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Review Article

A systematic review on conservative treatment options for OSGOOD-Schlatter disease

Cornelia Neuhaus [a, b, *], Christian Appenzeller-Herzog [c], Oliver Faude [b]

[a] Department of Therapy, University Children's Hospital of Basel, Basel, Switzerland
[b] Department of Sport, Exercise and Health, University of Basel, Birsstrasse 320 B, 4052, Basel, Switzerland
[c] University Medical Library, University of Basel, Spiegelgasse 5, 4051, Basel, Switzerland

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ABSTRACT

Objectives: Osgood-Schlatter disease (OSD) is a sport- and growth-associated knee pathology with locally painful alterations around the tibial tuberosity apophysis. Up to 10% of adolescents are affected by OSD. Treatment is predominantly conservative. The aims of this systematic review are to comprehensively identify conservative treatment options for OSD, compare their effectiveness in selected outcomes, and describe potential research gaps.

Methods: A systematic literature search was conducted using CENTRAL, CINAHL, EMBASE, MEDLINE, and PEDro databases. In addition, ongoing and unpublished clinical studies, dissertations, and other grey literature on OSD were searched. We also systematically retrieved review articles for extraction of treatment recommendations.

Results: Of 767 identified studies, thirteen were included, comprising only two randomised controlled trials (RCTs). The included studies were published from 1948 to 2019 and included 747 patients with 937 affected knees. Study quality was poor to moderate. In addition to the studies, 15 review articles were included, among which the most prevalent treatment recommendations were compiled.

Conclusion: Certain therapeutic approaches, such as stretching, have apparent efficacy, 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 treatment options are most effective for patients with OSD.

1. Introduction

Osgood–Schlatter disease (OSD) is a common osteochondrosis pathology during adolescent growth (Lohrer, Nauck, Scholl, Zwerver, & Malliaropoulos, 2012). In most cases, OSD is a clinical diagnosis with locally painful alterations around the tibial tuberosity apophysis. It results in knee pain, often severe enough to cause limping, sometimes accompanied by swelling or deformity, and frequently resulting in long-term symptoms with functional impairment. Patients experience pain on descending stairs, after prolonged periods of sitting with the knee immobile, while kneeling, and during sports activities (Gholve, Scher, Khakharia, Widmann, & Green, 2007). The knee pain can often be severe enough to cause limping. OSD as a growth-related condition is a relevant problem in young athletes. Suzue et al. investigated the prevalence of osteochondrosis in 494 child and adolescent soccer players—198 players (40%) had positive knee findings; thirteen of those (6.5%) an OSD diagnosis (Suzue et al., 2014). Another study reported that up to 30% of OSD patients had bilateral involvement (Gholve et al., 2007). Although OSD is more common in boys, with more girls becoming involved in sports the gender gap is narrowing (Domingues, 2013). OSD most frequently occurs between the ages of 8 and 13 years in girls, and between 10 and 15 years in boys (de Lucena, dos Santos Gomes, & Oliveira Guerra, 2011). A Brazilian study showed an OSD prevalence of 9.8% (11.0% in boys and 8.3% in girls) in a sample of 956 adolescent students (de Lucena et al., 2011). Hall et al. analysed 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 (Hall, Barber Foss, Hewett, &

* Corresponding author. University Children's Hospital Basel, University of Basel, Department of Therapy, Spitalstrasse 33, 4056, Basel, Switzerland.
E-mail addresses: cornelia.neuhaus@ukbb.ch (C. Neuhaus), christian.appenzeller@unibas.ch (C. Appenzeller-Herzog), oliver.faude@unibas.ch (O. Faude).

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Myer, 2015).

The exact cause of OSD is unknown. It could be secondary to repetitive microtrauma of the tibial tuberosity or due to a tight quadriceps (de Lucena et al., 2011). 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 (Tzalach, Lifshitz, Yaniv, Kurz, & Kalichman, 2016). This force results in irritation and, in severe cases, 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 (Smith & Varacallo, 2019).

There is a remarkable lack of information on growth-related injuries in young athletes and their prevention and rehabilitation (Faude, Rössler, & Junge, 2013). OSD is frequently considered a self-limiting condition, but this perspective should be challenged. The healing period in the bradytrophic tissue of a growth plate under traction can last one to two years (Hefti, 2015)—a significant period of time in the context of adolescent timespans. An effective treatment approach and the implementation of prevention programs before OSD onset are strongly needed (Guldhammer, Rathleff, Jensen, & Holden, 2019).

Although a wide range of treatment philosophies exist for OSD, it is predominantly treated conservatively. For the purposes of this review, conservative treatment is defined as icing, bracing, casting, or splinting (Hefti, 2015; Smith & Varacallo, 2019), and physiotherapy (e.g., stretching, strengthening, rest, and activity modification) (Smith & Varacallo, 2019). Non-operative treatment is defined as pharmacological treatment for pain relief, either orally with non-steroidal anti-inflammatory drugs (NSAIDs) (Smith & Varacallo, 2019) or by local anaesthetic injected into the painful area of the tibial tuberosity (Topol et al., 2011).

A recently published systematic review by Cairns et al. focused on the therapeutic interventions in children and adolescents with patellar-tendon-related pain (Cairns et al., 2018). Despite the unlikeliness of OSD-related pain complaints spontaneously improving 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 rarely well-described. An evidence-based, multi-management program should be available to facilitate affected adolescents' return to sport.

The literature agrees that surgery is not the most effective treatment for OSD (Cairns et al., 2018). With regard to conservative and non-operative treatment options, some anecdotal and practical experience from conference presentations, and some empirical data on the potential benefits are available (Core Advantage, 2019; Strickland Protocol, 2016). However, an integrative view of conservative or non-operative treatment options and their effectiveness to improve 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 review was conducted according to the Preferred Reporting Items for Systematic reviews and Meta-Analysis (PRISMA) statement (Moher, Liberati, Tetzlaff, Altman, & Group, 2009). The systematic review was registered in PROSPERO (CRD42018106215).

2.1. Data sources and search strategy

Based on scoping searches, we expected a low number of eligible high-quality studies for inclusion. Therefore, we chose a highly sensitive search strategy in order to detect the largest possible set of relevant articles. 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). The original search was completed on 13th April 2018 and the updated search on 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 (reference chasing). The key reviews were retrieved during title abstract screening and also used for the extraction of therapy recommendations (see below). Furthermore, ongoing 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 (ongoingtrials: 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 November 1, 2013 to Volume February 6, 2018; update to Volume December 7, 2019), "Physiopraxis" (from Volume January 9, 2011 to Volume March 16, 2018; update to Volume January 18, 2020), "Pediatric Physical Therapy" (from Volume Spring 25, 2013 to Volume April 30, 2018; update to Volume January 32, 2020), "Physiotherapy" (from Volume March 96, 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 March 1, 2007 to Volume December 10, 2016; update to Volume December 13, 2019), and "Physical Therapy in Sport" (from Volume February 11, 2010 to Volume March 30, 2018; update to Volume January 41, 2020) using the terms "Osgood AND Schlatter".

2.2. Eligibility criteria and study selection

The PICOS framework (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, symptoms duration, function (e.g., capacity to kneel), range of motion, muscle length or sport participation (O); the study design was either a prospective- or retrospective-observational study, a case control study, a case series, a randomised or non-randomised 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 key reviews were English, German, or French language and a content specific to OSD (e.g., reviews with general overuse sports injuries were excluded). Studies and key reviews were independently selected by two

investigators (CN, OF). A final decision on eligibility was achieved by consensus.

2.3. Data extraction

Data extraction was carried out by one author (CN). The following data were extracted: authors, year, study design, country, participants (e.g., 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.

2.4. Quality assessment

The Physiotherapy Evidence Database (PEDro) scale, a valid measure of the methodological quality of a clinical trial, was used (Maher, Sherrington, Herbert, Moseley, & Elkins, 2003). 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".

2.5. Data analysis

Due to the heterogeneous nature of the included studies (e.g., different study designs, interventions, outcome measures, and quality of data), a quantitative analysis was not applicable. We narratively synthesised the results based on the domains of interest. In addition, all retrieved reviews were evaluated with regard to recommendations and referenced sources for the treatment of OSD.

3. Results

3.1. Search results, study characteristics, and quality assessment

Bibliographic database searching (original and update search) identified a total of 731 unique records and a further 37 records from other sources (grey literature, conference abstracts, and reference chasing). After screening, thirteen articles were included (Lohrer et al., 2012; Topol et al., 2011; Kridelbaugh & Wyman, 1948; Ehrenborg, 1962; Reichmister, 1969; Levine & Kashyap, 1981; Trail, 1988; Krause, Williams, & Catterall, 1990; Yatsuka, Torisu, & Takami, 1992; Hussain & Hagroo, 1996; Strickland, Coleman, Brunswic, & Kocken, 2008; Duperron et al., 2016; Nakase et al., 2019) (Fig. 1, Appendix 2)—Table 1 gives an overview of their study characteristics and main results. Of the included studies, two were randomised controlled trials (RCTs) (Nakase et al., 2019; Topol et al., 2011), two were prospective (Strickland et al., 2008; Yatsuka et al., 1992), and eight were retrospective observational studies (Duperron et al., 2016; Ehrenborg, 1962; Hussain & Hagroo, 1996; Krause et al., 1990; Levine & Kashyap, 1981; Lohrer et al., 2012; Reichmister, 1969; Trail, 1988). The remaining study was a case series (Kridelbaugh & Wyman, 1948). Eight studies had no control group (Duperron et al., 2016; Hussain & Hagroo, 1996; Kridelbaugh & Wyman, 1948; Levine & Kashyap, 1981; Lohrer et al., 2012; Nakase et al., 2019; Reichmister, 1969; Strickland et al., 2008). A further potentially relevant record was excluded due to ineligible language (Karenko, 2016).

The included studies were published between 1948 and 2019 and comprised 747 patients with 937 affected knees (one study (Strickland et al., 2008) 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 (Trail, 1988; Yatsuka et al., 1992). Age range was 9–28 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, 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 (Nakase et al., 2019), another study was considered to be of moderate quality (Topol et al., 2011), ten studies had a PEDro score of four or less, indicating poor quality (Duperron et al., 2016; Ehrenborg, 1962; Hussain & Hagroo, 1996; Krause et al., 1990; Kridelbaugh & Wyman, 1948; Levine & Kashyap, 1981; Lohrer et al., 2012; Reichmister, 1969; Trail, 1988; Yatsuka et al., 1992), and one study could not be assessed because only the abstract was available (Strickland et al., 2008).

3.2. Detailed description of studies

The studies are described in chronological order starting from the oldest. Kridelbaugh (Kridelbaugh & Wyman, 1948) showed a subjective improvement after anterior thigh taping in 46% of patients. No further details were described. In 1962, Ehrenborg (Ehrenborg, 1962) retrospectively analysed 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 immobilised. The average duration of symptoms was 14.6 months in the plaster-treated group versus 27.8 months in the non-immobilised group, suggesting effectiveness of immobilisation. Reichmister (Reichmister, 1969) 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 (Levine & Kashyap, 1981) used an infrapatellar strap, which showed an improvement in 19 out of 24 knees after a period of 6–8 weeks. In 1988, Trail et al. (Trail, 1988) compared surgery (tibial sequestrectomy) with conservative treatment in a retrospective study involving 51 patients (Cairns et al., 2018). Conservative treatment and surgery showed no relevant differences. Conservative treatment was, however, not appropriately described. In the retrospective study by Krause et al. (Krause et al., 1990), 50 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. An 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. (Yatsuka et al., 1992) 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 (Hussain & Hagroo, 1996) followed 261 patients (365 knees) for 1–2 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. (Strickland et al., 2008) conducted a pilot study with 25 patients with OSD suffering from symptoms for 8 months on average (range of 1 week–36 months). Physiotherapy treatment consisted of myofascial release massage and stretching of the quadriceps group. When patients achieved a wall-squat with full range of motion of the knees (on average after 20 days), they were discharged and able

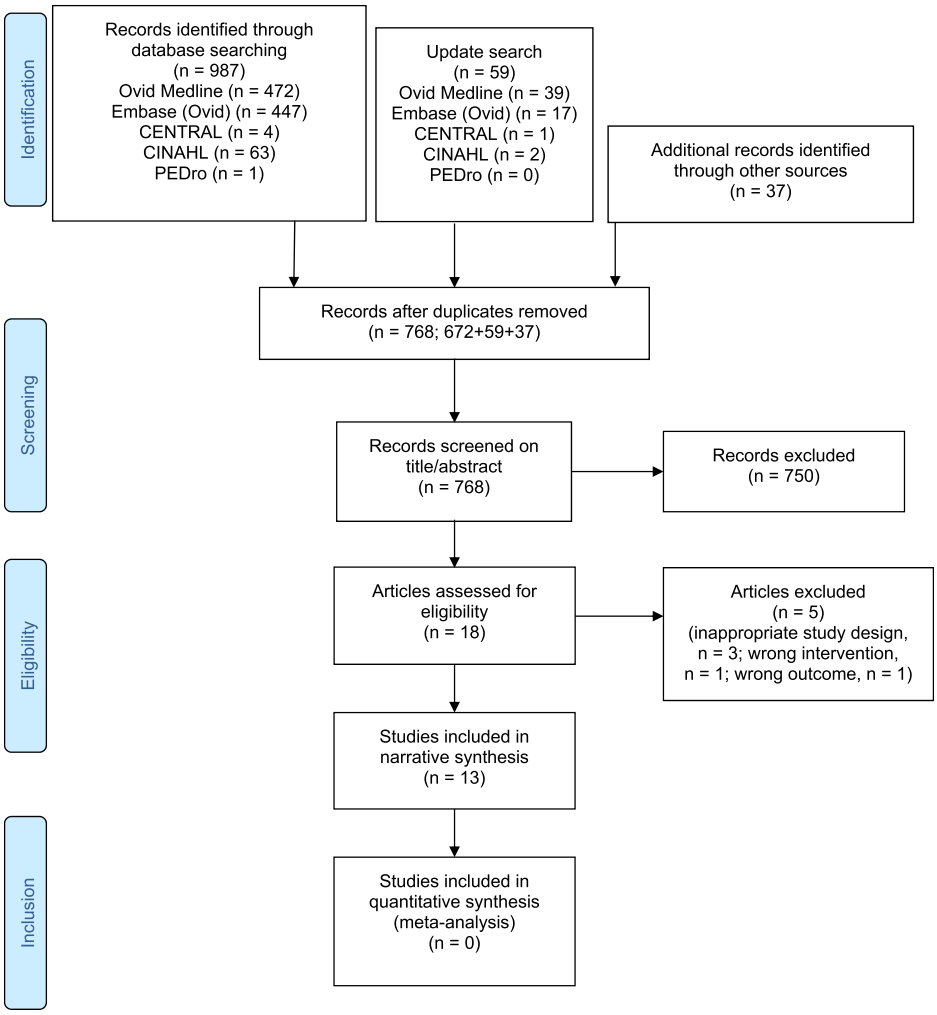

Fig. 1. Flow Diagram of the Literature Selection Process for original studies.

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. (Topol et al., 2011) 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 both sports limitation and sports-related symptoms was 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. (Lohrer et al., 2012) treated 14 patients (16 knees) with radial extracorporeal shock waves. After 5.6 years, 12 knees (75%) reached the best score on a patellar tendinopathy questionnaire. Duperron et al. (Duperron et al., 2016) immobilised 30 OSD patients' knees with a plaster for 4 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. (Nakase et al., 2019) readdressed the effectiveness of the dextrose injection. Thus, 38 patients who received non-invasive therapy for more than 1 month and had no improvement were randomly assigned into 2 groups to receive an injection with dextrose (plus anaesthetic) or saline (plus anaesthetic) in a double-blind procedure. Although both groups displayed marked improvements, negligible differences were found between the two groups at any follow-up time, which challenged the previous results from Topol et al. (Topol et al., 2011).

3.3. Reviews and therapy recommendations

To provide a closer look at current treatment recommendations, 15 articles were collated (Gholve et al., 2007; Mital & Matza, 1977; Antich & Brewster, 1985; Uzunov, 2008; Eberhardt, 2009; Charrette, 2012; Lipman & John, 2015; Beaubois, Dessus, & Boudenot, 2016; Vaishya, Azizi, Agarwal, & Vijay, 2016; Circi, Atalay, & Beyzadeoglu, 2017; Smith & Varacallo, 2018; Cairns et al., 2018; Nuhrenborger & Gaulrapp, 2018; Andrew J Kienstra, 2019; Ladenhauf, Seitlinger, & Green, 2019) (Table 3). Thirteen reviews were flagged as key reviews during title abstract screening of database search results, and grey literature searching additionally provided a clinical guideline (Andrew J Kienstra, 2019) and a review article (Uzunov, 2008).

The most frequently recommended treatments were activity modification (15/15) (Andrew J Kienstra, 2019; Antich & Brewster, 1985; Beaubois et al., 2016; Cairns et al., 2018; Charrette, 2012; Circi et al., 2017; Eberhardt, 2009; Gholve et al., 2007; Ladenhauf

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	Authors' Conclusion
Kridelbaugh et al., 1948, case-series, USA	13 patients completing Naval training; 16 knees (4 right, 6 left, 3 bilateral); 17–19 years; 13 males; no control group.	Tape (cross-strapping) around the knee.	Monthly	46.1% improved under treatment, 15.4% were not improved, 15.4% worsened, 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 out 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 immobilised but 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 immobilisation 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-immobilised knees b) 14.6 months (immobilisation for 4–6 weeks) c) 14.6 months (surgically treated). Mean observation period: 1–7 years	In the cases without immobilisation of the knee, 37 knees (50%) with lesions healed with a significant deformity of the tuberosity or ossicle formation, whereas this picture was seen in only 49 knees (32.6%) 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); 12–15 years; 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[c]	NR[c]	This method of treatment spares the children prolonged immobilisation in a cast.
Levine J et al., 1981, retrospective observational study, USA	17 patients; 24 knees (6 right, 4 left, 7 bilateral); 11–17 years; 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 6–8 weeks of use	NR[c]	NR[c]	Infrapatella strap provides a very satisfactory alternative.
Trail IA, 1988, retrospective observational study, England	51 patients; 56 knees (side NR[c]); 10–17 years; sex NR[c]	31 patients (33 knees) treated operatively (tibial sequestrectomy); 20 patients (23 knees) treated conservatively (reduction in activity with avoidance of sport); 3 patients had a plaster cast; 4 injection of local anaesthetic and steroid; 3 physiotherapy using ice packs and ultrasound.	Follow-up (average): 4 years 6 months (range 2–6 years) in the surgically treated group; 5 years 6 months (range 3–8 years) in the conservatively treated group	82% were asymptomatic in operated group; 91% in conservative group; $p < 0.8$	Duration of symptoms	Interview 2–8 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	Total of 62 patients; from 50 patients: 69 knees (16 right, 13 left, 20 bilateral, 20 NR[c]); from 12 patients affected side NR[c]; 10–14 years; 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). A further 12 patients spent some time in a plaster cylinder.	50 patients with no specific treatment: 60% were still unable to kneel without pain; 76% had no limitation of activity. 12 patients with plaster cylinder: 3 had chronic symptoms, 7 unable to kneel.	Duration of symptoms; Able to kneel without pain.	Average follow-up: 9 years	For most patients the symptoms of OSD resolved spontaneously, although many patients had difficulty in kneeling.
Yatsuka T et al., 1992, prospective observational study, Japan	14 OSD patients; 15 knees (side NR[c]); 11–28 years; sex NR[c]; 402 controls, 144 knees (with compression pain of the patella, side NR[c]); 18–41 years; sex NR[c]	OSD patients: hamstring stretching exercise (two methods) without medication and other physical therapy. Control group: 60/144—hamstring stretching exercises for one month, 84—observations only.	Patients: 5 min, three-times-daily 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 was improved (50%) in the exercise group. Hamstring tightness	Angle of hamstring tightness; Pain.	1, 4, and 8 months	NR[c]

Table 1 (*continued*)

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	Authors' Conclusion
				improved from 48.2° to 42.5°.			
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 a modified bandage in a few. a) conservative treatment: 237 patients b) surgery: 24 patients	a) For 6 months in those >15 years; for 1 year in those <15 years; follow-up 12–24 months (mean 1.5 years). 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 3–6 weeks	Return to normal activity	1–2 years	The treatment of OSD is predominantly conservative, and in fact can be entirely ignored. There is a very small role for operative treatment.
Strickland et al., 2008, prospective observational study (congress abstract), England	25 patients; affected knees NR[c]; 10–15 years; 19 males, 6 females; no control group	Wallslide test, myofascial release massage (MRM), stretching of the quadriceps group.	MRM daily for 2 min, once pain-free knee flexion was achieved, active stretching was performed daily by the patient.	All patients achieved a wall-squat with full range of motion of the knees on an average of 20 days (±12) with a maximum of 50. Improvement in wall slide was significant ($p < 0.02$).	Wall Slide	Baseline, NR[c], 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 (side NR[c]); 9–17 years; 51 males, 3 females	Randomly assigned: a) usual care for 3 months (therapist-supervised) b) lidocaine injection monthly for 3 months c) dextrose injection monthly for 3 months. All subjects were then offered dextrose injections monthly as needed for 1 year. All patients had to attempt 2 months of hamstring stretching and quadriceps strengthening.	Injections: monthly for 3 months compared with usual care.	NPPS[a] scores improved more in dextrose-treated knees than either lidocaine-treated ($p = 0.004$) or exercise-treated knees; $p < 0001$). Lidocaine was significantly better than usual care ($p = 0.024$).	NPPS[a]	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); 13–15 years; 9 males, 5 females; no control group	Radial extracorporeal shock wave therapy (ESWT).	1 weekly therapy session with a total of 3–7 therapy sessions. Follow up 5.6 years (3.4–6.7 years) later.	Median VISA[b] score was 100. 75% reached 100 out of 100 VISA points. No side effects of the ESWT.	VISA[b] score	Follow up 5.6 years after treatment	Demonstrated that radial ESWT is a 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 immobilisation allows a short time to restart sports, and seems to be correlated with the presence of the ossicle.
Nakase J et al., 2019, RCT, Japan	38 patients; 49 knees (side NR[c]); 12–13 years; 37 males, 1 female; no control group	Injection of 1% lidocaine with 20% dextrose or 1% lidocaine with saline.	1 monthly injection for 3 months.	VISA scores of the dextrose and saline groups were 58.7 ± 18.3 and 63.4 ± 16.4 (maximum 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[b] score	1 month after first and second injection; 2 months after first and 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.

[a] NPPS: Nirschl Pain Phase Scale.
[b] VISA: Victorian Institute of Sports Assessment Patellar Tendinopathy Questionnaire.
[c] NR: not reported.

Table 2
PEDro scale scores of the included studies.

PEDro Scale Item	Kridelbaugh & Wyman, 1948	Ehrenborg, 1962	Reichmister, 1969	Levine & Kashyap, 1981	Trail, 1988	Krause et al., 1990	Yatsuka et al., 1992	Hussain & Hagroo, 1996	Strickland et al., 2008[b]	Topol et al., 2011	Lohrer et al., 2012	Duperron et al., 2016	Nakase et al., 2019
Eligibility criteria[a]	–	–	–	–	–	–	–	–	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.
[a] Not accounted.
[b] Not rated.

et al., 2019; Lipman & John, 2015; Mital & Matza, 1977; Nuhrenborger & Gaulrapp, 2018; Smith & Varacallo, 2018; Uzunov, 2008; Vaishya et al., 2016), quadriceps and hamstring stretching (13/15) (Andrew J Kienstra, 2019; Antich & Brewster, 1985; Beaubois et al., 2016; Charrette, 2012; Circi et al., 2017; Eberhardt, 2009; Gholve et al., 2007; Ladenhauf et al., 2019; Lipman & John, 2015; Nuhrenborger & Gaulrapp, 2018; Smith & Varacallo, 2018; Uzunov, 2008; Vaishya et al., 2016), medication (NSAIDs) (11/15) (Andrew J Kienstra, 2019; Antich & Brewster, 1985; Circi et al., 2017; Eberhardt, 2009; Gholve et al., 2007; Ladenhauf et al., 2019; Lipman & John, 2015; Nuhrenborger & Gaulrapp, 2018; Smith & Varacallo, 2018; Uzunov, 2008; Vaishya et al., 2016), ice (11/15) (Andrew J Kienstra, 2019; Antich & Brewster, 1985; Charrette, 2012; Eberhardt, 2009; Gholve et al., 2007; Ladenhauf et al., 2019; Lipman & John, 2015; Nuhrenborger & Gaulrapp, 2018; Smith & Varacallo, 2018; Uzunov, 2008; Vaishya et al., 2016), quadriceps strengthening (9/15) (Andrew J Kienstra, 2019; Antich & Brewster, 1985; Charrette, 2012; Gholve et al., 2007; Ladenhauf et al., 2019; Lipman & John, 2015; Nuhrenborger & Gaulrapp, 2018; Smith & Varacallo, 2018; Vaishya et al., 2016), and knee straps or braces (8/15) (Andrew J Kienstra, 2019; Charrette, 2012; Gholve et al., 2007; Lipman & John, 2015; Nuhrenborger & Gaulrapp, 2018; Smith & Varacallo, 2018; Uzunov, 2008; Vaishya et al., 2016). Surgery was indicated only for painful bony protrusion (Andrew J Kienstra, 2019; Circi et al., 2017; Eberhardt, 2009; Ladenhauf et al., 2019; Mital & Matza, 1977; Nuhrenborger & Gaulrapp, 2018). Patient and parent education was mentioned five times (Andrew J Kienstra, 2019; Beaubois et al., 2016; Cairns et al., 2018; Eberhardt, 2009; Nuhrenborger & Gaulrapp, 2018) and one review recommended core stability and balance training (Ladenhauf et al., 2019). The review articles were published between 1977 and 2019. Cited studies were from the years 1903–2019. The most cited studies were: Topol et al. (Topol et al., 2011), Hussain et al. (Hussain & Hagroo, 1996), and a review article by Mital et al. (Mital & Matza, 1977). One review (Eberhardt, 2009) adapted therapy recommendations to a three-grade 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 immobilised in a cast, and undergo specific rehabilitation programs (Eberhardt, 2009). Circi et al. and Ladenhauf et al. recommended to reduce sports activity and perform non-impact exercise such as swimming or cycling (Circi et al., 2017; Ladenhauf et al., 2019). Nühnenborger et al. (Nuhrenborger & Gaulrapp, 2018) recommended ice, however 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 recognised, but evidence-based guidelines do not exist, implying 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. As for any health condition, clinicians aim to avoid chronic problems and offer patients evidence-based treatment options. Currently, a lack of evidence or consensus causes uncertainty on what can be recommended for OSD (Holden & Rathleff, 2019) and treatment is based merely on clinical experience and expert opinion (Ladenhauf, Seitlinger, & Green, 2020). For example, therapists individually adapt physiotherapy exercises. In the available review articles, the discussed treatment options are quite comparable. Remarkably, the same publications were repeatedly referenced and only one review article based its recommendations—in part—on an RCT. Only one review article advised core stability and balance training (Ladenhauf et al., 2019). In the included articles, the most

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	Pain relief, doing virtually nothing to numerous surgical manoeuvres; rest, strapping, immobilisation (cast), rarely: surgical treatment	Osgood RB (1903); **Reichmister J (1969)** [a]**;** Smillie IS (1962); Watson-Jones R (1976); (other references not clearly stated)
Antich TJ, 1985, Review, USA	Pain limited activities, 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)** [a]**;** 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 to strengthen and improve flexibility (quadriceps, hamstring, iliotibial band, gastrocnemius). Not recommended initially: high-intensity, quadriceps-strengthening exercise. Moderate to severe pain: activity modification, rest, NSAIDs, immobilisation.	Beovich R (1988); **Hussain A (1996)** [a]**;** Mital MA (1980); Ross MD (2003);
Uzunov V, 2008, Review, NZL	Rest, ice, compression, elevation (RICE), warming up before activity, icing after activity, rest, activity modification, infrapatellar strap, anti-inflammatory medication, physiotherapy, stretching (hamstring, calf, hip), immobilisation (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)** [a]; 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	Limitation of activity, 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, parent 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, gastrocnemius exercises, immobilising (cast or brace), surgical treatment.	Binazzi R (1993); Frank JB (2007); Kujala UM (1985); Orava S (2000); **Trail IA (1988)** [a];
Circi E, 2017, Review, Turkey	Non-impact activities (swimming, cycling), hamstring and quadriceps flexibility exercises, controlled immobilisation, NSAIDs, injections. Rarely indicated: surgical treatment (removal of ossicle fragmentation). Not recommended: injection of corticosteroids into patellar tendon.	Cakmak S (2014); **Topol GA (2011)** [a];
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, advice 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)** [a]; **Trail IA (1988)** [a];
Nührenbörger C, 2018, Review, Luxembourg	Patient education, ice, limitation of activities, NSAIDs, protective knee padding and physical therapy (lower extremity stretching and strengthening). 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: immobilisation.	Beovich R (1988); **Hussain A (1996)** [a]**;** Rostron PK (1979); **Topol GA (2011)** [a]; 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)** [a]; Midtiby SL (2018); Rathleff MS (2019); Rostron PK (1979); **Topol GA (2011)** [a]; Vaishya R (2016)

[a] Original studies, also included in this review.

frequently mentioned therapy was injections (Nakase et al., 2019; Reichmister, 1969; Topol et al., 2011), followed by splinting methods using a patellar strap, tape, or bandage (Hussain & Hagroo, 1996; Kridelbaugh & Wyman, 1948; Levine & Kashyap, 1981). Immobilisation with a cast was studied twice (Duperron et al., 2016; Krause et al., 1990). Lohrer et al. tested shock wave therapy in a pilot study, which is another type of passive intervention (Lohrer et al., 2012). One study investigated the use of two different hamstring stretching techniques (Yatsuka et al., 1992). Other researchers used a combination of surgery (tibial sequestrectomy), casting, injections, and physiotherapy (Ehrenborg, 1962; Trail, 1988).

Of the two identified RCTs, 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 (Sanderson & Bryant, 2015). Whereas Nakase et al. (Nakase et al., 2019) ran a double-blind comparison of two injection groups, Topol et al. (Topol et al., 2011) conducted a three-armed RCT that also analysed 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 (Topol et al., 2011; Nakase et al., 2019; Rabago, Topol, Podesta, Cheng, & Fullerton, 2020). 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 of 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. Existing evidence on exercise therapies is 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 (e.g., duration, frequency, intensity) are missing all the more (Holden & Rathleff, 2019). Thus, unfortunately, the formulation of evidence-based treatment recommendations, as defined in our aims for this systematic review, is currently not feasible.

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 was presented at the European College of Sports Science Conference in Portugal in 2008 (Strickland et al., 2008). The protocol is mainly a combination of myofascial release massage (2 min daily) and active stretching of the quadriceps femoris muscle. Comparable therapeutic approaches may appear effective and successful.

Although it is important to seek evidence-based therapy for existing OSD conditions, it is also important to focus on prevention strategies that reduce overuse 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 (Holden & Rathleff, 2019). 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 (Rössler et al., 2014). 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 (Rössler et al., 2018). 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 specialisation (Valovich McLeod et al., 2011).

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). Furthermore, the PEDro scale quality assessment confirmed that the overall study quality is a major limitation.

6. Conclusion and future directions

No evidence exists on the effectiveness of specific exercise programs for patients with OSD; only poor evidence exists for the use of injections with local anaesthetic. In such absence of high-quality evidence, the first step should be to rely on expert consensus for best-practice recommendations (Table 3) (Minas & Jorm, 2010). 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 (Faude, Rössler, & Junge, 2013).

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Author contributions

CN and OF designed and organised this systematic review. CAH organised the literature search process. CN and OF analysed the data and wrote the manuscript draft. CAH critically revised the article.

Ethical statement

As this is a Systematic Review, Ethical Approval was not required.

Declaration of competing interest

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.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ptsp.2021.03.002.

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