A systematic review on conservative and non-operative treatment options for Osgood-Schlatter disease

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Abstract

Background: Osgood-Schlatter disease (OSD) is a sport- and growth-associated knee pathology with painful osteochondrosis around the tibial tuberosity. Up to 10% of adolescents are affected by OSD. Treatment is primarily conservative or non-operative and includes injections, ice, braces, casts, tape and/or physiotherapy. However, treatment outcomes are often insufficiently described and there is lack of evidence for current best practice.

Objective: The aims of this systematic review are to comprehensively identify conservative or non-operative treatment options for OSD, to compare their effectiveness in selected outcomes, and to describe potential research gaps.

Methods: This systematic review was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement. CENTRAL, CINAHL, EMBASE and MEDLINE via Ovid, and PEDro were searched through to January 6, 2020. In addition, ongoing and unpublished clinical studies, dissertations, and other grey literature on OSD were retrieved. We included prospective, retrospective, case control, randomised, and non-randomised studies reporting on the effectiveness of any conservative or non-operative treatment of 6- to 28-year-old OSD patients. Studies written in English, German, or French were included. The quality of the included studies was assessed using the PEDro scale and extracted

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outcome data were narratively synthesized. In addition, we also systematically retrieved review articles for extraction of treatment recommendations.

Results: Of 767 identified studies, thirteen were included: two randomised controlled trials (RCTs), two prospective and eight retrospective observational studies, and one case series. Eight studies had no control group. The included studies were published from 1948 to 2019 and included 747 patients (563 male, 119 female, 65 sex not reported) with 937 affected knees. The study quality was poor to moderate. The two included RCTs examined the effectiveness of surplus dextrose-injection in OSD patients treated with local anaesthetics injection and came to opposite conclusions. Other than that, inter-study heterogeneity prohibited any descriptive cumulative analyses. Among the 15 review articles, the most prevalent treatment recommendations were activity modification (15/15), quadriceps and hamstring stretching (13/15), medication (11/15), ice (11/15), strengthening of the quadriceps (9/15), and knee straps or brace (8/15).

Conclusion: Conflicting evidence exists to support the use of dextrose injections. Certain therapeutic approaches, such as stretching, seem to work, but no RCT comparing specific exercises with sham or usual care treatment exists. Carefully controlled studies on well-described treatment approaches are needed to establish which conservative or non-operative treatment options are most effective for patients with OSD.

Key words: knee pain, tibial tuberosity, overuse injury, treatment, adolescents

1. Introduction

Osgood–Schlatter disease (OSD) is one of the most common osteochondrosis pathologies during growth (1). It is a sport-associated injury with severe knee pain around the tibial tuberosity and is often associated with long-term symptoms, functional impairment, and disability. It most frequently occurs between the ages of 8 and 13 years in girls, and between 10 and 15 years in boys. A Brazilian study showed a prevalence of OSD of 9.8% (11.0% in boys and 8.3% in girls) in a sample of 956 adolescent students (2). Up to 30% of OSD patients had bilateral involvement (3). Suzue et al. investigated the prevalence of osteochondrosis in 494 children and adolescent soccer players. One hundred and ninety-eight players (40.1%) had positive knee findings and thirteen of those (6.5%) had diagnosis of OSD (4). OSD as a growth-related condition is a relevant problem in young athletes. It is more common in boys. However, the gender gap is narrowing as more girls are becoming involved in sports (5). In most cases, OSD is a clinical diagnosis with symptoms of localized pain in the region of the tibial tubercle. In some instances, it is associated with swelling. Patients complain about pain on descending stairs, on prolonged periods of sitting with the knee fixed, while kneeling and during sports activities such as running and jumping, which put a load on the knee when in flexion, leading to eccentric quadriceps contraction (3). The severe knee pain often causes a patient with OSD to limp. The exact cause of this condition is unknown. It could be secondary to repetitive microtrauma of the tibial tuberosity or to a tight quadriceps (2). A common hypothesis on the aetiology of OSD suggests an asynchronous development of bone and soft tissues, in particular the rectus femoris muscle, during the maturation stage (6). This force results in irritation and, in severe cases, in a partial avulsion of the tibial tubercle apophysis. The force is increased with higher levels of activity and especially after the periods of rapid growth typically seen in adolescence (7).

A remarkable lack of information on growth-related injuries, their prevention and rehabilitation in young athletes exists (8). OSD is frequently considered a self-limiting condition, but this conception is unsatisfactory. The healing period in the bradytrophic tissue of a growth plate under traction can last one to two years (9). Hall et al. analyzed data from 357 multi-sport and 189 single-sport female athletes and found that single-sport athletes have a four times higher risk of developing patellar tendinopathy and OSD than multi-sport athletes (10).

Before OSD even occurs, implementation of prevention programs targeting growth-related overuse injuries is strongly indicated. Training methods adapted to the developmental status might help to reduce injuries and growth-related overuse conditions (8). An effective treatment

approach, however, is needed, because OSD is very likely not a self-limiting condition (11). While a wide range of treatment philosophies exist for OSD, it is predominantly treated conservatively. Adults with persistent symptoms may need surgical treatment if they do not respond to conservative treatment (12), though there is currently no conclusive support for surgical intervention in OSD patients (13). Conservative treatment options for OSD include the following: ice, physiotherapy, or even a cylindrical cast, that holds the knee in extension and is worn for several weeks (9). Smith et al. recommended local application of ice and medication such as non-steroidal anti-inflammatory drugs (NSAIDs) in order to relieve pain. Furthermore, a protective kneepad may be worn over the tibial tubercle to protect from direct trauma. Rest and activity restrictions are also often recommended (7). A further non-operative treatment option is an injection with dextrose and/or lidocaine in the area of pain on the tibial tuberosity (14).

A recently published systematic review by Cairns et al focused on the therapeutic interventions in children and adolescents with patellar-tendon-related pain (13). Although OSD-related pain complaints are not likely to spontaneously improve when treated with a “wait and see” approach, systematic evaluations of treatment strategies are currently lacking. Hamstring and quadriceps stretching and strengthening exercises are frequently recommended. However, the exact muscle-stretching techniques as well as the overall bundle of prescribed exercises are often not well described. An evidence-based, multi-management program should be available to facilitate affected adolescents’ return to sport.

With regards to conservative and non-operative treatment options, some anecdotal and practical experience from conference presentations, and some empirical data on the potential benefits is available (15, 16). However, an integrative view of conservative or non-operative treatment options and their effectiveness to improve the recovery from OSD is currently missing. Thus, the aims of this systematic review were:

1. To comprehensively identify conservative and non-operative treatment options for OSD and compare their effectiveness in selected outcomes.
2. To provide recommendations for evidence-based treatment options and for future research.

2. Methods

The systematic review has been registered in PROSPERO (CRD42018106215). The review is reported according to the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) statement (17). Initially, we expected a very low number of eligible studies for deeper analysis. Therefore, we chose a highly sensitive search strategy in order to detect the largest possible set of relevant articles.

Data sources and search strategy

We searched the following bibliographic databases: MEDLINE and Embase via OVID, the Cochrane Central Register of Controlled Trials (CENTRAL), the Cumulative Index to Nursing and Allied Health Literature (CINAHL), and the Physiotherapy Evidence Database (PEDro) (original search 13th April 2018; updated search 6th January 2020). The search terms and strategy were developed by an information specialist (CAH). Text words (synonyms and word variations) and database-specific subject headings for OSD were used (Appendix 1). In order to identify possible additional studies, the bibliographic references of all included articles and key reviews were screened. The key reviews were retrieved during title abstract screening. Furthermore, on-going and unpublished clinical trials, dissertations and theses, congress abstracts, and other grey literature were retrieved from the following URLs using the search terms “Osgood AND Schlatter” and reviewed for inclusion/exclusion according to the eligibility criteria (ongoing trials: www.science.gov, greylit.org, projectreporter.nih.gov/reporter.cfm; apps.who.int/trialsearch;dissertations/theses:www.opengrey.eu,search.proquest.com/pqdt/advanced/dissertations,www.dart-europe.eu, www.ndltd.org, oatd.org, www.openthesis.org; other grey literature: search.datacite.org).

We also hand-searched the following journals: “Sportphysio” (from Volume 1 November 2013 to Volume 6 February 2018; update to Volume 7 December 2019), “Physiopraxis” (from Volume 9 January 2011 to Volume 16 March 2018; update to Volume 18 January 2020), “Pediatric Physical Therapy” (from Volume 25 Spring 2013 to Volume 30 April 2018; update to Volume 32 January 2020), “Physiotherapy” (from Volume 96 March 2010 to Volume 104 March 2018; update to Volume 105 December 2019), “Monatsschrift Kinderheilkunde” (from Volume 163 2015 to Volume 166 2018; update to Volume 168 January 2020), “Journal of Children’s Orthopaedics” (from Volume 1 March 2007 to Volume 10 December 2016; update to Volume 13 December 2019), and “Physical Therapy in Sport” (from Volume 11 February 2010 to Volume 30 March 2018; update to Volume 41 January 2020) using the terms “Osgood AND Schlatter”.

Eligibility criteria and study selection

The PICOS tool (Population, Intervention, Comparison / Control, Outcome, and Study design) was used to define the following inclusion criteria: patients with OSD of six to 28 years of age (P); analysis of at least one conservative or non-operative intervention in either single-arm or controlled study design (I); if applicable, compared with an additional intervention or no treatment (C); assessment of at least one of the following outcomes: pain, function, or sport participation (O); the study design was either a prospective- or retrospective-observational study, a case control study, a case series, a randomized or non-randomized trial, or an abstract-only publication, (S). Only records written in English, German or French were considered. Animal studies, case reports, cross-sectional studies, letters, editorials, and diagnostic or other assessment studies were excluded. We applied no publication date restrictions. Inclusion criteria for the reviews were articles written in English, German or French. The content was specific about OSD. Reviews with general overuse sports injuries were excluded. Studies were independently selected by two investigators (CN, OF). A final decision on eligibility was achieved by consensus.

Data extraction

Data extraction was carried out by one author (CN). The following data were extracted: authors, year, study design, country, participants (i.e., sex, age, sample size for intervention, and control groups), type of intervention, duration and time of intervention, outcome measures (pain, function, sport participation, and any additional outcome reported), and main conclusions.

Quality assessment

The Physiotherapy Evidence Database (PEDro) scale, a valid measure of the methodological quality of a clinical trial (18) was used. This scale comprises 11 dichotomous items with a maximal score of 10. Studies were rated by one researcher (CN), who was not blinded to study authors, place of publication, and results. A PEDro score of seven or greater was considered as “high quality”, studies with a score of five or six were considered to be of “moderate quality”, and those with a score of four or less “poor quality”.

Data analysis

Due to the heterogeneous nature of the included studies (i.e., different study designs, interventions, outcome measures, and quality of data) a quantitative analysis was not applicable. We narratively synthesized the results based on the domains of interest. In addition,

all retrieved reviews were collected and evaluated with regard to recommendations and referenced sources for the treatment of OSD.

3. Results

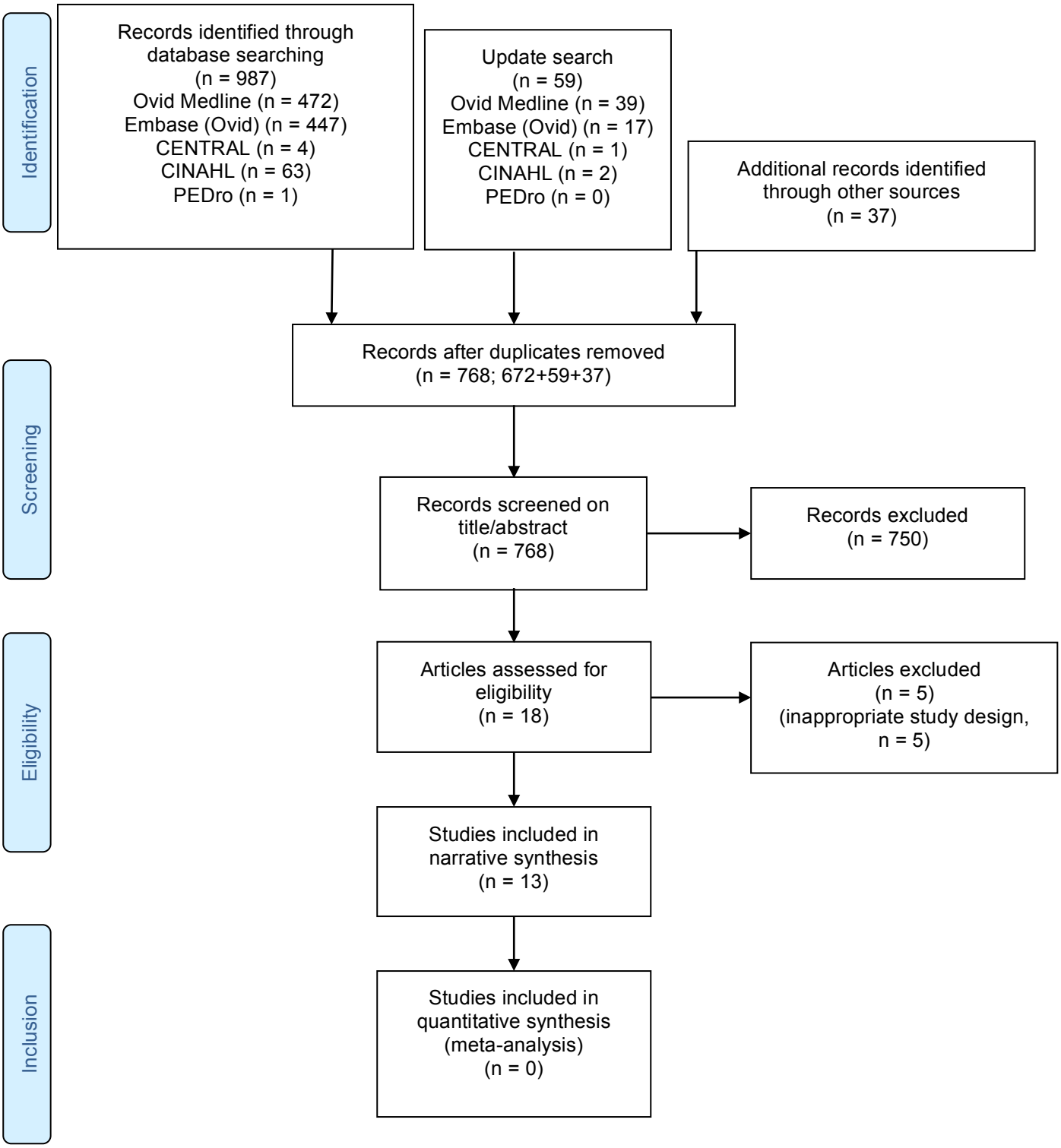
Search results, study characteristics, and quality assessment

Bibliographic database searching identified a total of 731 unique records and 37 additional records were identified through other sources (grey literature, conference abstracts, and reference chasing). After screening, thirteen articles were included (1, 14, 19-29) (Figure 1). Table 1 gives an overview of their study characteristics and main results. Of the included studies, two were randomized controlled trials (RCTs) (14, 29), two were prospective (25, 27) and eight were retrospective observational studies (1, 20-24, 26, 28). The remaining study was a case series (19). Eight studies had no control group (1, 19, 21, 22, 26-29). A further potentially relevant record was excluded due to ineligible language (30).

The included studies were published between 1948 and 2019 and comprised 747 patients with 937 affected knees (one study (27) did not report the number of affected knees). Of these patients, 563 were male and 119 female. The sex of the remaining 65 patients from two studies was not reported (23, 25). Age range was nine to 28 years. There was substantial heterogeneity among the studies in terms of population size, patient age, and sex (Table 1). Follow-up periods varied from one month to nine years. Treatment methods were analgesics (NSAIDs), avoiding sports activity, ice application, injections, thigh-muscle stretching, immobilisation of the knee joint with a resin cast, plaster or an infrapatellar strap, tape or knee bandaging, physiotherapy, massage, and extracorporeal shock wave therapy. No detailed descriptions of exercises or physiotherapy programs were provided.

The quality assessment using the PEDro scale indicated that the overall study quality was very low (Table 2). Only one study was of high quality (29), another study was considered to be of moderate quality (14). Ten studies had a PEDro score of four or less, indicating poor quality (1, 19-26, 28). One study could not be assessed because only the abstract was available (27).

Figure 1. Flow Diagram of the Literature Selection Process



Detailed description of studies

The studies are described in chronological order starting from the oldest. Kridelbaugh (19) showed a subjective improvement after anterior thigh taping in 46% of patients. No further details were described. In 1962, Ehrenborg (20) retrospectively analyzed a series of 170 patients. Of the 218 affected knees, 144 were treated with a cast for four to six weeks, and 74 knees were not immobilized. The average duration of symptoms was 14.6 months in the plaster-treated group versus 27.8 months in the non-immobilized group, suggesting effectiveness of immobilization. Reichmister (21) applied combined injections of corticosteroid and anaesthetics (Decadron® and Xylocaine®) into the infrapatellar bursa. All ten treated cases were completely cured by the time of the final injection (on average 1.9 injections). Levine (22) used an infrapatellar strap, which showed an improvement in 19 out of 24 knees after a period of six to eight weeks. In 1988, Trail et al. (23) compared surgery (tibial sequestrectomy) with conservative treatment in a retrospective study involving 51 patients (13). Surgery had no benefit over conservative treatment methods, which were not described any further. In the retrospective study by Krause et al. (24), fifty OSD patients (69 knees) were instructed to do what they could do during the acute phase of the disorder and no treatment or activity restrictions were documented. At the last follow-up, 36 (76%) had no limitations, but for 60%, kneeling continued to be uncomfortable. Additional 12 OSD patients had spent some time in plaster. Only ten patients are mentioned in the article: three had chronic symptoms and seven were unable to kneel. Yatsuka et al. (25) examined 15 knees with OSD, which were treated with hamstring stretching exercises without any further therapy. Hamstring stretching resulted in pain relief for 11 out of the 15 knees. Hussain and Hagroo (26) followed 261 patients (365 knees) for one to two years and reported that 237 patients (91%) responded well to heterogeneous conservative measures including activity modification, rest with NSAID medication, and knee bandaging. Strickland et al. (27) conducted a pilot study with 25 patients with OSD suffering from symptoms for eight months on average (range of one week to 36 months). Physiotherapy treatment consisted of myofascial release massage, and stretching of the quadriceps group. When patients achieved a full-wall-squat (on average after 20 days), they were discharged and able to return to their sporting activities as normal, with no reported further problems. Patients returned to their sport in a shorter time than the authors anticipated. At various follow-up dates (1–5 years), only two patients reported recurrence, though they likely had not followed the recommended advice on stretching. Topol et al. (14) randomly assigned 54 patients to usual care (hamstring stretching, quadriceps strengthening exercises), local anaesthetic (lidocaine injection), or local anaesthetic plus dextrose injection. Average Nirschl Pain Phase Scale scores

improved more in the dextrose-treated knees (from 4.6 to 0.7) than the lidocaine-only-treated (from 4.2 to 1.8) or usual-care-treated knees (from 4.3 to 3.1). Moreover, the duration of sports limitation and the duration of sports-related symptoms were reduced in the dextrose injection group compared to the other groups and all patients who gave up sports or were unable to perform exercises were part of the usual care group. Lohrer et al. (1) treated 14 patients (16 knees) with radial extracorporeal shock waves. After 5.6 years, 12 knees (75%) reached the maximum score on a patellar tendinopathy questionnaire. Duperron et al. (28) immobilized 30 OSD patients' knees with a plaster for four weeks. Time until resuming sports was on average 14.4 ± 14.2 weeks, but 10 out of 30 patients still suffered from pain after plaster removal. The latest study by Nakase et al. (29) readdressed the effectiveness of the dextrose injection. Thus, 38 patients who received non-invasive therapy for more than one month and had no improvement were randomly assigned into two groups to receive an injection with dextrose (plus anaesthetic) or saline (plus anaesthetic) in double-blind procedure. While both groups displayed marked improvements, negligible differences were found between the two groups at any follow-up time, which challenged the previous results by Topol et al. (14).

Reviews and therapy recommendations

To provide a closer look at current treatment recommendations, 15 articles were gathered (3, 12, 31-43) (Table 3). While 13 reviews were flagged as key reviews during title abstract screening of database search results, grey literature searching provided a clinical guideline (42), and an additional review article (33). The most frequently recommended treatments were activity modification (15/15) (3, 12, 31-43), quadriceps and hamstring stretching (13/15) (3, 12, 32-39, 41-43), medication (NSAIDs) (11/15) (3, 12, 32-34, 36, 38, 39, 41-43), ice (11/15) (3, 32-36, 38, 39, 41-43), quadriceps strengthening (9/15) (3, 32, 35, 36, 38, 39, 41-43), and knee straps or braces (8/15) (3, 33, 35, 36, 38, 39, 41, 42), Surgery was indicated only as an exception (12, 31, 34, 41-43). Patient and parent education was mentioned five times (34, 37, 40-42) and one review recommended core stability and balance training (43). The review articles were published between 1977 and 2019. Cited studies were from the years 1903 to 2019. The most cited studies were: Topol et al.(14), Hussain et al. (26), and a review article by Mital et al. (31). One review (34) adapted therapy recommendations to a clinical classification scale for OSD symptoms. For patients classified with grades one and two (pain symptoms are completely absent after the end of sports activities), parent education, modification of sports activities, NSAIDs, ice, hamstring stretching, and shock-absorbing insoles were recommended. Patients classified with grade three (pain does not disappear between sports activities) were

advised to rest, be immobilized in a cast, and undergo specific rehabilitation programs (34). Circi et al. and Ladenhauf et al. recommended to reduce sports activity and perform non-impact exercises such as swimming or cycling (12, 43). Nührenborger et al. (41) recommended ice application, whereas application techniques and characteristics were not described in detail.

4. Discussion

The main result of this review is the absence of high-quality studies evaluating the effectiveness of interventions for the treatment of OSD. The number of included studies was low and the studies were heterogeneous. Hence, conducting a quantitative analysis was impossible. The number of available review articles covering OSD treatment options is even larger than the number of available original studies. The problem of OSD in athletically active children and adolescents is being recognized, but evidence-based guidelines do not exist, meaning that treatment recommendations are based on clinicians' experience and anecdotal evidence.

OSD is a long-term pain condition that occurs during adolescent growth with a potential to develop into chronic knee pain. Therefore, it is important to avoid chronic problems and to offer patients optimal management with evidence-based practice. Any lack of evidence or consensus causes uncertainty on how much activity can be recommended (44). The treatment of OSD is merely based on clinical experience and expert opinion (45). The therapist individually adapts exercises performed in physiotherapy. The suggested treatment options within the available review articles are quite comparable. Remarkably, the same publications were repeatedly referenced and only one review article based its recommendations in part on an RCT. The therapist individually adapts exercises performed in physiotherapy. Only one review article advised core stability and balance training (43). In the included articles, the most frequently mentioned therapy was injections (14, 21, 29) followed by splinting methods using a patellar strap, tape, or bandage (19, 22, 26). Immobilization with a cast was studied twice (24, 28). Lohrer et al. tested shock wave therapy in a pilot study, which is another type of passive intervention (1). One study investigated the use of two different hamstring stretching techniques (25). Other researchers used a combination of surgery (tibial sequestrectomy), casting, injections, and physiotherapy (20, 23).

The two identified RCTs on OSD treatment both examined injection therapy with or without a hypertonic dextrose solution, which is also known as prolotherapy. Apart from OSD, hypertonic dextrose is also used in other tendinopathies and fasciopathies with unclear effectiveness (46). Whereas Nakase et al. (29) ran a double-blind comparison of two injection groups, Topol et al.

(14) conducted a three-armed RCT that also analyzed a usual care group. Concerning the controversial conclusions of the two RCTs on the effectiveness of dextrose, there is no obvious resolution. Different factors including the use of inappropriate comparator (saline), quality of blinding, divergent outcome scales and statistical methods could have played a role (14, 29, 47). More research is needed to conclusively learn about the potential benefits of hypertonic dextrose injections for OSD.

When considering all of the studies and their results, a “consensus” treatment recommendation may be the modification of physical activity. Taping or patellar strapping is frequently recommended, which is similar in motivation to the approach of isometric strengthening the quadriceps in knee extension and stretching the hamstrings. However, there is a lack of RCTs that provide high-level evidence in favour of stretching or strengthening exercises for the lower extremity in children or adolescents with OSD. The evidence for the application of exercise therapy options in patients with OSD is even contradictory and controversial. Considering the lack of evidence with regard to the efficacy of treatment options in general, it is obvious that recommendations on specific intervention characteristics (i. e. duration, frequency, intensity of exercise-based interventions) are missing all the more (44). Thus, unfortunately, the formulation of evidence-based treatment recommendations, as defined in our systematic review aim two, is currently not feasible.

Although it is extremely important to seek evidence-based therapy for existing OSD conditions, it is also important to focus on prevention strategies that reduce overload injuries. The long-term impact of a person with OSD being unable to participate in typical physical activity and sports team peer groups should not be underestimated (44). The underlying reasons why one adolescent develops OSD yet an equally active peer does not, is not well understood. With regard to injuries in general, scientifically evaluated exercise-based prevention programmes already exist for young athletes (48). For instance, a multi-national cluster-RCT found that an injury prevention warm-up programme is effective in reducing overuse injury rate to the lower extremities in young football players (49). However, though included in this injury category, no specific data on OSD were reported. The prevention of pediatric overuse injuries requires a comprehensive, multidimensional approach that may include improved injury surveillance, identification of risk factors for injury, thorough physical examination prior to participation, supervision and education, improved training and conditioning programs, and delayed specialization (50).

Review of the grey literature offers valuable information about possible treatment programs, which are frequently commercially advertised. A prominent example is the so-called Strickland protocol, which has been presented at the European College of Sports Science Conference in Portugal 2008 (27). The protocol is mainly a combination of myofascial release massage (2 min daily) and active stretching of the m. quadriceps femoris. Comparable therapeutic approaches may appear effective and successful. Very few original studies, however, are available on the treatment of OSD, in particular RCTs that document the overall effectiveness of a treatment compared to no treatment or treatment as usual.

5. Methodological considerations

Strengths of this systematic review are the inclusion of German, French, and English articles and the searching of grey literature sources. To the best of our knowledge, this level of detail has not been achieved in previous reviews. Limitations of this systematic review are the heterogeneity of the included studies, the inclusion of non-peer-reviewed studies, the widespread lack of control groups and the missing data in patient characteristics (e.g. number of affected knees). The PEDro scale quality assessment confirmed that the overall study quality is a major limitation.

6. Conclusion and future directions

Poor evidence exists for the use of injections with local anaesthetic and no evidence for an exercise program for patients with OSD. In such absence of high-quality evidence, the first step should be to rely on expert consensus for best practice recommendations (Table 3) (51). It is desirable that, in a subsequent step, high-quality clinical RCTs be conducted. Future investigations should focus both on well-described and approved treatment approaches and on specific exercise programs. Children are generally regarded as the future of our society and, therefore, their health should be of particular importance (8).

Conflict of Interest Statement: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author contributions: CN and OF designed and organized this systematic review. CAH organized the literature search process. CN and OF analyzed the data and wrote the manuscript draft. CAH critically revised the article.

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Table 1. Summary of the Results of Included Studies

Author, year, study type, country	Patients (n), knees (n), age (y), sex , controls	Type of intervention	Duration and time of intervention	Results	Outcome Measures	Time points	Conclusion
Kridelbaugh et al., 1948, case-series, USA	13 patients, 16 knees (4 right, 6 left, 3 bilateral); 17-19years; 13 males; no control group	Tape (cross strapping) around the knee	monthly	46.1% improved under treatment, 15.4% were not improved, 15.4% were made worse, 23.1% unable to make any follow-up	- x-rays - subjective improve-ment	6 weeks	OSD may be precipitated and / or symptoms aggravated by the increased exercise carried on during Naval training
Ehrenborg G., 1962, retrospective observational study, Sweden	170 patients; 218 knees (47 right, 75 left, 48 bilateral); 9-15 years; 102 males, 68 females	a) 30 patients (74 knees), were not immobilized, excused from school gymnastics, in a few cases an elastic bandage was applied to the knee, some had a brief period of bedrest b) 144 knees were treated by immobilization of the knee in plaster (84 males, 91 knees; 49 females, 53 knees) c) 17 patients with 18 surgically treated knees (8 males, 9 females)	Duration of symptoms a) 27.8 months in the non-immobilized knees b) 14.6 months (immobilization for 4-6 weeks) c) 14.6 months Mean observation period: 1-7 years	In the cases without immobilization of the knee, half of the lesions healed with significant deformity of the tuberosity or ossicle formation, whereas this picture was seen in only 1/3 of the plaster group	- knee mobility - girth of the limb - x-ray of the knee	1 – 7.3 years (mean observation)	The OSD lesion is traumatic in origin. Its treatment should be in accordance with modulated principles of modern traumatology.
Reichmister J., 1969, retrospective observational study, USA	10 patients, 14 knees (4 right, 2 left, 4 bilateral); 12-15y; 9 males, 1 female; no control group	Injections (Decadron, Xylocaine), told to resume activity when they felt better. Treatments: 1-4 injections.	Injections were continued weekly until the patients no longer complained of tenderness over the tibial tubercle.	2-3 days after injections the children resumed activity. All of the 10 cases were relieved completely by the time of their last injection.	activity NR[3]	NR[3]	This method of treatment spares the children the prolonged immobilization in a cast.
Levine J et al. , 1981, retrospective observational study, USA	17 patients, 24 knees (6 right, 4 left, 7 bilateral); 11-17years. 15 males, 2 females; no control group	Infrapatella strap during periods of activity	2 weeks – 12 months (average 12.17 weeks)	79.1% improved after 6 to 8 weeks of use	NR[3]	NR[3]	Infrapatella strap provides a very satisfactory alternative.
Trail IA, 1988, retrospective observational study, England	51 patients, 56 knees (side NR[3]), 10-17y, sex NR[3]	31 patients (33 knees) treated operatively (tibial sequestrectomy); 20 patients (23 knees) treated conservatively (reduction in activity with avoidance of sport, 3 pat. had a plaster cast, 4 injection of local anaesthetic and steroid, 3 physiotherapy using ice packs and ultrasound	Follow-up (average): 4y 6m in the surgically treated group; 5y 6m in the conservatively treated group	82% were asymptomatic (operated group); 91% (conservative group); p < 0.8	duration of symptoms	Interview 2 to 8 years after surgery or conservative therapy	Tibial sequestrectomy has no significant benefit over conservative methods of treatment.

Krause BL et al., 1990, retrospective observational study, England	62 patients, from 50 patients 69 knees affected (16 right, 13 left, 20 bilateral, 20 NR[3]), (from 12 patients affected side NR[3]); 10-14years; 33 males, 17 females	Interview, examination clinically and radiologically after no treatment or after plaster cylinder	50 patients had no specific treatment (do what they were able to). Further 12 patients had spent some time in a plaster cylinder.	50 patients: 60% were still unable to kneel without pain; 76% had no limitation of activity. 12 patients: 3 had chronic symptoms, 7 unable to kneel	- duration of symptoms - to kneel without pain	Average follow-up: 9 years	For most patients the symptoms of OSD resolve spontaneously, although many patients may have difficulty in kneeling
Yatsuka T et al., 1992, prospective observational study, Japan	14 pat. with OSD; 15 knees (affected side NR[3]); 11-28y; sex NR[3]; 402 controls, 144 (18-41years) of them with compression pain of the patella	OSD patients: hamstring stretching exercise (two methods) without medication and other physical therapy Control group: 60/144 - hamstring stretching exercises for one month, 84 were observed	Patients: five minutes three times a day hamstring stretching exercises; Evaluation of the effects of exercises was done at 4 or 8 months after initial visit.	Pain was relieved in 45 patients, improved angle of hamstring tightness with an average of 12°-15°. Controls: compression pain of the patella were improved (50%) in the exercise group. Hamstring tightness improved from 48.2° to 42.5°.	- angle of hamstring tightness - pain	1, 4 and 8 months	NR[3]
Hussain A, Hagroo GA, 1996, retrospective observational study, Saudi Arabia	261 patients, 365 knees (67 right, 90 left, 104 bilateral); 9-26 years; 253 males, 8 females; no control group	Initial treatment for all patients was conservative: analgesics (NSAIDs), avoiding sports activity, and modified Robert Jones bandage in a few. a) conservative treatment: 237 patients b) surgery: 24 patients	a) - for 6 months in those > 15years - for 1 year in those < 15 years - Follow-up 12-24 months (mean 1.5y) b) surgery and crutches, cylinder casts/Robert Jones bandages - Follow-up 3-6 weeks (mean 4.5 weeks)	91% responded well to the conservative treatment. All patients returned to their normal activities after 3-6weeks	- return to normal activity	1 - 2 years	We conclude that the treatment of OSD is predominantly conservative, and in fact can be entirely ignored. There is a very small place for operative treatment.
Strickland et al., 2008, prospective observational study (congress abstract), England	25 patients, affected knees NR[3]; 10-15y; 6 females, 19 males; no control group	Wallslide test, myofascial release massage (MRM), stretching of the quadriceps group	MRM daily for 2 minutes, once pain free knee flexion was achieved, active stretching was performed daily by the patient	All patients achieved full wall squat in an average of 20 days (±12) with a max. of 50. Improvement in wall slide was significant ($p<0.02$).	Wall Slide	Baseline, NR[3], follow-up 1-5 years	MRM and stretching are likely to be an important intervention in the active treatment of this disabling condition.

Topol et al., 2011, RCT, Argentina	54 patients, 65 knees, affected side NR[3]; 9-17y, 51 males, 3 females	Randomly assigned: 1. usual care for 3 months (therapist-supervised) 2. Lidocaine injection monthly for 3 months 3. Dextrose injection monthly for 3 months • all subjects were then offered dextrose injections monthly as needed for 1 y • all patients had to attempt 2 months of hamstring stretching, quads strengthening	Injections: monthly for 3 months compared with usual care	NPPS[1] scores improved more in dextrose-treated knees than either lidocaine-treated (p=.004) or exercise-treated knees; p < 0001). Lidocaine was significantly better than usual care (p=.024)	NPPS[1]	Baseline, 3 months	Dextrose injection resulted in more rapid and frequent achievement of unaltered sport and asymptomatic sport than usual care.
Lohrer et al., 2012, retrospective observational study, Germany	14 patients, 16 knees (8 right, 6 left, 2 bilateral); 13.2-14.7y; 9 males, 5 females; no control group	Radial extracorporeal shock waves (ESWT)	Weekly one therapy-session, a total of 3-7 therapy-sessions. Follow up 5.6y (3.4-6.7y) later.	Median VISA[2] score was 100. 75% reached 100 out of 100 VISA points. No side effects of the ESWT.	VISA[2] score	Follow up 5.6 years after treatment	This pilot study demonstrates that radial ESWT is safe and promising treatment for adolescent athletes with OSD
Duperron L et al., 2016, retrospective observational study, France	30 patients; 30 knees (13 right , 17 left); 9-15 years; 22 males, 8 females; no control group	Cruro-maleolar immobilisation with resin cast (knee)	immobilisation for 4 weeks	- median time to restart sport 11 weeks - median time to be back at the same level of performance 16 weeks	Time to restart sport; Time to be back at the same level of performance	All patients were contacted by telephone at least 4 months after the last consultation	The immobilization allows a short time to restart sports, and seems to be correlated in the ossicle's presence.
Nakase J et al., 2019, RCT, Japan	38 patients; 49 knees, affected side NR[3]; 12.3±1.1 years; 37 males, 1 females; no control group	Injection of 1% lidocaine with 20% dextrose or 1% lidocaine with saline	Injections for 3 months (monthly 1 injection)	VISA scores of the dextrose and saline groups were 58.7 ± 18.3 and 63.4 ± 16.4 (max score 100). At 1-month follow-up: 76.9 ± 20.4 and 72.6 ± 22.2 and at 2-month follow-up 73.3 ± 26.8 and 74.6 ± 26.7. Final follow-up 85.7 ± 18.7 and 83.2 ± 19.2. No differences were found between the two groups at any time point.	VISA[2] score	- 1 month after first injection + second injection - 2 months after first injection + third injection - 3 months after first injection	The authors were not able to evaluate the efficacy of the dextrose injection compared to that of saline.

[1] NPPS: Nirschl Pain Phase Scale
[2] VISA: Victorian Institute of Sports Assessment Patellar Tendinopathy Questionnaire
[3] NR: not reported

Table 2. Scores on the PEDro Scale in the Included Studies

PEDro Scale Item	Kridel-baugh et al., 1948	Ehren-borg, 1962	Reich-mister, 1969	Levine et al., 1981	Trail, 1988	Krause et al., 1990	Yatsuka et al., 1992	Hussain, 1996	Strickland et al., 2008[2]	Topol et al., 2011	Lohrer et al., 2012	Duperron et al., 2016	Nakase et al., 2019
Eligibility criteria[1]	-	-	-	-	-	-	-	-	NR	-	+	+	+
Random allocation	-	-	-	-	-	-	+	-	NR	+	-	-	+
Concealed allocation	-	-	-	-	-	-	?	-	NR	-	-	-	?
Groups similar at baseline	-	-	-	-	?	-	-	-	NR	?	-	-	+
Subject blinding	-	-	-	-	-	-	-	-	NR	-	-	-	+
Therapist blinding	-	-	-	-	-	-	-	-	NR	+	-	-	+
Assessor blinding	?	-	?	?	?	-	?	-	NR	?	-	-	?
Adequate follow-up	-	-	+	+	+	+	+	+	NR	+	+	+	+
Intention-to-treat analysis	?	?	?	?	?	?	?	+	NR	+	?	+	?
Between-group statistical comparisons	-	+	+	-	+	-	+	-	NR	-	-	+	+
Point measures and variability data	-	-	-	-	+	+	+	+	NR	+	+	+	+
Total Score	0/10	1/10	2/10	1/10	3/10	2/10	4/10	3/10	NR	5/10	2/10	4/10	7/10

+, item satisfied; -, item not satisfied; ?, item unclear
[1] not accounted
[2] not rated

Table 3. Summary of Treatment Recommendations given in Review Articles

Author, Year, Study Design, Country	Treatment	Cited authors from the treatment section of the article
Mital MA, 1977, Review, UK	Relieving pain, doing virtually nothing to numerous surgical manoeuvres; rest, strapping, immobilization (cast), rarely: surgical treatment	Osgood RB (1903); **Reichmister J (1969)** [1]**;** Smillie IS (1962); Watson-Jones R (1976); (other references not clearly stated)
Antich TJ, 1985, Review, USA	Activities pain limited, patient education, Iontophoresis, anti-inflammatory medication, local anaesthetic, heating with hot packs (anterior and posterior thigh) followed by quadriceps and/or hamstring stretching, strengthening of the quadriceps, ice-massage	Bertolucci LE (1982); Bowers KD (1981); Bunch WH (1981); Grass AL (1978); Harris PR (1982); Katz JF (1981); Kelly JM (1971); **Levine J (1981)** [1]**;** Micheli LJ (1983); Mital MA (1977); Mital MA (1980); Reichmaster J (1961); Rostron PKM (1979); Smillie IS (1978); Willner P (1969)
Gholve PA, 2007, Review, USA	Mild pain: Ice, limitation of activities, NSAIDs, protective knee padding, physical therapy: strengthening and improving flexibility (quadriceps, hamstring, iliotibial band, gastrocnemius). Not recommended initially: high-intensity quadriceps-strengthening exercise. Moderate to severe pain: Activity modification, rest, NSAIDs, immobilization.	Beovich R (1988); **Hussain A (1996)** [1]**;** Mital MA (1980); Ross MD (2003);
Uzunov V, 2008, Review, NZL	Rest, ice, compression, elevate (RICE), warming up before activity, icing after activity, rest, activity modification, infrapatellar strap, anti-inflammatory medication, physiotherapy, stretching (hamstring, calf, hip), immobilization (cast)	Bhatia MM (2004); Brodwell Jackson D (1993); Cliggot (2001); Dunn JF (1990); Gerulis V (2004); Globus S (2002); Hirano A (2002); Kolt GS (2003); Lackey E (2006); **Levine J (1981)** [1]; McCance KL (2002); McCarty LP (2005); McKesson (2004); Meisterling RC (1998); Peck DM (1995); Prentice WE (2001); Reeves KD (2006); Subotnick SI (1977); Wall EJ (1998);
Eberhardt O, 2009, Review, Germany	Therapy management is based on the clinical classification grade 1 and 2 (pain symptoms are completely reduced after the end of sports activities): Parent education, modification of sports activities, NSAIDs, ice, hamstring stretching, shock absorbing insoles. Grade 3 (pain does not disappear between sports activities): rest, immobilisation in a cast, specific rehabilitation program. Surgery only in rare cases (excision of ossicles). Not recommended: local injection of corticosteroids.	Faigenbaum AD (1999); Renström PA (1997) Wong J (2006)
Charrette M, 2012, Review, USA	Restricted activity, cryotherapy, Vitamin C, lower extremity stretching and strengthening, knee strap or brace	El-Husseini TF (2010); Micheli LJ (1983);
Lipman R, 2015, Review, USA	Pain control, rest, ice, compression and elevation (PRICE), NSAIDs, physical therapy (quadriceps stretching, strengthening, taping, bracing)	Crossley K (2001); Kodali P (2011); Maher P (2013); Zumwalt M (2008);
Beaubois Y, 2016, Review, France	Correcting biomechanical disorders, pain modulated sports rest, analgesics should be avoided, quadriceps stretching, massage by a third person in the evening, hamstring strengthening, parents education	De Lucena GL (2011); Pessin T (2003); Rambaud A (2013); Sarcevic Z (2008); Schrouff I (2015);

Vaishya R, 2016, Review, Afghanistan	Limit physical activities, ice, NSAIDs, protective padding, physiotherapy: quadriceps, hamstrings, gastrognemius exercises, immobilising (cast or brace), surgical treatment	Binazzi R (1993); Frank JB (2007); Kujala UM (1985); Orava S (2000); **Trail IA (1988)** [1];
Circi E, 2017, Review, Turkey	Non-impact activities (swimming, cycling), hamstrings and quadriceps flexibility exercises, controlled immobilization, NSAIDs, injections, rarely indicated: surgical treatment (removal of ossicle fragmentation), not recommended: injection of corticosteroids into patellar tendon	Cakmak S (2014); **Topol GA (2011)** [1];
Smith JM, 2017, Review, USA	Rest, activity modification, ice, NSAIDs, knee pad, Hamstring stretching, quadriceps stretching and strengthening	Gholve PA (2007); Launay F. (2015); Peck DM (1995)
Cairns G, 2018, Systematic Review, UK	Load modification, patient and parent education, advise on a return to sport based on symptoms, weak evidence to support the use of dextrose injections, no evidence to support the use of specific types of exercises	**Topol GA (2011)** [1]; **Trail IA (1988)** [1];
Nührenbörger C, 2018, Review, Luxembourg	Patient education, ice, limitation of activities, NSAIDs, protective knee padding and physical therapy: stretching and strengthening (lower extremity). Surgical treatment (only as an exception).	Circi E (2017); Gaulrapp H (2016);
Kienstra AJ, 2019, Clinical Guideline, USA	Ice, NSAIDs, knee pad, physical therapy (strengthening quadriceps, stretching quadriceps and hamstring), activity modification, injection, parent and patient education. Rarely indicated: surgery, not recommended: immobilization.	Beovich R (1988); **Hussain A (1996)** [1];Rostron PK (1979); **Topol GA (2011)** [1]; Wall EJ (1998); Weiss JM (2007);
Ladenhauf HN, 2019, Review, Austria	Rest, no physical activities (except swimming, cycling), anti-inflammatory medication, ice, physical therapy (core stability, strengthening and stretching of the lower extremity. Rarely indicated: surgical treatment (removal of ossicle fragmentation). Not recommended: bracing, casting, corticosteroids.	**Hussain A (1996)** [1]; Midtiby SL (2018); Rathleff MS (2019); Rostron PK (1979); **Topol GA (2011)** [1]; Vaishya R (2016)

[1] Original studies, also included in this review

Appendix 1. Grey Literature Search

Osgood-Schlatter Grey Literature URLs
(search term: «Osgood Schlatter»)

Ongoing/unpublished Trials:

From www.science.gov:

https://clinicaltrials.gov/ct2/show/NCT02799394

https://clinicaltrials.gov/ct2/show/NCT01300754

https://clinicaltrials.gov/ct2/show/NCT02824172

https://clinicaltrials.gov/ct2/show/NCT01826071

https://clinicaltrials.gov/ct2/show/NCT03589001

From greylit.org:

0

From https://projectreporter.nih.gov/reporter.cfm:

0

From http://apps.who.int/trialsearch/:

In addition to the 4 clinical trial (NCT…) listed above:

http://apps.who.int/trialsearch/Trial2.aspx?TrialID=JPRN-JMA-IIA00236

http://apps.who.int/trialsearch/Trial2.aspx?TrialID=JPRN-UMIN000013899

http://apps.who.int/trialsearch/Trial2.aspx?TrialID=NTR5499

Dissertations and theses:

From www.opengrey.eu:

http://hdl.handle.net/10068/708946

From https://search.proquest.com:

https://search.proquest.com/docview/896958799/B37EB75F46DF4B8APQ/1?accountid=14616

https://search.proquest.com/docview/230893809/B37EB75F46DF4B8APQ/2?accountid=14616

https://search.proquest.com/docview/304028482/B37EB75F46DF4B8APQ/3?accountid=14616

https://search.proquest.com/docview/303647852/B37EB75F46DF4B8APQ/4?accountid=14616

From www.dart-europe.eu:
http://www.dart-europe.eu/full.php?id=1045339
http://www.dart-europe.eu/full.php?id=813425

From Networked Digital Library of Theses and Dissertations (www.ndltd.org):
http://search.ndltd.org/show.php?id=oai%3Aunion.ndltd.org%3AIBICT%2Foai%3Arepositorio.ufrn.br%3A123456789%2F13208&back=http%3A%2F%2Fsearch.ndltd.org%2Fsearch.php%3Fq%3Dosgood%2BAND%2Bschlatter
http://search.ndltd.org/show.php?id=oai%3Aunion.ndltd.org%3AOCLC%2Foai%3Axtcat.oclc.org%3AOCLCNo%2F464888656&back=http%3A%2F%2Fsearch.ndltd.org%2Fsearch.php%3Fq%3Dosgood%2BAND%2Bschlatter

From Open Access Theses and Dissertations (https://oatd.org/):
http://hdl.handle.net/1946/25854
http://www.theseus.fi/handle/10024/120699
http://www.theseus.fi/handle/10024/127093
http://repositorio.ufrn.br/handle/123456789/13208
http://bdtd.bczm.ufrn.br/tedesimplificado//tde_busca/arquivo.php?codArquivo=4160
http://www.theseus.fi/handle/10024/140698
http://hdl.handle.net/10803/399871
http://hdl.handle.net/11441/56007
http://fondosdigitales.us.es/tesis/tesis/3151/enfermedad-de-osgood-schlatter-aportacion-clinica-y-ultraestructural-sus-criterios-diagnosticos-y-terapeuticos/
http://hdl.handle.net/1765/39212

From OpenThesis (http://www.openthesis.org/):
http://www.openthesis.org/documents/Association-Between-Impairments-Function-in-227190.html
http://www.openthesis.org/documents/Exercise-Type-Musculoskeletal-Health-Injury-277038.html

Congress proceedings:
From World Physical Therapy (http://www.wcpt.org/):
0

From International Organisation of Physical Therapists in Paediatrics (http://www.wcpt.org/ioptp):
0

Clinical guidelines:

From UpToDate (www.uptodate.com):
https://www.uptodate.com/contents/osgood-schlatter-disease-tibial-tuberosity-avulsion?search=osgood%20schlatter&source=search_result&selectedTitle=1~69&usage_type=default&display_rank=1

Other:

From DataCite Search (https://search.datacite.org/):
https://www.researchgate.net/publication/281149735_The_Pathophysiology_and_Rehabilitation_of_Osgood-Schlatter_Syndrome?channel=doi&linkId=55d8b00e08aed6a199a889f0&showFulltext=true
https://zenodo.org/record/970185#.Wrtp12eLVGo

From other sources (google, citation chasing, …):
http://ispub.com/IJOS/3/1/7021
http://www.osgood-schlatter-disease.com/faq-osgood-schlatters/osgood-schlatters-disease/
https://www.cadth.ca/sites/default/files/pdf/htis/J0209%20%20Interventions%20for%20the%20Management%20Osgood-Schlatter%20final.pdf
http://video.rch.org.au/ortho/fact_sheets/OSGOOD-SCHLATTER.pdf