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REVIEW

A review of hands-on based conservative treatments on pain in recreational and elite athletes

Une revue des traitements conservateurs à visée antalgique chez les sportifs amateurs et professionnels

J. Fleckenstein[a,b,c,*], **W. Banzer**[a]

[a] *Department of Sports Medicine, Institute of Sports Sciences, Goethe University, Ginnheimer Landstr, 39, 60487 Frankfurt am Main, Germany*
[b] *Department of TCM/Acupuncture, Institute of Complementary Medicine, Personalhaus 4, University of Bern, CH-3010 Bern, Switzerland*
[c] *Department of Sports Medicine and Exercise Physiology, Institute of Sports Sciences, Justus-Liebig University Giessen, Kugelberg 62, 35394 Giessen, Germany*

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Summary
Objectives. — Acute pain in sports tells us what not to do. Persisting pain limits the athletes' activity and threatens his career. The reduction of pain is sought being highly beneficial for the sportsman, as it is shown that pain has only a weak connection to injury but a strong connection to the body image. Thus, pain therapy in sports medicine is a primary need of the athlete. Principle treatment goals are pain relief and return to play as quick as possible. Therapies in sports should primarily focus on conservative than on invasive approaches, with drugs being avoided as far as possible. There is a broad range of treatment approaches that could be applied in concert based on scientific and clinical decision making to reduce symptom severity, pain-associated dysfunction, and the risk of pain to be a tremendous cut in an elite athlete's career. Knowledge on this non-pharmacologic conservative pain medicine should not be restricted to health professionals, but the whole entourage of the athlete. This review highlights the current evidence with a focus on recreational and elite athletes. Based on their clinical evidence, it is hands-on techniques that can be recommended (Grade A: nerve blocks and injection techniques, ultrasound and laser therapy, manipulation mobilization, massage

* Corresponding author. Department of Sports Medicine, Institute of Sports Sciences, Goethe-University, Ginnheimer Landstr, 39, 60487 Frankfurt am Main, Germany.
E-mail addresses: fleckenstein@sport.uni-frankfurt.de (J. Fleckenstein), banzer@sport.uni-frankfurt.de (W. Banzer).

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and traction; Grade B: acupuncture and dry needling). The occurrence of possible side-effects is, as far as reported, very unlikely. However, the methodological quality of the majority of retrieved studies limits the overall generalizability.
Conclusion. — Conservative non-pharmacologic therapies reflect an adequate strategy to relief pain in elite athletes. Chronic states of pain reflect more complex scenarios requiring further comprehensive techniques. Future research should thus also address multimodal approaches combining several of the mentioned therapies.

MOTS CLÉS
Douleur chronique ;
Traitement de la douleur ;
Fatigue neuromusculaire ;
Prévention:
Réhabilitation ;
Douleur du sportif

Résumé
Actualités. — La douleur aiguë est un signe d'alerte qui induit l'arrêt de la pratique sportive. Lorsqu'elle se prolonge, la douleur limite l'activité de l'athlète et peut anticiper la fin de sa carrière. Soigner la douleur est une nécessité, surtout qu'elle n'a qu'une relation très relative avec l'étendue des lésions, mais une relation forte avec l'image corporelle. Traiter la douleur devient alors une nécessité pour l'athlète, afin de lui offrir une thérapie adaptée et favoriser ainsi sont retour à l'entraînement et à la compétition. Les thérapies antalgiques en médecine du sport devraient être « conservatives » au lieu « d'invasives », avec une limitation de la consommation de médicaments. Il existe maintenant des preuves scientifiques et médicales qui confortent l'utilisation potentielle d'une multitude d'approches thérapeutiques qui permettraient de réduire l'intensité de la douleur, les altérations fonctionnelles associées aux douleurs, et le risque d'arrêt anticipé et brutal de la carrière sportive. Les connaissances de ces thérapies dites « conservatives » ne devraient pas être restreintes aux professionnels de santé, mais également à l'entourage de l'athlète.
Perspectives. — Cette revue met en évidence les preuves cliniques dont nous disposons pour indiquer ces thérapies chez des sportifs amateurs et professionnels. Les principaux résultats suggèrent que les techniques manuelles sont indiquées avec un haut niveau d'efficacité (Grade A : blocs nerveux, mésothérapie, ultrasons, laser, mobilisation et manipulation, massage et traction ; Grade B : acupuncture, dry needling, ou puncture à sec de thérapie des points myofasciaux sensibles à la pression (points trigger)). L'apparition potentielle d'effets secondaires est assez peu probable. Cependant, la qualité méthodologique de la majorité des études retrouvées limite malgré tout une trop importante généralisation des résultats. En résumé, les thérapies non-pharmacologiques conservatives semblent être une stratégie adéquate pour diminuer la douleur des athlètes. Les douleurs chroniques sont des états plus complexes et demandent des techniques plus étiologiques. La recherche devrait s'orienter vers la validation d'approches multimodales qui combinent plusieurs thérapies.

1. Introduction (analgesic need and abuse in sports medicine)

When we speak of pain, we understand it as a deeply human experience, because it involves not only nociception and the immediate physiological reactions to it, but also emotional, cognitive, and social consequences [1]. Pain by definition is an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage. Pain has been shown being a poor protector against injury, since it occurs far too late in the case of sudden injury or of very slow damage to provide a useful preventive measure [2]. Instead it is proposed that pain signals the existence of a body state where recovery and recuperation should be initiated [2].

Acute pain in sports tells us what not to do. Persisting pain limits the athletes' activity, endangers his health, and threatens his career [3]. As an example, myofascial pain resulting from muscle strain, pull, or tightness has been reported to cause 45.6% of all injuries in elite Ontario youth provincial and national soccer players observed within 4 years [4]. Consequently, treating this pain would reduce the risk of injury for the sportsman. However, attitudes of team and athletes, cultural and societal attitudes, gender aspects, as well as misknowledge, may impede the access to adequate pain relief [5—7].

The specific need for an adequate pain therapy in athletes is substantiated by the following epidemiological data. The prevalence of low back pain in a group of approximately 6000 undergraduates in sport sciences was about 15% [8], and was especially associated with the participation in gymnastics, judo, handball, and volleyball. The self-reported prevalence of pain in physically demanding college academic programs has been reported being 32%. Within this population, 77% of patients report their pain as recurring [9]. Among Italian rowers, the lifetime prevalence of low

back pain is 64.7% and the 1 year prevalence 40.6% [10]. Low back pain is more likely to occur in endurance sports [11]. There is evidence resulting from female elite handball and football players that the prevalence of LBP increases from the resting period to the competitive periods of the season [12]. Other pain than of the lower back has been reported: a smaller study found 41% of 63 female collegiate athletes to suffer from painful hips [13]. Almost half of young athletes describe some occasional or low-intense form of pelvic pain [14]. The onset of shoulder pain was 34% in 56 female handball athletes [15]. Professional karate-do and mixed martial arts fighters present with a high prevalence of temporomandibular disorders, including myofascial pain of the masticatory muscles [16]. A survey among 203 youth baseball players revealed that pain caused 30% of players to have less fun playing; and 46% of players reported at least once being encouraged to keep playing despite having arm pain [17]. In summary, this means that at least one out of three athletes to suffer from pain.

Traditionally, the principles of pain management adhere to the World Health Organization's pain ladder. First step is to administer non-opioid analgesics. In case this is insufficient, steps 2 and 3 add weak or strong opioids [18]. Still, opioids are not the medications of first choice in an athlete's therapeutic concept. Besides, the use of weak and strong opioids is prohibited in-competition according to the world anti-doping agency [19]. A broad variety of non-pharmacologic interventions might thus be helpful, to address the need of a sufficient pain therapy in such groups of patients [20]. In this context, the role of alternatives to pharmacotherapy is acknowledged by different medical colleges, e.g., the Australian and New Zealand College of Anaesthetists ANZCA [21].

In Sports Medicine, the first-line principle especially in the treatment of muscular injuries is ''ice, elevation, and compression'' [22]. This should be followed by subsequent therapies, conservative approaches are emphasized [23]. Still, the knowledge regarding conservative treatments is often limited to the groups of the respective specialized health professionals, but should be known all over the place.

To gain an overview of the conservative treatment analogues in sports-related pain, this article reviews current practice and feasible solutions in the therapeutic and preventive need of the athlete. A focus of this comprehensive article lies on the existing clinical evidence in the sports setting.

2. Terminology and classification

According to the Oxford dictionaries, the term conservative therapy refers to a medical treatment that aims to preserve the existing tissue as far as possible. Other descriptions refer to a clinical condition with the least aggressive of available therapeutic options or to treatments designed to avoid radical medical therapeutic measures or operative procedures. In our definition of conservative pain therapy we combined the Oxford definition to the classification made in the core curriculum of the International Association for the Study of Pain IASP dividing treatments into either pharmacology or other methods [24]. The term ''other methods'' subsumes the whole spectrum of non-pharmacologic pain therapy, including stimulating techniques, psychological interventions, as well as surgery (Table 1). Consequently, we excluded any type of surgical therapies (Table 1 VIII) to match the above mentioned Oxford definition. We did not focus on psychological and psychiatric treatments (Table 1 I and II) as we are not experts in this field. We consider work rehabilitation (Table 1 VI) being equal to return to sports, and whenever possible we addressed this topic dealing with the included treatments. Exercise being mentioned as a treatment option in Table 1 V ''physical medicine and rehabilitation'' was excluded as this review deals with exercise- and sports-related pain.

3. Results

As athletes are very vulnerable to pain, this review focusses on clinical articles within this peer-group. In case no clinical studies could be retrieved, available experimental trails using exercise-induced pain models were reported. A summary of clinical studies enrolled in athletes or sports-related conditions is shown in Table 2.

3.1. Stimulation-produced analgesia

3.1.1. Transcutaneous electrical nerve stimulation (TENS)

Therapies in the field of electrical nerve stimulation use electrical energy for medical purpose. Mechanism of TENS usually refer to the gate control theory altering sensory transmission at the dorsal horn, as well as by activating endogenous opioid pathways. Large studies investigating its use in the relief of pain in athletes or in conditions related to exercise are missing. Case reports showed electric intramuscular stimulation to alleviate acute myofascial pain of the lower back in an elite American football player [25] and electrical stimulation to reduce pain caused by spondylolysis in two adolescent athletes [26]. A case series from 1979 reported TENS to be effective in treating pain in 20 athletes, with 75% of athletes presenting with good or excellent pain relief [27]. A recent and detailed case report illustrates the successful pain reduction and return to progressive sports activity in a runner with chronic Achilles tendinopathy [28]. Authors suggest, that the utilization of noxious electric stimulation may have altered the pain perception of the nervous system, as evidenced by an improvement in pain pressure threshold testing. Individuals with patellofemoral pain who received a single patterned electrical neuromuscular stimulation had immediate improvement in gluteus medius activation and a reduction in pain during functional tasks [29]. This is in agreement with a study showing neuromuscular electrical stimulation to improve recovery and painfulness from intensive training in professional team sports players [30]. Besides pure electrical stimulation, magnetic field therapy or iontophoresis can also be considered being electric therapies. It is sought that electrotherapy decreases pain, strengthens innervated muscle, maintains and trains denervated muscles, and promotes wound healing. A Cochrane review on electrotherapy for neck pain showed pulsed or repetitive electromagnetic stimulation and TENS to be superior to placebo [31], however this review is not based on athlete data. Future research is thought to

Table 1 Other methods in pain therapy according to the IASP [24].

Method	Treatments
I Psychological treatments	Cognitive-behavioural and behavioural interventions, e.g., relaxation strategies, biofeedback, stress management, group therapy
II Psychiatric evaluation and treatment	Addressing psychiatric and psychologic comorbidities, e.g., psychotherapy
III Stimulation-produced analgesia	Peripheral stimulation techniques, e.g., Transcutaneous electrical nerve stimulation (TENS) Acupuncture-like TENS Acupuncture, dry needling Vibration
IV Interventional pain Management including nerve blocks and lesioning	Analgesic nerve blocks, eg., myofascial trigger point injection, peripheral blocks, sympathetic blocks, epidural steroid injection, plexus blocks, intraspinal opioids, neurolytic blocks, phenol motor point blocks, cryoneurolysis, radiofrequency lesions
V Physical medicine and rehabilitation	Temperature modalities, eg., heat and cold, diathermy, ultrasound Manipulation mobilization, massage and traction Exercise**
VI Work rehabilitation	Management of the work place environment, return to work (sport)
VII Complementary therapies	Treatments that are not accepted as part of conventional medicine, opposed to mainstream medicine, e.g., alternative medicine systems such as traditional Chinese medicine, mind-body interventions such as mental healing, biologically based therapies such as herbs, manipulative body-based methods such as osteopathy, energy therapies such as Reiki, bioelectromagnetics-based therapies such as magnetic fields
VIII Surgical pain management	n/a*

*/** mark excluded sections froms this review, as *we did not specify the point surgical pain management, nor did we focus on **exercise as a specific treatment, as the topic of this review is exercise-related pain. TENS transdermal electric nervous stimulation.

likely change estimates of effects and definite conclusions cannot be drawn. According to the National Institute for Health and Care Excellence (NICE) this would correspond to a recommendation grade C.

3.1.2. Acupuncture-like TENS

We could no retrieve studies dealing with acupuncture-like TENS or electrostimulated acupuncture in athletes.

3.1.3. Acupuncture and dry needling

Acupuncture is a technique originating from Chinese medicine, with thin needles that are inserted at defined spots, e.g., acupuncture points. It has been shown that acupuncture acts via several mechanism that all have in common to alter pain transduction and transmission on a peripheral, spinal or central level. Several small studies report data resulting from elite athletes, however quality of studies is poor. A questionnaire-based investigation among 118 Taiwanese elite wrestlers showed about 55% of athletes using acupuncture to treat pain and injury [32]. A case series described the use of side-line acupuncture during the 2010 Warrior Games [33]. Eight athletes have been treated with auricular acupuncture due to muscular problems and pain reduced from 7.1 to 1.0 on a numeric rating scale (range 0—10 with 10 being the worst imaginary pain). Acupuncture was shown to be superior to topical NSAIDs and stretching alone in the treatment of heel pain in 38 recreational athletes [34]. A recent study in a Nordic Ski population ($n = 15$) reported acupuncture to be a feasible on-site treatment to significantly reduce muscle soreness in average over 5 days [35].A cochrane analysis from 2012 reviewed 20 heterogeneous studies in 2012 participants with acute ankle sprains, showing an overall benefit of acupuncture compared to no treatment or other options [36]. However, authors state that recommendations are not reliable as studies are probably biased and methodology is poor. In addition this review is not limited to sports-related ankle sprains.

Cupping is a acupuncture-based technique, and a recent systematic review reports pain-relieving effects in 498 amateur and professional athletes [37]. However retrieved studies have a high risk of bias.

Dry needling is a specialized needle technique that aims to disable myofascial trigger points (mTrP) by means of mechanical stimulation. Several sports-related case reports describe the use of dry needling to reduce myofascial pain, eg., chest pain in a military athlete [38], chronic low back pain in a military active [39], shoulder pain in a recreational athlete [40], shoulder pain in three tennis/racquetball players [41], hamstring strain in a collegiate pole-vaulter [42], tendinopathy in two runners [43] or knee pain in a high level ballet dancer [44]. Several of these cases included additional stretching techniques or physical exercise. All of the above mentioned athletes treated improved regarding pain and function resuming pre-injury activity levels on a short-term. Some observations were even made on a long-term (up to 24 month). All athletes were able to return to sport within 2—3 weeks. The number of dry needling interventions ranged from one to nine sessions.

Table 2 Sports-related pain in humans: characteristics of clinical studies.

Therapy	Author	Type	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between	Other outcomes groups
Stimulation-produced analgesia										
Transcutaneous electrical nerve stimulation (TENS)	Chu 2004 [25]	Case report	1	Elite soccer player	Acute myofascial pain	Electrical twitch obtaining intramuscular stimulation	N/a	Complete pain relief	N/a	Improved range of motion, satisfaction
	Fellander Tsai 1998 [26]	Case report	2	Adolescent athletes	Spondylolysis	External electrical stimulation and bracing	N/a	Asymptomatic, no pain return to sports	N/a	
	Garl 1979 [27]	Case series	20	Athletes	Pain	TENS	N/a	75% of athletes presenting with good or excellent pain relief		
	Eckenrod e 2015 [28]	Case report	1	Male runner	Bilateral Achilles tendinopathy	Noxious electric stimulation to tendons, single session	N/a	Pressure pain threshold: increase on both sides		Lower Extremity Functional Scale (LEFS): 73→76/80 points Victorian Institute of Sports Assessment-Achilles→64% 96%
	Glaviano 2016 [29]	Cohort study	22	Recreational athletes	Patellofemor al pain	Single patterned electrical neuromuscular stimulation	Sham PENS	Pain intensity (VAS) a)During squats b)During lateral step down	a)VAS −1.8 vs. −0.4 cm VAS b)VAS −2.3 vs. − 0.6 cm VAS	Increased percentage of gluteus medius activation
	Taylor 2015 [30]	Randomised counter-balanced study	28	Professional rugby and football academy players	Intensive, muscle damaging, maximal speed training	Neuromuscular electrical stimulation for 8 h	Control	Muscle soreness (7—fold Likert scale)	0.93 vs. 1.32 at 2 hours 1.21 vs. 2.0 at 24 hours	Sign. difference of peak power output, jump height and plasma creatine kinase at 24 hours

Table 2 (*Continued*)

Therapy	Author	Type	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between	Other outcomes groups
Acupuncture	Lin 2011 [32]	Survey	118	Wrestlers	Injuries and treatments	TCM	N/a	Usage of TCM as a pain therapy in 55%	N/a	
	deWeber 2011 [33]	Case series	8	Athletes	Muscular problems/pain	Auricular acupuncture	N/a	Pain reduction	N/a	
	Karagouni s 2011 [34]	RCT	38	Recreational athletes	Heel pain	Acupuncture	Ice + topical NSAID + stretching	Improved pain description and mobility-function	Sign	
	Garlanger 2017	Feasibility	15	Nordic skiers	Muscle soreness	Acupuncture	N/a	Pain intensity and muscle soreness	Posttreatment pain decreased from 2.6 to 1.9 cm VAS over five days	The majority (73%) of participants reported minimal side effects
	Bridgett 2018	SR	498 11	Athletes	Heterogeneo us	Cupping	Heterogeneou s	Pain intensity	Cupping was reported as beneficial for perceptions of pain and disability, i when compared to mostly untreated control groups	Cuppin also caused increased range of motion, and reductions in creatine kinase
Dry needling	Westrick 2012 [38]	Case report	1	Athlete	Chest pain	Dry needling	N/a	Complete pain remission within 2 weeks, return to sports after 1 month	N/a	Consistent at follow-up visit 3 month
	Rainey 2013 [39]	Case report	1	Athlete	Chronic low back pain	Dry needling	N/a	Pain reduction after 96 hours	N/a	Consistent at follow-up visit 12 weeks

Table 2 (*Continued*)

Therapy	Author	Type	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between	Other outcomes groups
	Clewley 2014 [40]	Case report	1	Recreational athlete	Shoulder pain	Dry needling	N/a	Pain reduction after two treatments	N/a	Sign. improvements in shoulder range of motion in all planes, and other outcomes at discharge (6 weeks)
	Ingber 2000 [41]	Case report	3	Athlete	Shoulder pain	Dry needling	N/a	Pain reduction, return to play within 1 month	N/a	Painless function at follow-up 2 years
	Dembows ki 2013 [42]	Case report	1	Athlete	Hamstring strain	Dry needling	N/a	Clinically meaningful improvement by day 12 return to full sports participation without pain by day 20	N/a	Painless function at follow-up 4 month
	Jayaseela n 2014 [43]	Case report	2	Athletes	Tendinopathy	Dry needling	N/a	Pain free/almost fully reduced after 8 weeks	N/a	Painless function at follow-up 6 month
	Mason 2014 [44]	Case report	1	Athlete	Knee pain	Dry needling	N/a	Asymptomatic after 1 week	N/a	Painless function at follow-up 3 month
	Osborne 2010 [45]	Case series	4	Athletes	Shoulder injury	Dry needling	N/a	Short-term pain relief and improved function	N/a	
	Yeo 2014 [46]	Case series	21	Athletes	Chronic Achilles tendinopathy	Ultrasound guided dry needling	N/a	Reduced pain intensity	N/a	Four fifth of the patients were able to return to sports
	Huguenin 2005 [47]	RCT	59	Athletes	Myofascial pain	Dry needling	Sham intervention	Sign: reduced pain intensity	No sign. between groups	Sham intervention can be considered a manual trigger point release

Table 2 (*Continued*)

Therapy	Author	Type	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between	Other outcomes groups
	Kamali 2018 [48]	RCT	40	Overhead athletes	Unilateral shoulder impingement	Dry needling 1)Upper trapezius 2)Infraspinatus [ISP)	No control, two active treatments	Both: pain intensity and diasability sign decreased ISP: Pressure pain threshold sign increased	Dry needling of ISP had greater effects	
Interventional pain management including nerve blocks and lesioning										
Analgesic nerve blocks	Kearney 2015 [58]	Meta-analysis	732 18	Patients & athletes	Achilles tendinopathy	Injection therapy	-Placebo -control	1) Reduced pain intensity, 7 studies, *n* = 219) 2) Earlier return to sports (*n* = 335)	1)Mean Difference [95%CI]—22.94 [—37.53, —8.36] 2)Risk ratio [95% CI)] 1.39 [1.00, 1.94]	79% of data were in athletes. very low quality evidence
	Drakos 2013 [59]	Retrospective	37	Athletes	Muscle strains and ligaments sprains	Corticosteroid and local anesthetic injections	N/a	All players returned to play after injection	N/a	Seventeen (55%) players did not miss a single game, and nine (30%) did not miss a single day
	Steven 2010 [60]	Case series	3	Athletes	Muscle strains	Ultrasound-guided steroid injection	N/a	Sign. pain relief within a few days return to sport within 3 weeks	N/a	Painless function at follow-up at 36 months, and 14 month respectively
	O'Connell 2002 [61]	Case series	17	Athletes	Osteitis pubis	Symphyseal cleft injection	N/a	87.5% experienced immediate relief 62.5% sign. Pain relief after 2 weeks	N/a	87.5% return to sport 48 h after the procedure

Table 2 (*Continued*)

Therapy	Author	Type	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between	Other outcomes groups
Interventional pain management including nerve blocks and lesioning										
Prolotherapy	Rabago 2009 [62]	SR	208 9	Patients	Lateral epicondylitis likely sports-related	3 prolotherapy, 2 polidocanol, 3 autologous whole blood and 1 platelet-rich plasma	Active, saline, control or placebo	31.2% symptom-free after 2 month All: sign. reduction of pain intensity	N/a	Cohen's d ranged from 0.68 to 6.68
	Dong 2016 [63]	SR	1913 27	Patients	Lateral epicondylitis likely sports-related	Injection therapies	Placebo, active	Pain scores, weighted mean difference hyaluronate 3.98—5.82 prolotherapy 1.57—3.6	Hyaluronate injection and prolotherapy might be more effective	Regarding the intermediate-term effects (6 months/26 weeks), some commonly used injection therapies can be considered treatment candidates, such as botulinum toxin, platelet rich plasma and autologous blood injection. Corticosteroid injection is not recommended.
	Rabago 2005 [64]	Review	11 studies	Patients	Musculo-skeletal disorders likely sports-related	Prolotherapy	N/a	Reduction of pain intensity	N/a	Current data suggest that prolotherapy has a positive effect compared with baseline status

Table 2 (*Continued*)

Therapy	Author	Types	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between	Other outcomes groups
Interventional pain management including nerve blocks and lesioning										
	Morath 2018 [65]	SR, meta-analys is	592 18	patients	Chronic painful Achilles tendinopathy	Sclerotherapy, prolotherapy	N/a control	Sign. reduced pain intensity	Weighted mean difference VAS 4.67 cm, 95% CI −5.56 to −3.76	Only one serious AE and two minor AEs
	Topol 2005 [66]	Case series	24	Athletes	Likely sports-related Chronic groin pain	Monthly injection of 12.5% dextrose and 0.5% lidocaine	N/a	Reduced pain intensity	Sign	83% patients had no pain and 92% were unrestricted with sports at folow up (range 6-32 months)
	Topol 2008 [67]	Case series	75	Athletes	Chronic groin pain	Monthly injection of 12.5% dextrose and 0.5% lidocaine	N/a	Reduced pain intensity	Sign	66/75 (88%) returned to unrestricted sport, 6 did not improve
	Ojofeitimi 2016 [68]	Case report	1	Dancers	Metatarsoph alangeal joint pain	A treatment program (37 sessions: taping, padding, physical therapy, a series of prolotherapy injections, and activity modification	N/a	One year after discharge, the dancer reported pain-free dancing with no taping or padding	N/a	Dance Functional Outcome Survey (DFOS) score improved from 16% to 86% Medical Outcomes Study 36- Item Short-Form Health Survey (SF-36) physical scores improved from 24 to 47

Table 2 (*Continued*)

Therapy	Author	Types	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between	Other outcomes groups
Interventional pain management including nerve blocks and lesioning										
Nerve blocks	Lutter 1986 [69]	Cohort study	182	Sports-active	Sub- calcaneal pain	Nerve blocks	N/a	Successful pain reduction		Running is a risk factor for subcalcaneal pain. Approximately 20% of patients require 3 to 4 months before recovery to sports activity without surgery
	Peebles 2017 [70]	Report	N/a	Athletes	Sacroiliac joint dysfunction in low back pain	Intra-articular or periarticular injections or nerve blocks	N/a	N/a	N/a	
	Gebauer 2005 [71]	Case report	1	Athlete	Exercise induced leg pain	Sympathetic block	N/a	Return to sport after one treatment	N/a	
	Kingsley 2014 [72]	Case report	1	Youth athlete	Chest pain slipping rib	Hooking manoeuvre	N/a	Pain reduction Responder Rate (pain decrease > 50%) = 75%	N/a	Nerve block is described as a second line treatment.
Pulse-dose radiofrequency	Masala 2017 [73]	Prospe ctive study	32	Athlete	Chronic pubalgia	Pulse-dose radiofrequency	N/a	Sign. pain reduction,		Pain intensity decreased up to 9 mo in 31 patients No adverse events

Table 2 (*Continued*)

Therapy	Author	Types	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between groups	Other outcomes
Physical medicine and rehabilitation										
Temperature modalities	Adamczyk 2016 [75]	RCT	36	Physically active men	Postexercise recovery	Cold water immersion ice massage	Passive recovery	Pain intensity (VAS)	Cold water immersion sign. at 48, 72 and 96 h; ice massage at 72 and 96 h vs. control	Faster decrease in lactate lower skin temperature decrease in discomfort at 72 h
	Costantin o 2005 [76]	RCT	45	Athletes	Tendonitis	Cryoultrasound		1)Laser therapy 2)t.e.c.a.r therapy	Decreased pain intensity	Sign. improvement cryoultrasound vs. laser
	Giombini 2002 [78]	RCT	44	Athletes	Tendinopathy	Hyperthermia	Ultrasound	Decreased pain intensity	Sign. vs. ultrasound	
	Giombini 2001 [79]	RCT	40	Athletes	Sports- related muscle injury	Hyperthermia	Ultrasound	Decreased pain intensity	Sign. vs. ultrasound	Hyperthermia: increase hematoma resolution after 2 weeks
	Giombini 2006 [80]	RCT	37	Athletes	Tendinopathy	Hyperthermia	1)Ultrasound 2)Exercise	Decreased pain intensity		Sign. vs. ultrasound Sign. vs. exercise
	Khamwon g 2015 [81]	RCT	28	Male volunteers	Exercise-induced muscle damage	Sauna	Control	Pain intensity pressure pain threshold	No sign.	Increase in passive range of motion of wrist flexion and extension Increase in grip and wrist extension strength
Ultrasound	Mansfield 2013 [83]	Case report	1	One elite soccer athlete	Knee pathology after trauma	Ultrasound as part of a intensive 15-day rehabilitation program	N/a	Full return to sports after 15 days	N/a	

Table 2 (*Continued*)

Therapy	Author	Types	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between	Other outcomes groups
Physical medicine and rehabilitation										
	Malliaropoulos 2017 [84]	Case series	10	Track and field athletes	Navicular stress injuries	Therapeutic ultrasound	N/a	Increase of ultrasound pain threshold increase of pain intensity (VAS)	N/a	
	Chester 2008 [85]	RCT	16	Recreational athletes	Achilles tendon pain	Ultrasound	Eccentric load	Pain intensity (VAS)	No sign	
Extra-corporeal Shock Wave Therapy	Malliaropoulos 2016 [8]	Cohort study	44	Patients in a sport and exercise medicine outpatient clinic	Stenosing tenosynoviti s	ESWT	N/a	Sign. reductions in pain scores	N/a	Sign. functional improvements Pretreatment symptom duration was significantly correlated with the number of rESWT sessions required (r = 0.776) and 1-year posttreatment pain score (r = 0.335)
	Mori 2017 [89]	Case report	1	Paralympic athlete	tetraparesis (cerebral palsy)	ESWT	N/a	Pain intensity (VAS) reduction after 3 sessions	N/a	Potentially performance enhancing
	Vulpiani 2007 [90]	prospe ctive	73	Athletes	Jumper's knee	ESWT	N/a	Pain intensity + clinical outcome: 73.5% satisfactory results (excellent to good)	N/a	Return to sports 6 weeks in 87.5% of cases

Table 2 (*Continued*)

Therapy	Author	Types	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between	Other outcomes groups
Physical medicine and rehabilitation										
	Vetran 2013 [91]	RCT	46	Athletes	Jumper's knee	ESWT	Platelet-rich plasma injection	Sign. Improvement of *P* severity of symptoms, function, ability to participate in sport and pain intensity (VAS)	No sign	Injection sign. auperior at 6- and 12-month follow-up
	Smith 2014 [92]	RCT	46	Athletes	Chronic patellar tendinopathy	ESWT	Platelet-rich plasma injection	Sign. Improvement of *P* severity of symptoms, function, ability to participate in sport and pain intensity (VAS)	No sign	Injection sign. auperior at 6- and 12-month follow-up
	Zwerver 2011 [93]	RCT	127	Athletes playing volleyball, basketball, or handball	Patellar tendinopathy f	ESWT	Placebo	Reduced pain intensity and VISA-P score (includes pain)	Sign. effect for time but no treatment x time interaction effect	
Low-level laser therapy	Morimoto 2013 [96]	Observational	41	Recreational athletes	Sport injuries	LLLT (830 nm, 6—7 W/cm2, mean: 4.1 sessions	N/a	Rate of effectiveness (pain relief score of 5 or less) after LLLT was 65.9%	N/a	
	Stergioula s 2008 [97]	RCT	52	Recreational athletes	Chronic Achilles tendinopathy	LLLT + ecc. Exercise (820 nm, 60mW/cm2, 5.4 J/session, 6 points 12 sessions, 1/wk)	Placebo +ecc. exercise	Pain intensity (100 mm VAS)	53.6 mm vs. 71.5 mm at 4 weeks, 37.3 mm vs. 62.8 mm at 8 weeks, 33.0 mm vs. 53.0 mm at 12 weeks	Morning stiffness, active dorsiflexion, palpation tenderness, and crepitation Showed the same pattern in favor of the LLLT group
Manipulation mobilization, massage and traction										

Table 2 (*Continued*)

Therapy	Author	Types	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between	Other outcomes groups
Physical medicine and rehabilitation										
	Chang 2014 [98]	RCT	54	Recreational athletes	Sports- related lower extremity periostitis	LLLT (670—950 nm, 1.4 J/cm2, 15 sessions, 3/d)	Conventional treatment (drug/PT)	Severity of pain (Likert scale)	Generalized estimating equations: 0.45 and 0.61 points lower for LLLT on the second and fifth days	Balance function sign. improved in the LLLT group
	Takenori 2016 [99]	RCT	32	College athletes	Motion pain due to injury	LLLT (810 nm, 51.4W/cm^2, 5.4 J/spot, 20 × 30sec)	Placebo	Pain intensity (Modified Numerical Rating Scale MNRS)	Effectiveness rate 75% vs. 0% Pain relief rate 36.94% vs. 8.20% Pain intensity -2.03 vs. 0.56 cm MNRS	
	Foley 2016 [100]	Observational	395	University athletes	Diverse	LED-LLLT consecutive treatment sessions and a follow-up of 1 - 4 months in 65 subjects	N/a	Pain attenuation on a visual analog scale (VAS): all subjects had a final VAS score of zero		Return to play 9.62 d
	Almeida 2013 [101]	Meta- anaylsis	1222	Male athletes, all but one	Adductor-related groin pain	Exercise therapy	1)Physio-therapy 2)Multi-modal treatment (heat, manual therapy and stretching)	Pain measure	1)Risk ratio [95%CI] 2.50 [1.43 to 4.37] 2)No differences, 50% of participants	1) Earlier return to sport
	Kong 2012 [102]	RCT	110	Athletes	Low back pain	Chinese massage + herbal ointment	Chinese massage	Reduced pain intensity and quality	Sign. vs. massage alone	Affective scores sign. decreased after 1 month

Table 2 (*Continued*)

Therapy	Author	Types	N	Subjects	Purpose	Active Treatment	Comparator	Result	Significance between	Other outcomes groups
Physical medicine and rehabilitation										
	Visconti 2015 [103]	Observational	221	Ultramaratho *n* runners	Delayed- onset muscle soreness	Massage	N/a	Pain intensity (NPR)	Decrease of 3.6 points (sign.)	
	Nunes 2016 [104]	RCT	74	Triathlon athletes	Ironman symptoms	Massage	Sitting	Pain intensity (VAS) pressure pain threshold	Mean difference VAS −0.7 cm (sign)	Fatigue (VAS) −15 mm no effects on pressure pain threshold
Complementary therapies										
Mind-Body Interventions	Deroch 2011 [114]	Retrospective	205	Athletes	Sports related pain	Coping strategies	N/a	Sign. interaction between ignoring pain and pain intensity	N/a	
	Boyle 2004 [115]	Case control	24	Volunteers	DOMS	Yoga	Control	Reduced pain intensity	Sign. vs. control	
	Litchke 2012 [116]	RCT (Pilot)	24	Athletes	Health- related quality of life	Breathing (2 conditions)	Control	Decreased bodily pain improved vitality	Sign. concurrent flow breathing vs. control	
Phytotherapy	Johar 2012 [119]	RCT	16	Volunteers	DOMS	Topical menthol	Topical ice	Reduced pain intensity and increased tetanic force	Sign. vs. ice	No effect on voluntary force
	Wilson 2015 [120]	SR	206	Untrained participants [106] and athltes [100]	Symptoms following exercise training and sport	Ginger 2.2- g/d	Placebo	Reduced muscle soreness (VAS)	5 out of 6 RCTS showed sign. to placebo	Roughly 2 g$d21 of ginger may modestly reduce muscle pain stemming from eccentric resistance exercise and prolonged running

The table indicates the retrieved studies on pain in athletes and sports. N: number of athletes; LLLT: low level laser therapy; ecc: eccentric; VAS: visual analogue scale; ESWT: extracorporeal shock wave therapy; TENS: transdermal electric nervous stimulation; sign: significant; MPT: mechanical pressure threshold; t.e.c.a.r: diathermy capacitive therapy; DOMS; delayed onset muscle soreness; NPR; numeric pain rating scale.

A case series reported the management of shoulder injuries using dry needling in four elite volleyball players from the Great Britain National Women's Volleyball Squad [45], reducing their pain by approximately 50%. Yeo et al. reported on a specialized dry needling variation: an ultrasound-guided dry needling of tendinous triggers in combination with percutaneous paratenon decompression in 21 patients with chronic Achilles tendinopathy [46]. The intervention reduced the pain intensity at rest by approximately 43% and during activity by 54%. More than four fifth of the patients were able to return to their sporting interests.

Dry needling of gluteal muscles was effective to improve straight leg raise and reduce pain in 59 male runners [47], all athletes during the 2002 Australian Rules football season. The visual analogue scale assessment of hamstring pain and tightness and gluteal tightness after running showed improvements immediately after the intervention. However, authors found a sham treatment to be effective, too. They held the tip of a blunted needle to the skin over the trigger point applying pressure. This can be considered being a manual trigger point release and could explain its effectiveness. A recent study in 40 overhead athletes with shoulder impingement syndrome compared dry needling of the infraspinatus versus the upper trapezius muscle, showing both approaches to be equally effective in reducing pain intensity and disability [48].

In summary, we could retrieve 10 clinical case reports, 4 case series, 2 RCTs and one Cochrane review suggesting the possible benefit of acupuncture, dry needling and acupuncture-related techniques to reduce sports-related pain. We could not detect negative studies. According to the NICE criteria, this would correspond to a recommendation grade B. Still, methodologically sound and large confirmatory studies are missing. Regarding the safety of acupuncture, there is numerous data indicating the general net benefits of the treatment [49].

3.1.4. Vibration

Vibration is the propagation of short and fast elastic waves as a physical treatment, this acting mechanically on irritated tissues. In sports, no clinical studies have been reported, and recommendations can be only drawn on the basis of experimental studies. These data indicated vibration not to alter pain perception in healthy male gymnasts [50]. However, whole-body vibration was shown to reduce pressure pain intensity in an experimental model of DOMS in untrained subjects [51]. This is in line with a study experimentally inducing DOMS by means of eccentric exercise and hypertonic saline, indicating vibration to remarkably reduce the sore area pain levels by approximately 24% [52]. Vegar et al. retrieved another six studies or reports in their review, assuming vibration to be an effective intervention as a treatment and control in DOMS, however studies are heterogeneous as they compare vibration therapy to whole-body vibration or even vibration training [53]. There is one study showing vibration added to a foam roller to cause greater effects on individuals' pain tolerance in 45 recreationally active adults [54]. There is not enough clinical evidence to draw a recommendation at this point.

3.2. Interventional pain management including nerve blocks and lesioning

3.2.1. Analgesic nerve blocks

The injection of substances by means of cannulas to athletes is a doubtable approach in athletes, as it counteracts current attempts to avoid injections at all [55]. A variety of stimulating substances could be (mis-)used, and the full adherence to the black lists of the World Anti-Doping Agency is strongly recommended before offering such treatment.

Corticosteroids, local anaesthetics, and ketorolac are the most commonly used injectable agents used for pain control and/or an anti-inflammatory effect in athletes [56]. A review from 2011 highlights the impact of injection therapies in the treatment of tendinous disorders, which might be sports-related. Authors identified 7 injection techniques out of 11 RCTs and found all of them to be promising in reducing pain, eg., dry needling, autologous blood, high-volume, platelet-rich plasma, sclerosis, steroids and aprotinin injections [57]. Authors assume that intra- or peritendinous injections by themselves might already influence the symptoms of patellar tendinopathy positively. One of the insights on injection therapies may be that any injection with an irritant solution can be beneficial for the treatment of a condition. A Cochrane review investigating the use of injection therapies for Achilles tendinopathy [58] included 7 studies that were performed in athlete subgroups. There was very low quality evidence in favour of injection therapy in short-term (under three months) pain (219 participants, seven trials) and in the return to sports (335 participants, seven trials), and no firm conclusions can be drawn. A retrospective analysis examined the effects of corticosteroid and local anaesthetic injections for muscle strains and ligament sprains in the National Football League [59], showing all players to return to play after injection. Therapeutic injection of steroids and anaesthetic under ultrasound guidance appears to reduce pain in professional baseball pitchers with acute side strains [60]. Still this approach is to debate, as the addition of steroids to anaesthetics requires a Therapeutic Use Exemption (TUE) to authorize that athlete to take the needed medicine [19] Authors of the case series do not report details in this regard. Symphyseal cleft injections of methyprednisolone and bupivacaine in 16 athletes with osteitis pubis induced immediate relief and the ability to resume sporting after 48 h in 87.5% of patients, and 31% having persisting symptoms at a 2 and 6 month follow-up [61]. Again, authors did not mentioned the topic of TUEs.

Prolotherapy figures among the novel and sparely investigated approaches. It aims to enhance healing in fascial structures by injecting monosaccharides (dextrose) or other sugar-containing substances. There is some evidence, that prolotherapy is effective in the treatment of lateral epicondylitis [62,63] and has been suggested promising in chronic musculoskeletal pain [64]. A recent meta-analysis suggests sclera- and prolotherapy to be effective in painful Achilles tendinopathy as well, and reported a significant drop in pain intensity [65]. However, all of these analysis have in common that underlying diseases are very likely sports-related, but no direct implication in regard to athletes can be drawn. Regarding athletes, there is one study

that started prolotherapy in 24 elite male kicking-sport athletes with chronic groin pain that did not respond to rest or various kinds of physical therapy, with 22 of them returning unrestrictedly to sports within 3 months [66]. This is in line with a representative case series among 75 elite athletes suffering from groin pain [67]. A case report suggests a treatment program that, besides prolotherapy, included taping, padding, physical therapy, and activity modification is effective in the management of a dancer's metatarsophalangeal joint pain [68].

Myofascial TrP injection has been suggested being a promising therapy in myofascial pain. Besides the well-reported studies in general pain states, systematic clinical studies in athletes are missing.

The use of nerve blocks in athletes is referred to in diagnosis and treatment guidelines, however relevant RCT studies are missing. One narrative review dating from 1986 reports nerve blocks to be an adequate conservative approach in patients with subcalcaneal pain related to sports activity [69], as is in sacroiliac joint dysfunction in the athlete [70]. There is one case of exercise-induced leg pain in a female collegiate soccer player successfully treated with a sympathetic block [71]. One initial block allowed the patient to compete most of the fall season asymptomatically. Following a second block she could finish the season without symptoms. A report suggests intercostal nerve blocks being an appropriate therapy in pain due to slipping rib syndrome in the case of a 14 year old athlete [72].

Radiofrequency lesions have been reported to reduce VAS by more than 50% in athletic pubalgia, with one of 32 patients perceiving no improvement, and all others having improvements in pain up to 9 month [73]. Six of the patients returned to training following two treatment sessions.

According to the NICE criteria, analgesic nerve blocks and injection therapies seem to elicit moderate to strong pain relieving effects in athletes (Grade A). Still, there no recommendation can be made regarding the stimulating substance or the specific technique due to a lack of comparative studies.

3.3. Physical medicine and rehabilitation

3.3.1. Temperature modalities

Data regarding hot and cold therapies for the purpose of analgesia in athletes are very limited and mainly based on experimental data. Whereas cold therapy is supposed to evoke reductions in pain, blood flow, oedema, inflammation, muscle spasm, and metabolic demand, it is heat therapy that besides pain relief is sought to increase the blood flow, metabolism, and elasticity of connective tissues. Cold-water immersion used by athletes for post-exercise recovery did not show superiority on pain thresholds and muscle soreness when compared to a control group [74]. Cold water immersion and ice massage reduced pain when applied for supporting experimental post-exercise recovery [75]. One available clinical study suggest that cryoultrasound is superior to laser therapy in the reduction of pain intensity due to tendonitis in athletes [76]. A Cochrane review found insufficient evidence to determine whether whole-body cryotherapy can reduce self-reported muscle soreness and pain, or improve subjective recovery, following exercise in physically active young adult males [77].

Hyperthermia has been shown to be superior improving the pain intensity compared to ultrasound in patients with sports-related overuse tendinopathies [78] and in sports-related muscle injuries [79] The same group confirmed their results in athletes suffering from pain due to supraspinatus tendinopathy [80]. Sauna application prior to an experimentally exercise-induced muscle damage demonstrated effectiveness in reduction of sensory impairment, but not in regard of pain thresholds [81]. Systematic reviews are missing.

Therapeutic ultrasound is supposed to deliver energy (pulsed or continuous) to deep tissue sites through ultrasonic waves. This provokes *n* increase in tissue temperature that is supposed to mediate the same effects like heat therapy. An experimental study on exercise-induced muscle damage showed continuous ultrasound to decrease pain perception and increase pain thresholds [82]. Regarding sports, a case report showed therapeutic ultrasound to be effective as part of an intensive 15-day rehabilitation program to return an elite soccer athlete to sport [83]. Its decrease in the perception of navicular pain correlates with the grade of fracture following navicular stress injuries in a study in track and field athletes [84]. A randomised study revealed 6 weeks of ultrasound therapy when compared to eccentric load to descriptively (ΔVAS 13.9 mm) but not significantly reduce pain after sports [85].

Extracorporeal Shock Wave Therapy (ESWT), refers to a treatment using extracorporally generated shockwaves. It is thought, that by means of their capacity, forces are forwarded by mechanotransduction, and that these stimuli induce healing in the respective tissues. Reviews regarding its effectiveness in painful tendinopathies, without specifically referring to sports-related tendinopathies, are inconclusive [86,87]. A case series revealed a significant reduction in pain scores up to a one year follow-up in the treatment of sports-related finger tendosynovitis with radial extracorporeal shock-waves in a sport and exercise medicine outpatient clinic [88]. This is in line with a case report in a paralympic athlete suggesting the role of ESWT in the reduction of pain and fatigue experienced during athletic performance [89]. A RCT showed the effectiveness on painful jumper's knees in 73 athletes [90]. Time to return to sports remained 6 weeks in the performing sports patients. This is in agreement with a recent study showing shock waves to improve the symptoms of jumper's knees in athletes by a similar extent than autologous platelet-rich plasma injections [91], as was the treatment of chronic painful patellar tendinopathy in athletes [92]. These three studies are in contrast to a study showing a pain-reducing effect of ESWT on patellar tendinopathy in 127 jumping athletes during the competitive season, but not significantly different when compared to placebo [93]. To our knowledge, there is no other large study investigating the effects of ESWT on muscular function or pain in athletes. Besides some inconclusive results regarding the use of extracorporeal shock wave therapy in tendinopathies, larger studies are needed to evaluate the role of ESWT in the context of analgesic sports medicine.

Low-level laser therapy (LLLT) uses low-power lasers or light-emitting diodes, and is thought to especially stimulate the mitochondria to an increased ATP production,

modulation of reactive oxygen species and induction of transcription factors, among them redox factor-1 -dependent activator protein-1, nuclear factor B, p53, activating transcription factor/cAMP-response element-binding protein, or hypoxia-inducible factor [94]. According to the current literature, low level laser therapy can be considered being a second-line treatment in chronic tendon injuries, however there is no clear link to sports-related tendon pain [95]. In sports, an observational study in athletes suffering from sports injuries contributed a very good pain relieving effect to the laser application [96]. Stergioulas et al. showed LLLT in addition to eccentric exercise to significantly reduce pain in recreational athletes with chronic Achilles tendinopathy, when compared to placebo LLLT in combination with the same exercise [97]. Chang et al. showed some minor pain reduction in adult men suffering from sports-related lower extremity periostitis, comparing LLLT to a conventional treatment group and healthy subjects [98]. Still, there was no overall effect at the end of the study after 5 days. A recent study in 32 college athletes with motion pain due to sports injuries, showed LLLT to provide an immediate pain relief effect by 28.74% in three out of four cases [99]. A recent uncontrolled study could demonstrate LED phototherapy to significantly and safely reduce the time to return to play based on the resolution of pain and inflammation in university athletes, with no adverse events [100]. This study investigated a total of 395 injuries including sprains, strains, ligament damage, tendonitis and contusions.

According to the NICE criteria, temperature modalities seem to elicit moderate to strong pain relieving effects in athletes (Grade A). More solid evidence could be retrieved for ultrasound and laser therapies than cold and warm treatments. Methodological complaints and risk of bias are major shortcomings of the retrieved studies.

3.3.2. Manipulation mobilization, massage and traction

The field of massage and related techniques is large and hard to define. Therapies have in common to produce biomechanical pressure, this increasing muscle compliance and decreasing stiffness, as well as mediating vagal relaxation. Many of the reported studies examine massage techniques as a part of conventional physiotherapy. A cochrane review identified two trials with 122 participants (all but one being male athletes) who had experienced adductor-related groin pain. Authors stated that besides limited evidence, passive techniques, like massage, seemed inferior to active modalities (eg, exercise therapy) improving short term outcomes, but also return to sports in athletes [101]. Clinical data suggest Chinese massage combined with and without herbal ointment improved nonspecific low back pain in a RCT with 110 athletes [102]. Authors showed herbal ointment to statistically improve the effects of massage, but the clinical meaningful difference is very small. Massage has been shown to reduce pain intensity in 25 ultramarathon runners [103]. This was confirmed by a large randomized controlled trial involving 75 Ironman triathlon athletes [104]. Authors could show that massage decreases pain and perceived fatigue.

A 2011 literature review identified 4 studies comparing the effects of manual therapy with stabilization exercises in athletes with chronic low back pain, showing both treatments to be effective [105]. A study in 59 elite Australian rules footballer showed small effects of a sports chiropractic manual therapy on the incidence of lower limb muscle strains, this reducing perceived low back pain when compared to conventional medical practice. However, this article has been retracted because ethical approval of the study was missing [106]. A case series of 30 athletes with chronic adductor-related groin pain reports a return-to-sport ratio of 90% and pain reduction from 8.7 cm to 2.2 cm on a visual analogue scale, when treated with manual therapy [107]. Manual therapy consisted of circular movements followed by compression techniques. Several case reports suggest the use of chiropractic in the management of musculoskeletal pain in a junior hockey player [108], shoulder pain in a softball athlete [109], pain due to a sudden, non-traumatic, ballistic movement of the cervical spine during a Teakwondo competition [110], or thoracic pain in a collegiate runner [111]. A recent systematic review showed the efficacy of manual joint mobilization on pain relief and functional improvement of acute lateral ankle sprains, without specifically referring to sports-related sprains [112].

To summarize, there is a huge body of evidence justifying the use of manipulation mobilization, massage, and traction in sports-related pain conditions (Grade A). Trained and experienced therapists should be considered to reduce harms.

3.4. Complementary therapies

The IASP curriculum subsumes complementary medicines to be non-mainstream [24]. Some could be related in part to this section, e.g. TENS or acupuncture, but where covered in the chapter on stimulation-induced analgesia.

3.4.1. Alternative medicine systems, e.g. homeopathic medicine

No substantial data could be retrieved.

3.4.2. Mind-body interventions

Meditation, mindfulness, relaxation, biofeedback and others have been attributed being a part of mind-body therapies, aiming to promote stress reduction (decrease in sympathetic activity) and well-being by changing the manner in which mind and body respond to their environmental or internal stressors. Their use in the control of chronic pain is frequent, attributing small to medium effect sizes [113]. Regarding sports, a qualitative analysis in 10 injured athletes showed imagery to facilitate pain management [114]. Two-hundred and five athletes from combat sports suffering sports-related pain within the previous month were surveyed regarding their coping strategies [114]. It was not distraction from pain, praying, reinterpreting pain sensations or pain catastrophizing, but ignoring pain that turned out to significantly interact with pain intensity. Yoga training and a single bout of yoga appear to attenuate the peak of experimentally induced delayed onset muscle soreness in women [115]. There is evidence suggesting breathing to reduce bodily pain in wheelchair rugby athletes when compared to control [116]. However, systematic data on the improvement of pain in athletes is missing, and no general conclusion can be drawn at this point. There is not enough evidence to draw a recommendation at this point.

3.4.3. Energy therapies, e.g. Reiki and therapeutic touch

No substantial data could be retrieved.

3.4.4. Biologically based therapies

Several botanicals, herbal medicine or nutritional add-ons are subsumed under the term biologically based therapies. Due to the large variety, there is no general consent on the use of phytotherapeutics. One example is the use of comfrey, hitherto declared to be safe in side effects. It is not to rule out, that these biologically-active compounds may infringe anti-doping regulations. Strict education and analysis of phytotherapeutics is required prior to administration [117]. It has been shown, that comfrey, possibly mediated via its component allantoin acid, reduces muscular soreness, pain and joint disorders [118]. It has been shown not to be inferior when compared to topical NSAIDs, however we could not assess the cited study relating to athletes [118]. Still, well-designed trials adhering to guidelines are needed to confirm results regarding the potential effectiveness of herbal medicine (e.g., harpagophytum procumbens, salix alba, solidago chilensis, capsaicin or lavender essential oil) in sports. Menthol, an organic compound obtained from peppermint, was shown to be superior to ice reducing pain intensity and improving force in an experimental setting of delayed onset muscle soreness [119]. Ginger has been evaluated being an analgesic in sport [120]. The evidence indicates that roughly 2 g·per day of ginger may modestly reduce muscle pain originating from eccentric resistance exercise or prolonged running. Biologically based therapies may be a safer and alternate approach to relief pain in athletes when compared to drugs [121]. Still, studies in pain relief are necessary to estimate their effectiveness. Due to the heterogeneity of the above reported studies, no recommendations can be made up to now.

3.4.5. Bioelectromagnetics

No substantial data could be retrieved.

4. Conclusions

Several therapies have been proposed being a single or comprehensive option in the treatment of pain in sports. On the basis of the current body of evidence, this narrative review recommends the use of interventional pain management including nerve blocks and injection techniques, and physical medicine and rehabilitation -eg., temperature modalities especially ultrasound and laser therapy, as well as manipulation mobilization, massage and traction-, all recommend on Grade A. Acupuncture and Dry needling being part of stimulation-produced analgesia can be graded B, mainly due to the heterogeneity of studies and their risk of bias. All three method groups have in common that they refer to hands-on techniques. Non-drug therapies in pain seem clearly to do more good than harm in patients, as far as reported. Still, the overall quality of retrieved data is poor and broad confirming trials are missing.

Whereas studies examining effects on acute pain in sports seemed to be more prevalent, it is chronic pain where subsidiary studies are missing. As presented above, chronic pain states figure the states tremendously influencing an elite athlete's career. For chronic pain patients, it could be multimodal concepts being proposed an effective approach [122]. The combination of physical and psychosocial training methods and training programs would be such a comprehensive approach in view of the athletes and trainers. As described, a huge body of therapies avoiding possible harms would opt being part of such strategies. Still, to our knowledge, there is only one publication, dealing with the idea of a multimodal concept in the treatment of athletic pain [123]. This is substantiated by a meta-analysis, showing the general benefit of a 6-week multimodal physiotherapy program for the nonsurgical management of anterior knee pain [124]. A consensus statement recently published by the International Olympic Committee IOC summarised a broad variety of definitions and therapies when dealing with pain in elite athletes [125]. However, the authors present the pharmacological pain therapy in the centre of the treatment path. A differentiated analysis of other conservative methods in accordance with the requirements of multimodal pain management is far from.

Finally, besides improving athletes' health, it would be of sustained socioeconomic interest to develop strategies that either prevent pain or reduce the time athletes can fully return to their sports.

Disclosure of interest

The authors declare that they have no competing interest.

WB and JF are the Heads of the Scientific Chapter of the German Medical Acupuncture Society DÄGfA e.V.

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