respectively. A total of 92% (n = 492) and 88% (n = 100) of athletes return to sports at any level, and 89% (n = 185) and 81% (n = 103) returned to their pre-injury level of sports for conservative and surgical approaches, respectively. The time to return to sports was 4.6 and 6.8 months for conservative and surgical approaches, respectively.
Conclusions: Conservative management (bracing, sports modification and physiotherapy) of athletes with spondylolysis show excellent return to sports rates at any level and at the pre-injury level at a mean of 4.6 months. Those who fail the conservative treatment can be successfully managed with surgical treatment with a high rate of return to sports at 6.8 months.
Level of Evidence: Level IV, Systematic review of level IV studies
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1. Introduction

Low back pain is a common symptom among young athletes, reaching prevalence rates up to 50% (Harreby et al., 1999; Olsen et al., 1992). Spondylolysis consists on a pars interarticularis defect of the vertebrae. It is often caused by repetitive microtrauma starting a vertebral stress reaction which may progress to fracture and/or slippage of a vertebra (spondylolisthesis) (Foreman et al., 2013). In this sense, spondylolysis is one of the most common causes of low back pain in young athletes (Maroon, 2002) ranging from 15 to 47% (Blanda, Bethem, Moats, & Lew, 1993; Micheli & Wood, 1995; Morita, Ikata, Katoh, & Miyake, 1995; Rossi & Dragoni, 1990; Soler & Calderón, 2000), in opposite to the reported incidences of 3–6% in the general population (Amato, Totty, & Gilula, 1984; Fredrickson, Baker, McHolick, Yuan, & Lubicky, 1984; Roche & Rowe, 1951). Spondylolysis is often seen in adolescents as

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the pars interarticularis has not been fully matured and it is more susceptible to overuse injury. Moreover, younger individuals who participate in sports requiring frequent overstretching (hyperextension) are at higher risk, once extension or lateral bending causes shear forces across the pars interarticularis of the joint facet (Eddy, Congeni, & Loud, 2005; Letts, Smallman, Afanasiev, & Gouw, 1985). Besides low back pain (exacerbated by hyperextension), pain radiating to the buttock and hamstrings tightness may be found (Farfan, Osteria, & Lamy, 1976; Tallarico, Madom, & Palumbo, 2008). The pars articularis of L5 is the most affected, accounting for 85–95% of cases, followed by the one of L4 with 5–15% of cases (Amato et al., 1984; Blanda et al., 1993; Fredrickson et al., 1984; Roche & Rowe, 1951; Rossi & Dragoni, 1990; Soler & Calderón, 2000).

Once this injury is caused by vertebral overloading, the first step is to discontinue the inciting activity. In addition, semirigid or rigid brace (4–6 weeks) is often applied concomitantly to rest, posteriorly complemented by muscle strengthening and activity restoration (with reduced impact) (Letts et al., 1985; Tallarico et al., 2008). If the athlete is asymptomatic at 4–6 weeks, the return to sports aided by brace may be considered (d'Hemecourt, Zurakowski, Kriemler, & Micheli, 2002; Herman, Pizzutillo, & Cavalier, 2003). However, in cases that the brace precludes sports participation, it is required a painless lumbar extension and stork test, and decrease on hamstring tightening before allowing a stepwise return to play (Letts et al., 1985). The conservative treatment provides satisfactory results, avoiding the need for a more invasive approach (d'Hemecourt et al., 2002; Miller, Congeni, & Swanson, 2004; Selhorst et al., 2016; Sys, Michielsen, Bracke, Martens, & Verstreken, 2001; El Rassi, Takemitsu, Woratanarat, & Shah, 2005), and is considered successful when the injured patient returns to pain-free activity in about 6–9-month period, However, if after this period the symptoms do not resolve or the condition has progressed to a spondylolisthesis grades III or IV, the surgical treatment should be considered (Donaldson, 2014; Drazin et al., 2011; Letts et al., 1985). Return to sports clearance after surgery is often considered at 6 months for non-contact activities and at 12 months for collision sports. Still, unrestricted participation in collision sports after fusion surgery is non-consensual (Rubery & Bradford, 2002).

The main treatment goal is to return the athlete to their preinjury sporting level of activity as soon and as safe as possible, preventing injury recurrence and long-term sequelae. There are a few systematic reviews that approach this topic in athletes with spondylolisthesis. However, these do not include all available studies (Iwamoto, Sato, Takeda, & Matsumoto, 2010; Overley et al., 2016) or used different eligibility criteria (Panteliadis, Nagra, Edwards, Behrbalk, & Boszczyk, 2016), do not provide a comprehensive analysis of sports and spondylolysis characteristics, as well as, the available clinical and functional outcomes (Overley et al., 2016), do not provide a focused analysis on return to play outcomes (Iwamoto et al., 2010), or did not included the conservative approach (Kolcun, Chieng, Madhavan, & Wang, 2017). Hence, this systematic review purpose was to assess the return to sports rate and timing after conservative or surgical treatment in athletes with spondylolysis.

2. Methods

2.1. Search strategy

The systematic review of the literature was conducted according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (Moher et al., 2015; Shamseer et al., 2015). The protocol used was registered prospectevelly at the International Prospective Register of Systematic Reviews (PROSPERO) (http://www.crd.york.ac.uk/prospero/; number: CRD42017069205).

The literature searches were performed using the Pubmed, Cochrane Library, SPORTDiscus databases. Original articles that assessed the outcomes and return to play (rate or timing) after conservative or surgical treatment of athletes with spondylolysis were reviewed. The searches were performed by two investigators (R. G.; R.A.), who completed the search independently, from database inception up to May 31, 2017. The results of both independent searches were confronted to check for overlapping; any disagreement was discussed until consensus was reached. The reference list of the most relevant original studies was scanned for additional studies. The search strategy comprised the Boolean operators (AND; OR) and the descriptor [Title/Abstract], which combined the following search terms: spondylolysis; istm*; sport; play; activity; athlete. An example of the search is depicted on Table 1.

2.2. Study selection

All the titles were inputted into EndNote software (Thomson and Reuters) and duplicates were removed using the *find duplicates* function. All the titles and abstracts were obtained from the abovementioned databases and were screened according the eligibility criteria. The potential relevant studies were identified and retrieved to assess the respective full text according the following inclusion criteria: (1) athletic population; (2) symptomatic spondylolysis; (3) conservative or surgical treatment; (4) report of return to play rate or timing; (5) English language studies. For exclusion criteria, it was established: (i) other reviews or meta-analyses; (ii) clinical commentaries or expert opinions; (iii) single case studies; (iv) technical notes; (v) animal studies or basic science; (vi) degenerative pathology; (vii) cases of spondylolisthesis.

2.3. Data collection and extraction

The main outcome of interest was the report of return to play (rate or timing) after conservative or surgical treatment for spondylolysis. In this sense, the return to play rate was extracted as mean percentage of return to any level of activity and return to the preinjury level. Moreover, the time until the return to sports was also extracted and converted into months for standardization purposes. The timing for conservative treatment was considered from the initial start of conservative measures up to the time to return to sports; for the surgical treatment, it was considered from the performance of the surgical procedure up to the time to return to sports, excluding, if reported, the preoperative treatment. In addition, the clinical, functional, mental or health-related quality of life and radiographic outcomes were retrieved. The patient outcome rating according to Steiner and Micheli classification system (Steiner & Micheli, 1985) was also collected according the

Table 1
Example of search strategy for Pubmed database.

Search	Search term(s)	Results
#1	Search **spondylolysis[Title/Abstract]**	1 332
#2	Search **istm*[Title/Abstract]**	63
#3	Search **(#1 OR #2)**	1 395
#4	Search **sport[Title/Abstract]**	25 205
#5	Search **play[Title/Abstract]**	591 016
#6	Search **activity[Title/Abstract]**	2 403 583
#7	Search **athlete[Title/Abstract]**	10 739
#8	Search **(#4 OR #5 OR #6 OR #7)**	2 911 665
#9	Search **(#3 AND #8)**	239

treatment applied.

As secondary outcome, the population characteristics (sample size, percentage of males, mean and range of age, body mass index, type and level of injury, type and level of sports, duration of symptoms and associated injuries), treatment features (type of treatment), follow-up duration and reported complications were analyzed.

2.4. Data analysis

The return to play rates (at any level and at the pre-injury level) and time to return to play were subgrouped according to conservative or surgical treatment and reported as pooled weighted averages and respective ranges. Due to the lack of comparative studies, a meta-analysis was not pursued.

2.5. Methodologic quality and risk of bias assessment

The level of evidence of each study was determined according the Oxford Centre of Evidence-Based Medicine classification. Moreover, the methodological quality was assessed by the Joanna Briggs Institute Checklist for Case Series tool (Institute, 2014). The appraisal was performed by two independent investigators (R.G.; R.A.), and the results were confronted to check for overlapping; any disagreement was discussed until consensus was reached.

Risk of bias was assessed according pre-determined criteria that address selection bias and confounding, performance bias, attrition bias, detection bias, reporting bias and information bias (Viswanathan & Berkman, 2012).

3. Results

3.1. Study selection

Initial database and hand search resulted in 399 records. A total of 28 full-text were read to assess their eligibility to be included in this study. From these, 14 studies were eligible and included in this systematic review (Blanda et al., 1993; Debnath et al., 2003; Donaldson, 2014; El Rassi, Takemitsu, Glutting, & Shah, 2013; Gillis, Eichholz, Thoman, & Fessler, 2015; Hardcastle, 1993; Iwamoto, Takeda, & Wakano, 2004; Menga, Kebaish, Jain, Carrino, & Sponseller, 2014; Nozawa, Shimizu, Miyamoto, & Tanaka, 2003; Raudenbush, Chambers, Silverstein, & Goodwin, 2017; Selhorst et al., 2016; Sutton, Guin, & Theiss, 2012; Sys et al., 2001; Álvarez-Díaz et al., 2011). Reason for the 14 excluded articles are described in the PRISMA flow chart (Fig. 1).

3.2. Population characteristics

Population characteristics from the 14 included studies are presented on Table 2. Overall, a total of 592 participants with ages comprised between 7 and 37 years old. The majority of the samples were comprised by male participants (59%) (Blanda et al., 1993; Debnath et al., 2003; Donaldson, 2014; El Rassi et al., 2013; Hardcastle, 1993; Iwamoto et al., 2004; Menga et al., 2014; Nozawa et al., 2003; Raudenbush et al., 2017; Selhorst et al., 2016; Álvarez-Díaz et al., 2011). The most common lumbar level in the athletic population is L4 (12.4%) and L5 (78.6%). All included athletes practiced organized sports and the most common were football (n = 157), soccer (n = 72) and baseball (n = 42). The level of sports activity showed heterogeneity within the included studies and only 5 studies reported this classification (Donaldson, 2014; Gillis et al., 2015; Iwamoto et al., 2004; Ranawat, Dowell, & Heywood-Waddington, 2003; Sys et al., 2001). Mean duration of symptoms was reported in 7 studies (Blanda et al., 1993; Debnath et al., 2003; El Rassi et al., 2013; Hardcastle, 1993; Menga et al., 2014; Selhorst et al., 2016; Sys et al., 2001) and ranged from 2.8 to 26.4 months. None of the studies reported the occurrence of associated injuries.

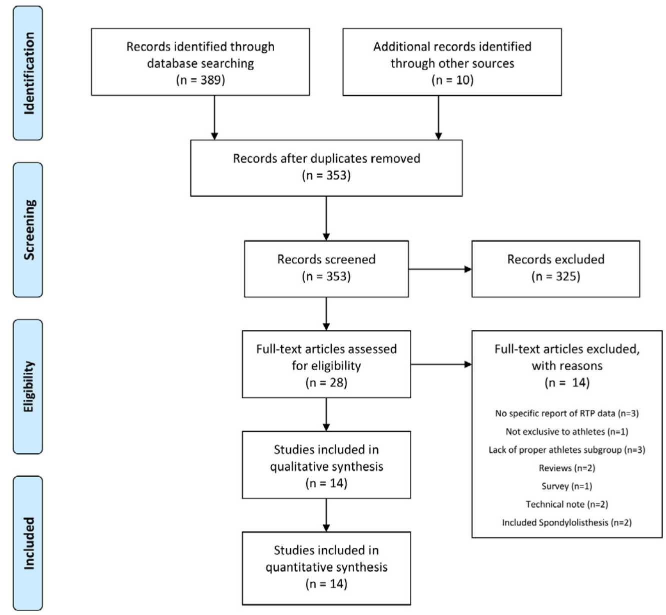

Fig. 1. PRISMA flow chart describing the screening strategy for included studies and resons on excluded studies.

3.3. Treatment characteristics

Eight studies (Blanda et al., 1993; Donaldson, 2014; El Rassi et al., 2013; Iwamoto et al., 2004; Selhorst et al., 2016; Sutton et al., 2012; Sys et al., 2001; Álvarez-Díaz et al., 2011) reported conservative approaches that diverged among the studies. The most consistent measures were modification/restriction of sports participation (Blanda et al., 1993; Donaldson, 2014; El Rassi et al., 2013; Iwamoto et al., 2004; Selhorst et al., 2016; Sutton et al., 2012; Álvarez-Díaz et al., 2011), bracing (Blanda et al., 1993; Donaldson, 2014; El Rassi et al., 2013; Iwamoto et al., 2004; Selhorst et al., 2016; Sys et al., 2001; Álvarez-Díaz et al., 2011) and physical therapy (mostly hamstring stretching, core strengthening, and back stabilization exercises) (Blanda et al., 1993; Donaldson, 2014; El Rassi et al., 2013; Sys et al., 2001; Álvarez-Díaz et al., 2011). One study mentioned bone stimulation as a complement to other conservative measures (Donaldson, 2014).

Seven studies (Debnath et al., 2003; Gillis et al., 2015; Hardcastle, 1993; Menga et al., 2014; Nozawa et al., 2003; Raudenbush et al., 2017; Sutton et al., 2012) managed the spondylolysis surgically using bone grafting techniques. Most of grafting techniques used iliac grafts (Debnath et al., 2003; Gillis et al., 2015; Hardcastle, 1993; Menga et al., 2014; Nozawa et al., 2003; Sutton et al., 2012) while one technique used local graft (spinous process autograft) (Raudenbush et al., 2017). For the iliac grafts, some authors prefer corticocancellous grafts (Gillis et al., 2015), while others use only cancellous bone (Debnath et al., 2003; Hardcastle, 1993; Menga et al., 2014). One study (Debnath et al., 2003) used either bone grafting or direct repair surgical technique. The surgical techniques used either screw (Debnath et al., 2003; Hardcastle, 1993; Menga et al., 2014; Raudenbush et al., 2017; Sutton et al., 2012) or wire (Debnath et al., 2003; Gillis et al., 2015; Nozawa et al., 2003) fixation. Main indication for surgical treatment was

Table 2
Population and treatment characteristics of the included original studies.

Reference	Sample (n; % males; age)	Level of injury	Type of Sports	Level of Sports Activity	Mean duration of symptoms (months)	Treatment	Follow-up (months)
Conservative treatment							
Donaldson 2014	n = 11 100% NR (15–18)	55% L5 36% L4 9% L4+L5	Ice hockey (n = 11)	Juniors to professional athletes	NR	Full rest from sports + physiotherapy (core strength, flexibility, and antilordotic back stabilization) + bracing (45%) + bone stimulation (18%)	NR
Iwamoto et al., 2004	n = 104 92.3% 20.7 (12–60)	1% L2 1.9% L3 8.7% L4 88.5% L5	Baseball (n = 29) Football (n = 14) Basketball (n = 14) Tennis (n = 7) Rugby (n = 4) Judo (n = 4) Golf (n = 3) Skiing (n = 3) Rowing (n = 3) Track and field (n = 3) Water polo (n = 3) Others (n = 17)	Non-athletic (n = 3); Low-level recreational (n = 28); High-level recreational (n = 61) Competitive level (n = 12)	NR	Continued sports practicing with mild pain (62%) or sports cessation (38%) + antilordotic lumbosacral bracing until pain was markedly reduced (100%)	24
Álvarez-Díaz et al., 2011	n = 34 100% 15.7 ± 2.5	2.9% L2 14.7% L3 11.8%L4 70.6% L5	Football (n = 34)	NR	NR	Cessation of sports activity and rehabilitation for 3 months (core strengthening and stability exercises, hamstrings stretching, and trunk rotational movements in a pain-free basis.) + bracing if pain at rest and daily life activities (44%)	24
Selhorst et al., 2016	n = 121 60.3% 14.4 ± 1.6	68.6% L5 9.9% multilevel	Organized sport (n = 121)	NR	4.5	Cessation of sports + bracing	40.8
Sys et al., 2001	n = 28 NR 17.2 (12–27)	67.9% L5 17.9% L4 17.1% L3 3.6% L2 3.6% L4+L5	Football (n = 11) Tennis (n = 5) Volley ball (n = 3) Basketball (n = 1) Baseball (n = 1) Handball (n = 1) Decathlon (n = 1) Hurdling (n = 1) Boxing (n = 1) Rugby (n = 1) Gymnastics (n = 1) Judo (n = 1)	Highly competitive athletes	2.8	Bracing (23 h/day) + conservative treatment (when the athlete was pain free with daily activities): - hamstring stretching, - abdominal strengthening, - pelvic tilts	13.2
El Rassi et al., 2013	n = 132 59% 13 (7–18)	83.3% L5 10.6% L4 6.1% multilevel	Soccer (n = 57) Basketball (n = 24) Gymnastics (n = 19) Swimming (n = 12) Football (n = 9) Baseball (n = 9) Horseback riding (n = 2)	NR	4.4	Bracing + sports modification + physical therapy (non-specified)	48 (12–144)
Blanda et al., 1993	n = 62 85.5% 15.5 (11–20)	85% L5 15% L4	Soccer (n = 15) Football (n = 13) Basketball (n = 13) Weight-lifting (n = 10) Gymnastics (n = 7) Baseball/softball (n = 7)	NR	4.1[b]	Restriction of activities for 3 months (in 50% of patients) + bracing + physical therapy (once pain free) - hamstring stretching - pelvic tilts - abdominal strengthening	50.4

(*continued on next page*)

Table 2 (*continued*)

Reference	Sample (n; % males; age)	Level of injury	Type of Sports	Level of Sports Activity	Mean duration of symptoms (months)	Treatment	Follow-up (months)
			Wrestling (n = 6) Other (n = 11)[b]			15% underwent surgery using single-level posterolateral fusion using bone-grafting (only one for pain relief, the others for development of listhesis)	
Surgical treatment							
Debnath et al., 2003	n = 22 68% 20.2 (15–34)	68.2% L5 13.6% L4 13.6% L3 4.5% L4/L5	Football (n = 13) Cricket (n = 4) Hockey (n = 3) Tennis (n = 1) Golf (n = 1)	NR	9.4	Preoperative physiotherapy (rest + trunk stabilization program) for 6 months Pars repair: - Buck's fusion (n = 19); - Scott's fusion (n = 3) Indications: failure of at least 6 months of conservative treatment (absolute rest from sport and a formal trunk stabilization programme)	NR
Gillis et al., 2015	n = 7 NR NR (16–23)	71.4% L5 28.6% L3	Football (n = 3) Volleyball (n = 2) Hockey (n = 1) Track (n = 1)	Collegiate and professional athletes (n = 4); High school athletes (n = 3)	NR	Pars repair + post-operative rehabilitation (4–6 weeks) Indications: Failure of conservative treatment and inability to participate in high impact activities.	NR
Sutton et al., 2012	n = 7 NR NR	71.4% L3 28.6% L4	Basket (n = 2) Baseball (n = 2) Football (n = 2) Volleyball (n = 1) Softball (n = 2)	NR	NR	All athletes underwent an initial conservative management and 75% required surgical management (Kakiuchi technique). Indications: Failure of 3 months of conservative treatment (activity modification, flexion-based exercises, nonsteroidal anti-inflammatory drugs, and thoracolumbar bracing) and inability to return to competition.	78
Nozawa et al., 2003	n = 20 70% 23.7 (12–37)	10% L4 5% L4+L5 85% L5	Climbing (n = 1) Golf (n = 3) Baseball (n = 3) Field athlete (n = 1) Tennis (n = 3) Walking (n = 5) Bicycle racing (n = 1) Swimming (n = 1) Softball (n = 1) Kendo (n = 1)	NR	NR	Surgical repair with segmental wire fixation. After surgery, a hard-type lumbar orthosis was used for 3 months and a soft-type orthosis for an additional 3 months Indications: Fulfillment of the following criteria: - <40 years old; - Failed conservative treatment; - Slip <25%; - Without severe degeneration of the adjacent discs; - Without nerve root irritation.	42
Hardcastle, 1993	n = 10 100% 20.9 (15–25)	90% L5 10% L4	Fast bowlers (n = 10)	NR	26.4	Surgical repair Activity was limited for the first 4–6 weeks, and a lumbosacral corset was worn. Sedentary work, driving, swimming and bicycle riding was allowed four weeks after the operation. Indications: Failure of at least 6 months of conservative treatment (physiotherapy; avoidance of fast bowling; local steroid injections)	NR
Raudenbush et al., 2017	n = 9 33.3% 15.4 (13–17)	77.8% L5 22.2% L4	Dance (n = 3) Football (n = 1) Wrestling (n = 1) Gymnastics (n = 1) Softball (n = 1) Track (n = 1) Basketball (n = 1)	NR	NR (at least 1 y)	Surgical repair Patients were restricted from bending, lifting more than 10 pounds, twisting, or sports activities for 3 months Indications: Failure of at least 12 months of conservative treatment (oral analgesics; physical therapy; activity modification)	11.9 (6–24)
Menga et al., 2014	n = 25 48.4%[a] 16 (10–37)[a]	83.8% L5[a] 6.5% L4[a] 6.5% L3[a] 3.2% multilevel[a]	NR	Competitive athletes	22 (7–60)[a]	Surgical repair (Buck's technique) Indications: Failure of conservative treatment (7–60 months)	at least 24 *

Legend: NR – Non reported.
[a] The results correspond to the totality of the study population and not only to the athletes.
[b] The results correspond to the totality of the study population and not only to the ones with spondylolysis.

failure to previous conservative management. A total of 34 complications were reported in 9 studies (Debnath et al., 2003; Gillis et al., 2015; Hardcastle, 1993; Nozawa et al., 2003; Ranawat et al., 2003; Selhorst et al., 2016, 2017; Sutton et al., 2012), including superficial wound infection, nonunion and hardware-related (breakage, pull-out). For conservative treatment only one study (Selhorst et al., 2016) reported complications (unspecified adverse events due to lumbar symptoms).

3.4. Clinical outcomes

The patient reported outcome measures are reported on Table 3. Pain intensity was assessed by four studies through a numeric rating scale (Gillis et al., 2015; Menga et al., 2014; Raudenbush et al., 2017; Selhorst et al., 2016). After conservative treatment (cessation of sports + bracing), there was an improvement of 1.7 and 3.6 points after a mean of 2 and 3.4 years of follow-up, respectively (Iwamoto et al., 2004; Selhorst et al., 2016). Surgical repair studies reported improvements ranging from 3 to 4.4 points of back pain (Gillis et al., 2015; Raudenbush et al., 2017) and one study reported one point of post-operative pain (Menga et al., 2014).

3.5. Functional outcomes

Functional ability was reported through Japanese Orthopaedic Association score (JOA) (Nozawa et al., 2003), Oswestry Disability Index (ODI) (Debnath et al., 2003; Gillis et al., 2015; Sutton et al., 2012), the Short-Form 36 (SF-36) physical component score (Debnath et al., 2003; Gillis et al., 2015), Micheli Functional Scale (MFS) (Selhorst et al., 2016) and Steiner and Micheli classification system (Blanda et al., 1993; El Rassi et al., 2013; Sys et al., 2001; Álvarez-Díaz et al., 2011).

For conservative approaches, the functional capacity (Steiner and Micheli classification) was rated as excellent in 82–84% of the patients after bracing and cessation of sports with or without bracing (depending on rest pain) (Blanda et al., 1993; Sys et al., 2001; Álvarez-Díaz et al., 2011) indicating full sports participating without need of bracing and no pain. One study reported only 36% of excellent and 56% of good results after conservative measures include bracing, sports modification, and physical therapy (El Rassi et al., 2013) that indicate that half of the patients reported occasional pain during vigorous activities. Selhorst et al. (Selhorst et al., 2016) reported a final MFS score of 12.5 ± 16 points after cessation of sports and bracing, which indicates low disability.

In the surgical studies, the JOA score improved from an average of 6.5 points after surgical repair with segmental wire fixation at a mean of 3.5 years of follow-up (Nozawa et al., 2003). After pars repair, the ODI score improved 29% and 12–20 points in the SF-36 physical component (Debnath et al., 2003; Gillis et al., 2015). Sutton et al. (Sutton et al., 2012) performed 3 months of conservative treatment followed by pars repairs, reporting a final ODI score of 5.4%, with only a few patients reporting minimal disability during sitting, lifting, standing and travelling.

3.6. Quality of life and mental status

Quality of life and mental status was assessed by SF-36 mental component (Debnath et al., 2003; Gillis et al., 2015) and only reported for surgical studies. There was an improvement of 16 points after arthrodesis (Debnath et al., 2003) and 3 points after pars repair (Gillis et al., 2015).

3.7. Radiologic healing outcomes

Radiographic outcome was assessed by repetition of imaging techniques after the selected applied treatment, either in every patient (Hardcastle, 1993; Sutton et al., 2012; Sys et al., 2001; Álvarez-Díaz et al., 2011) or restricting to only those that remained symptomatic (Debnath et al., 2003; Gillis et al., 2015).

Following conservative measures, conservative treatment + bracing showed complete healing in all athletes with unilateral lesions, in 56% of patients with bilateral lesions and no healing in those with pseudo-bilateral lesions (Sys et al., 2001). A total of 35% of bone healing was reported after sports modification, bracing and physiotherapy (El Rassi et al., 2013) and 37% of radiographic union after sports restriction, bracing and physiotherapy (hamstrings stretching, pelvic tilts and core strengthening) with some patients undergoing bone grafting repair (Blanda et al., 1993). In addition, Alvarez et al. (Álvarez-Díaz et al., 2011) reported negative control single-photon emission CT (SPECT) studies in 94% of cases after a 3 months rehabilitation and sports restriction, with or without bracing.

Concerning operative treatment, Debnath et al. (Debnath et al., 2003) compared two fusion techniques and reported worst radiographic outcome with Scott technique, with two patients requiring revision surgery due to nonunion. Gillis et al. (Gillis et al., 2015) reported that one patient complaining of recurrent symptoms, which the computed tomography (CT) scans revealed a pseudarthrosis. In several studies performing pars repair, all patients eventually achieved bone fusion at the repair site (Hardcastle, 1993; Nozawa et al., 2003; Sutton et al., 2012).

3.8. Return to sports

Criteria for returning to sports was either symptoms-based (3 studies) (Debnath et al., 2003; Iwamoto et al., 2004; Álvarez-Díaz et al., 2011), time-based (2 studies) (Nozawa et al., 2003; Raudenbush et al., 2017) or imaging based (2 studies) (Hardcastle, 1993; Álvarez-Díaz et al., 2011). Conservative approaches used more symptoms-based criteria and surgical approaches relied more time-based criteria. Imaging based criteria was used equally used in both approaches. Two studies (Sutton et al., 2012; Sys et al., 2001) reported that used CT for assessing the bone healing, but did not took into consideration these findings as return to play criteria (Table 3).

Overall, the mean return to play at any level was 92% (range, 68%–100%; n = 592) and 88% (range, 68%–100%; n = 464) return to the pre-injury sports activity level. The mean time to return to sports was 4.6 months. Subgrouping, a total of 92% (range, 68%–97%) and 88% (range, 71%–100%) of the patients returned to play after conservative (n = 492) (Álvarez-Díaz et al., 2011; Blanda et al., 1993; Donaldson, 2014; El Rassi et al., 2013; Iwamoto et al., 2004; Selhorst et al., 2016; Sys et al., 2001) or surgical (n = 100) (Debnath et al., 2003; Gillis et al., 2015; Hardcastle, 1993; Menga et al., 2014; Nozawa et al., 2003; Raudenbush et al., 2017; Sutton et al., 2012) treatment, respectively (Table 4). Returning to the pre-injury level was 81% surgical treatment (range, 70%–100%; n = 103) (Debnath et al., 2003; Hardcastle, 1993; Menga et al., 2014; Nozawa et al., 2003; Raudenbush et al., 2017; Sutton et al., 2012) and 89% following conservative treatment subgroup (range, 68%–97%; n = 185) (Blanda et al., 1993; Donaldson, 2014; El Rassi et al., 2013; Iwamoto et al., 2004; Sys et al., 2001; Álvarez-Díaz et al., 2011). Average time to return to sports was 4.3 months (range, 2–5.2 months) in the conservative (n = 430) (Donaldson, 2014; El Rassi et al., 2013; Iwamoto et al., 2004; Selhorst et al., 2016, 2017; Sys et al., 2001; Álvarez-Díaz et al., 2011) and 6.4 months (range, 6–7 months) surgical treatment (n = 54) (Debnath et al., 2003; Menga et al., 2014; Sutton et al., 2012), respectively.

Table 3
Post-treatment follow-up clinical, functional and radiological outcomes and return to play rates and timing.

Reference	Outcome assessment	Return to sports guidelines	RTP % RTP % same level timing to RTP	Results	Complications
Conservative treatment					
Donaldson, 2014	NR	NR	96% 96% 2 months (1.5–3.0)	NR	NR
Iwamoto et al., 2004	Created low back pain severity scale	After pain subsidence, the brace was removed and individual training to return to the original sporting activities was allowed.	87.5%* 87.5%* 5.4 months (1.0 –11.5)*	Level of low back pain pre 3.2 ± 0.4 Level of low back pain post 1.7 ± 0.5	NR
Álvarez-Díaz et al., 2011	Steiner and Micheli classification system	Asymptomatic; negative SPECT	68% 68% 5.2 months	Steiner and Micheli classification Excellent results 82% Good results 12% Fair results 3% Poor results 3%	NR
Selhorst et al., 2016	Micheli functional scale; pain rating	NR	92.6% NR 4.6 months	Micheli functional scale post: 12.50 ± 15.89 Pain at pre:4.82 ± 1.74 Pain at post: 1.23 ± 1.70 45.5% of low back pain recurrence - 39.5% had spondylolytic lesion	Unspecified adverse reaction (n = 10)
Sys et al., 2001	Steiner and Micheli classification system	CT scan was used to review lesions after a mean time of 13.2 months, although it has not influenced the decision to allow returning to play.	92.6% 89.3% (1 quit sports for non-medical reasons) 5.5 months	82.2% excellent 10.7% good 7.1% fair • 13 athletes who reported an acute onset: 69% osseous healing • 10 athletes with a progressive onset of • symptoms: 60% healing • 5 athletes with a progressive onset and sudden increase of symptoms: 40% healing	NR
El Rassi et al., 2013	Steiner and Micheli classification system; radiologic bone healing	NR	97% 92.4% 3 months	36.4% excellent 56.1% good 4.5% fair 3% poor Radiologic bone healing 35%	NR
Blanda, 1993	Steiner and Micheli classification system; radiologic bone healing	NR	97% 97%	84% excellent 12% good 6% fair Those who stop sports had a 16-fold odds to achieve excellent outcomes. Radiographic union 37%	NR
Debnath et al., 2003	SF-36; ODI score	The decision was based on the symptoms of the athlete.	75% 75% 7 months (4–10)	SF-36 physical pre: 27.1 ± 5.1 SF-36 physical post: 47.8 ± 7.8 SF-36 mental pre: 39.0 ± 4.0 SF-36 mental post: 55.4 ± 6.4 ODI pre: 39.5 ± 8.7 ODI post: 10.7 ± 12.9	Nonunion (n = 2)
Gillis et al., 2015	SF-36; ODI score: Visual analog score back; Visual analog score leg	NR	71.4% NR NR	Mean change from pre to post-treatment SF36 physical (+12.2) SF 36 mental (+2.9) Oswestry disability index (–29) Visual analog score back (–3) Visual analog score leg (–1.5)	Nonunion (n = 2), one due to material failure
Sutton et al., 2012	ODI	All patients were reassessed with CT scan at 3 months and attempted to return to competition whether or not radiographically healed.	100% 100% 6 months	ODI post-operative: 5.4% (0–12) Complete resolution of symptoms with CT-documented healing of the pars fracture without surgery (n = 2)	Superficial tenderness over site incision (n = 1)
Nozawa et al., 2003	JOA score Henderson classification	At 6 months, athletes were allowed to begin jogging and at about 12 months they returned to full sports activities.	100% 90% NR	JOA score pre: 21.2 ± 3.9 JOA score post: 27.7 ± 1.0 Henderson classification: 15 excellent; 5 good	Wire pull out and need for reoperation (n = 1); asymptomatic wire breakage (n = 2)
Hardcastle, 1993	NR	At 8 weeks, a CT scan was completed and if it showed evidence of union, full unrestricted activity was allowed.	100% 70% NR	NR	Wound infection with s.epidermidis (n = 2)

Table 3 (continued)

Reference	Outcome assessment	Return to sports guidelines	RTP % RTP % same level timing to RTP	Results	Complications
Raudenbush et al., 2017	VAS	After 3 months, patients were slowly allowed to return to exercise activities, with full return to activities at 5–6 months after surgery.	100% 88.9% 5–6 months	Mean pre-operative VAS 5.6 Mean post-operative VAS 1.2	No complications
Menga et al., 2014	VAS	NR	84% 76% 6 months (3–10)	Means post-operative VAS 1 (0–4)	Intralaminar screw fracture (n = 2)* Superficial wound infection (n = 1)*

*Accounting only the 40 patients that received conservative treatment (activity cessation plus bracing).
**The results are only available for this subgroup of nine patients which underwent direct repair.
***The results correspond to the totality of the study population and not only to the athletes.
Legend: NR – Non reported; JOA - Japanese Orthopaedic Association Score; SF-36 – Short-form 36; ODI - Oswestry Disability Index; CT – Computed tomography; VAS – Visual Analogic Scale.

Table 4
Pooled outcome for return to play rates and timing after conservative or surgical treatment.

Outcome: conservative vs. surgical	Pooled RTP	No. of studies included in the analysis	No. of patients included in the analysis
Pooled RTP (%)	92% vs 88%	7 vs 7	492 vs 100
Pooled RTP at the same level (%)	89% vs 81%	6 vs 6	371 vs 93
Pooled time to RTP (mo)	4.3 mo vs 6.4 mo	6 vs 3	430 vs 54

Legend: RTP – Return to play; No. – Number; mo. – Months.

3.9. Methodological quality

The mean methodological quality score was 4.3 points (range, 1 to 7) out of the 8 possible points (Table 5) with all studies classified as level IV. Most common methodological flaws comprised: lack of eligibility criteria (10 out of 14 studies); inclusion of all consecutive patients (10 out of 14 studies); lack of completeness of follow-up outcome reporting (6 out of 14 studies); and absence or insufficient statistical analysis (9 out of 14 studies). On the other hand, 11 studies (out of 14) identified the patients' condition with a standardized, reliable and valid diagnostic methods. .

The methodological nature of studies included, i.e. did not account for participant, assessment or treatment blinding and did not included randomization or comparison groups leads to the presupposition of high risk of bias. There were threats to the findings' precision (random error) as the studies did not performed a power sample calculation and did not provide comparison groups to assess the treatment efficiency. Threats to the validity (systematic error) were also found, including high risk for selection bias (self-selection of treatments, with no comparison groups which precludes randomization of interventions, sequence generation and allocation concealment), performance bias (co-interventions and lack of blinding of providers and participants) and detection bias (no assessor blinding). Four studies showed high risk of attrition bias (>10% of patients lost to follow-up) (Gillis et al., 2015; Selhorst et al., 2016; Sutton et al., 2012; Sys et al., 2001). Conversely, there was low risk of reporting and information bias in the included studies.

4. Discussion

The main finding of this systematic review is that conservative treatment of athletes with spondylolysis shows excellent rate of return to sports at any level and at the same level at a mean of 4.9 months. In those that remain symptomatic and could not return to their sporting activities, the surgical treatment provides a high

Table 5
Methodological quality according Joanna Briggs Institute Checklist for Case Series tool.

Reference	LoE	Inclusion criteria	Condition ascertainment	Valid method for ascertainment	Consecutive inclusion	Complete inclusion report	Demographics report	Outcome and follow-up	Statistical analysis	Total
Debnath et al., 2003	IV	–	+	+	–	–	+	+	+	5/8
Donaldson, 2014	IV	–	–	–	–	–	+	–	–	1/8
Gillis et al., 2015	IV	–	+	+	–	–	+	+	–	4/8
Iwamoto et al., 2004	IV	+	+	+	–	–	+	–	–	4/8
Álvarez-Díaz et al., 2011	IV	–	+	+	+	+	+	–	–	5/8
Nozawa et al., 2003	IV	–	–	–	–	–	+	+	–	2/8
Selhorst et al., 2016	IV	+	+	+	+	+	+	–	+	7/8
Sutton et al., 2012	IV	–	+	+	–	–	–	+	–	3/8
Sys et al., 2001	IV	–	+	+	–	–	+	–	+	4/8
Hardcastle, 1993	IV	–	+	+	–	–	+	–	–	3/8
Raudenbush et al., 2017	IV	–	–	–	+	+	+	+	–	4/8
Menga et al., 2014	IV	–	+	+	+	+	+	+	+	6/8
El Rassi et al., 2013	IV	+	+	+	–	–	+	+	+	6/8
Blanda, 1993	IV	+	+	+	–	+	+	+	–	6/8

Legend: NA – Non-applicable.

return to sports rate at 6.4 months. It must be considered that the surgical treatment is performed in those athletes that present a more severe pathology that have previously failed conservative treatment (Debnath et al., 2003; Gillis et al., 2015; Hardcastle, 1993; Menga et al., 2014; Nozawa et al., 2003; Raudenbush et al., 2017; Sutton et al., 2012) and require a longer time to return to sports to account for the postoperative tissue healing timeframe.

The patients' main goal of treatment is symptomatology resolution and return to their previous working or sportive activities. When considering athletes, especially at younger ages, chronic pain may prevent them from continuing their sports participation, even though other daily activities might remain painless (Nozawa et al., 2003). Conservative management frequently provides symptom relief (Iwamoto et al., 2004; Selhorst et al., 2016) and, in the case that symptoms do not subside or recur, the surgical treatment is traditionally considered with good results in decreasing pain (Gillis et al., 2015; Menga et al., 2014; Raudenbush et al., 2017). Conservative measures of the included studies were not always comprehensively reported and most commonly included bracing and/or sports cessation or modification. Cessation of sports activities (±3 months) and selective rest plays a crucial role in the conservative treatment as it minimizes the intervertebral motion promoting bony or fibrous healing and decreasing the risk of developing degenerative changes in the intervertebral disk or facet joints (El Rassi et al., 2013). Although the use of bracing is part of the classic treatment of spondylolysis, is not clearly proved that for itself can resolve all the spondylolysis symptoms. The potential benefits of bracing are allegedly lost when skeletal maturity is achieved (Tallarico et al., 2008). When symptoms persist after conservative approaches, the surgical treatment is considered and the posterolateral fusion is considered to be the gold standard for the treatment of spondylosis. Nonetheless, the pars repair may actually be considered an alternative in athletes without evidence of listhesis, as it avoids motion loss (Tallarico et al., 2008).

Professional athletes are under high pressure for all the stakeholders involved to return to their preinjury level of performance as fast as possible. Hence, the recovery of their functional abilities is paramount in this subgroup of patients. Although different outcome measures were used, considerable functional improvements were achieved after both conservative (Blanda et al., 1993; El Rassi et al., 2013; Selhorst et al., 2016; Sys et al., 2001; Álvarez-Díaz et al., 2011) and surgical treatment (Debnath et al., 2003; Gillis et al., 2015; Nozawa et al., 2003; Sutton et al., 2012).

Besides clinical and functional evaluation, the imaging studies might be of interest, namely CT scan, MRI or SPECT (Sutton et al., 2012). The CT exam has great value in the diagnostic assessment and follow-up to assess the fracture healing status (Syrmou et al., 2010). SPECT can provide additional insights regarding the fracture activity. Within this line, athletes with positive SPECT after previous negative radiograph may have higher chance of healing (Congeni, McCulloch, & Swanson, 1997). Additionally, the imaging studies are helpful in assessing the treatment outcomes and readiness to return to sports. The original included studies report reasonable radiologic outcomes after conservative and surgical treatment of spondylolysis (Blanda et al., 1993; Debnath et al., 2003; El Rassi et al., 2013; Sys et al., 2001; Álvarez-Díaz et al., 2011). Following conservative approaches (bracing, sports modification or restrictions and physiotherapy) it can be achieved bone healing (El Rassi et al., 2013; Sys et al., 2001), as well as bone union (Blanda et al., 1993). Álvarez-Díaz and colleagues (Álvarez-Díaz et al., 2011) reassessed their athletes using SPECT, reporting negative results in 94% of the patients; however, the authors highlighted that a negative SPECT exam must be interpreted as chronic inactive lesion, rather than a consolidated fracture (Lusins, Elting, Cicoria, & Goldsmith, 1994).

Every sport holds a risk for developing spondylolysis. It is believed that those sports involving repetitive movements of spinal hyperextension associated with axial loading are more likely to be associated with the development of spondylolysis. Within these lines, higher incidences have been reported in hockey, diving, wrestling, baseball, volleyball, racquet sports, and weightlifting, with higher incidence in gymnastics and American football (Drazin et al., 2011). The original studies included in this systematic review comprised athletes that practiced a variety of sports, with superior incidence within American football, soccer and baseball. The higher incidence in American football may be related to the repetitive actions of blocking, requiring sacral extension combined with an axial force of collision (Ferguson, Mcmaster, & Stanitski, 1974). In soccer may be related to the force momentum created during kicking (El Rassi et al., 2005) and in baseball to the hyperextension associated with rapid rotation during the ball launching (Drazin et al., 2011).

The findings reported in this systematic review should be translated into the clinical practice. Athletes presenting symptomatic spondylolysis should undergo conservative management as first line approach, including rest, bracing and exercise-based interventions (truck stabilization exercises and core strengthening) for at least 3–6 months. If injury aggravates (progression to spondylolisthesis), the symptoms persist and the athlete is not able to resume sporting activities the surgical treatment (pars repair) should be considered. Between 8 and 12 weeks postoperatively, a CT scan should be performed to assess bone healing. If scan shows evidence of union, the athlete should slowly resume exercise activities and when the physical, motor and cardiovascular fitness is recovered, and the athlete is able to perform the sport-specific activities without symptoms, the return to sports should be allowed.

The authors acknowledge some limitations within this systematic review. Firstly, the conclusions of this systematic review are limited to the low level of evidence of the available studies (level IV) which was associated to a high risk of bias. The heterogeneity within the conservative and surgical approaches, as well as, the absence of comparison or control groups and pre-post interventions (including the mean and standard deviation) precluded the performance of meta-analysis. The lack of completeness of follow-up outcome reporting and sample homogenization also limited the conclusions of this systematic review. In addition, the return to sports rates may be confounded by other factors, such as increasing age and pre-injury lower level of participation. For instance, in Iwamoto et al. (Iwamoto et al., 2004) study, a 60-year old patient was included and did not returned to sports due to other reasons (sports retirement).

5. Conclusion

Conservative management (bracing, sports modification and physiotherapy) of athletes with spondylolysis show excellent return to sports rates at any level and at the pre-injury level at a mean of 4.6 months. Those who fail the conservative treatment can be successfully managed with surgical treatment with a high rate of return to sports at 6.8 months.

Conflicts of interest

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