Use of extracorporeal shockwave therapies for athletes and physically active individuals: a systematic review

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ABSTRACT

Objective To determine the efficacy of extracorporeal shockwave therapy (ESWT) and investigate outcomes following the use of ESWT for athletes and physically active individuals.

Design Systematic review.

Data sources We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses and searched four databases: PubMed (NLM), Embase (Elsevier), CINAHL Complete (EBSCO) and Web of Science (Clarivate).

Eligibility criteria for selecting studies Included studies were randomised controlled trials, cohort and case–control studies, cases series and reports that evaluated outcomes following ESWT for athletes, physically active individuals and occupational groups requiring regular physical activity such as military cadets.

Results 56 studies with 1874 athletes or physically active individuals were included. Using the Oxford level of evidence rating, included studies were 18 level I (32.1%), 3 level II (5.4%), 10 level III (17.9%), 13 level IV (23.2%) and 12 level V (21.4%). Based on the level I studies, ESWT may be effective alone in plantar fasciitis, lateral epicondylitis and proximal hamstring tendinopathy and as an adjunct to exercise treatment in medial tibial stress syndrome and osteitis pubis in athletes or physically active individuals. In most studies, athletes were allowed to continue activities and training and tolerated ESWT with minimal side effects.

Conclusion ESWT may offer an efficacious treatment alone or as an adjunct to concurrent exercise therapy in selected sports-related injuries and without major adverse events. Further high-level research is needed to better define the role and clinical outcomes of ESWT.

WHAT IS ALREADY KNOWN

⇒ Extracorporeal shockwave therapy (ESWT) has been widely used for the management of common sports-related injuries both in physically active and sedentary patient cohorts.

WHAT ARE THE NEW FINDINGS

⇒ Patellar tendinopathy is the most widely studied condition for athletes, but the use of ESWT presents conflicting results.
⇒ Most studies evaluating ESWT for athletes and physically active individuals have a low level of evidence.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ Additional high-level research is needed to better define the role and clinical outcomes of ESWT in athletes and physically active individuals.

INTRODUCTION

Athletes, their teams and sports medicine organisations share a collective goal to optimise athlete health and preserve the ability to compete in sport while managing musculoskeletal injuries. Athletes often train and compete while travelling across different time zones which may limit recovery.[1] Not surprisingly, studies have suggested a higher rate of injuries during the preseason and during times of competition.[2] Common injuries including muscle strains,[3] tendinopathies[4] and bone stress injuries[5] may be difficult to treat in-season and have unpredictable recovery time following treatment interventions. Surgical management is often reserved for athletes during the off-season since postoperative rehabilitation may take up to 6–9 months.[4] Collectively, these factors contribute to a need for athletes and their caregivers to explore less invasive, safe and effective treatments that may allow continued in-season participation in sports.

Growing research has suggested that extracorporeal shockwave therapy (ESWT) may be effective for the management of sports-related injuries.[6] ESWT is a non-invasive intervention that creates sound or pressure waves that propagate through tissues to stimulate interstitial and extracellular responses.[7] Such biological responses include increased collagen synthesis,[8] cellular proliferation and wound healing,[9 10] and neovascularisation.[11]

The two main types of ESWT include radial shockwave therapy (R-SWT) and focused shockwave therapy (F-SWT). R-SWT generates radial pressure waves that create maximal energy at site of impact, while F-SWT has the capacity to penetrate deeper regions using sound waves emitted from the application site.[12] Treatment parameters typically include energy flux density, number of impulses, shockwave type and frequency of treatment sessions. Both forms of ESWT have been used to treat many different conditions including tendinopathies, bone injuries and muscle injuries, but their mechanistic effects may lead to varying

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outcomes for specific injuries.[13] The cost and time can be limiting factors for the use of ESWT as it may incur out-of-pocket costs and often require a minimum of three to four sessions based on published studies.[13]

High-level evidence for efficacy of ESWT has been reported in common athletic injuries, such as plantar fasciitis[14] and Achilles tendinopathy[15] with minimal side effects including temporary pain at the application site and skin bruising or erythema.[13] Given that ESWT often requires minimal to no time away from sport, and the treatment response can manifest as early as 1–3 months,[14 15] ESWT can be considered a feasible treatment option for athletes. However, previous systematic reviews investigating efficacy of ESWT have focused on pathologies (eg, Achilles tendinopathy or plantar fasciitis) rather than population studied.[16–21] While these reviews describe efficacy of ESWT by musculoskeletal condition, the results of these reviews may not be generalisable to athletes or physically active populations who wish to continue to compete or exercise in preferred activities during treatment. Similar to athletes, physically active individuals or occupational groups suffer from diverse musculoskeletal injuries which may limit their return to desired physical activities or work.[22 23] To date, no review has summarised available evidence of ESWT for athletes and for physically active individuals. Therefore, the purpose of this systematic review was to determine the efficacy of ESWT and synthesise the current literature evaluating outcomes for sports-related injuries following the use of ESWT for athletes across sports as well as physically active individuals or occupations.

METHODS

We performed this systematic review according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses.[24] The protocol was prospectively registered with INPLASY (202340102) for a scoping review, but after reflecting the reviewers' comments, another protocol was registered to conduct a systematic review (INPLASY 2023110075) defining plans a priori for a risk-of-bias assessment and potential statistical analysis.

Study selection and eligibility criteria

We included studies that investigated the efficacy of ESWT and outcomes following ESWT for athletes, physically active individuals and occupational groups requiring regular physical activity such as military cadets. In studies that indicated the proportion of athletes or physically active individuals included in the studies, those with greater than 80% of such populations were included for this review. The rationale for including physically active individuals and occupational groups was that their return to activities and jobs would be important and similar to athletes' goal to return to play. We included randomised controlled trials (RCTs), cohort studies, case–control studies, case series and case reports. We restricted the studies to those published in the English language based on the previous literature suggesting no evidence of bias even when studies written in other languages were excluded.[25 26]

We excluded review articles, abstracts, letters to the editors, commentaries, genetic or molecular studies and animal studies. We also excluded studies in which ESWT was used for the management of hypertonia or spasticity. Any disagreement between reviewers related to the eligibility of a study was resolved through discussion.

Search strategy

A librarian (CW) designed a search strategy using controlled vocabulary and keywords for ESWT and a variety of athletes and physically active adults or occupational groups prone to sports-related injuries (see online supplemental table 1 for full search strategy). We conducted separate searches in four databases: PubMed (NLM), Embase (Elsevier), CINAHL Complete (EBSCO) and Web of Science (Clarivate) on 21 April 2023. Duplicates were identified and removed using EndNote.

Data extraction

Two authors (HCR and PD) independently conducted data extraction. A template was used to extract authors, year of publication, origin (country where the study was conducted), study design, patient characteristics (age, sex and sample size), symptom duration, pathologies, ESWT parameters, activity restriction following ESWT, comparators, outcome measures, follow-up periods, main findings including return to sports or activities and adverse events. For study design, regardless of the authors' description or sample size, if the studies did not have control or comparators, they were classified as case series. Unless the authors specified as case–control studies, the studies with two groups that were not randomised were classified as cohort studies.[27] Level of evidence was assigned based on the recommendation adapted from the Oxford 2011 Levels of Evidence.[28] The pilot RCT was assigned as level II, and if the authors formulated the research question after the first patient was enrolled, the study was considered retrospective. Case report was assigned as level V.[29]

Data synthesis and statistical analysis

We initially planned meta-analyses if two or more studies were considered homogeneous (ie, similar comparators, same outcome measures and follow-up periods within the range of 2 weeks). However, given the heterogeneity among studies by populations, study designs, comparators, outcomes measured and follow-up periods, meta-analyses were not performed. We conducted qualitative syntheses of the available evidence of sports injuries using the data extracted above. While presenting the results, p values <0.05 were considered significant. Means with SD or standard errors of mean (SEM) for each group or mean differences (MD) with 95% CI were reported for group comparisons to consider the clinical importance of the results when appropriate and information were available.

Risk-of-bias assessment

To assess the risk of bias for RCTs, we used the revised Cochrane risk-of-bias tool (RoB V.2).[30] This tool evaluates the risk of bias according to five domains: randomisation process, deviations from intended interventions, missing outcome data, measurement of the outcome and selection of the reported result. If all domains are classified as 'low risk', studies can be rated as 'low risk of bias'. If at least one of the domains is classified as 'some concern', studies are rated as 'some concerns'. Studies are considered 'high risk of bias' if there is at least one domain classified as 'high risk' or two or more domains classified as 'some concerns'.

To assess the risk of bias for non-randomised comparative studies, we used the Risk of Bias in Non-randomised Studies of Intervention (ROBINS-I).[31] This tool evaluates the risk of bias according to six domains: bias due to confounding, bias in the selection of participants, bias in the classification of interventions, bias due to deviations from the intended interventions, bias due to missing data and bias in the selection of the reported results. If all domains are classified as a low, studies can be considered 'low risk of bias'. If all domains are classified as a low or moderate, studies are considered 'moderate risk of bias'. If there is at least one domain with serious risk, studies are considered 'serious risk of bias', and if there is at least one domain with critical risk, studies are considered 'critical risk of bias'. Last, studies are rated 'no information' in the absence of serious or critical risk of bias and there is a lack of information on one or more key domains.

Since the ROBINS-I is designed particularly for studies with cohorts or control groups, the Joanna Briggs Institute (JBI) Critical Appraisal Checklist was used to assess the risk of bias for case series[32] and case reports[33] which lack control groups. Each item in the checklist could be answered in one of the four responses: yes, unclear, no and not applicable. Following the guidance on how to use the JBI Critical Appraisal tool, the results of critical appraisal for all questions were presented as tables for case series and case reports rather than summarising with a score (online supplemental tables 5–6).[32]

Two authors (HCR and JS) independently assessed the risk of bias for included studies, and any discrepancy was resolved through discussion and mutual consensus.

Equity, diversity and inclusion statement

The author group consisted of both male and female resident physicians (physical medicine and rehabilitation and family medicine), student researchers, a librarian and professors. Our study population included both male and female participants from different geographic and cultural backgrounds.

RESULTS

After removing duplicates, the initial search resulted in a total of 609 studies. Of those results, 462 studies were removed after screening for title and abstract. The remaining 147 full-text studies were assessed for eligibility, and 91 studies were removed due to not meeting eligibility criteria mentioned above. The results included a total of 56 studies with 1874 athletes or physically active individuals (figure 1). There were 18 level I (32.1%), 3 level II (5.4%), 10 level III (17.9%), 13 level IV (23.2%)

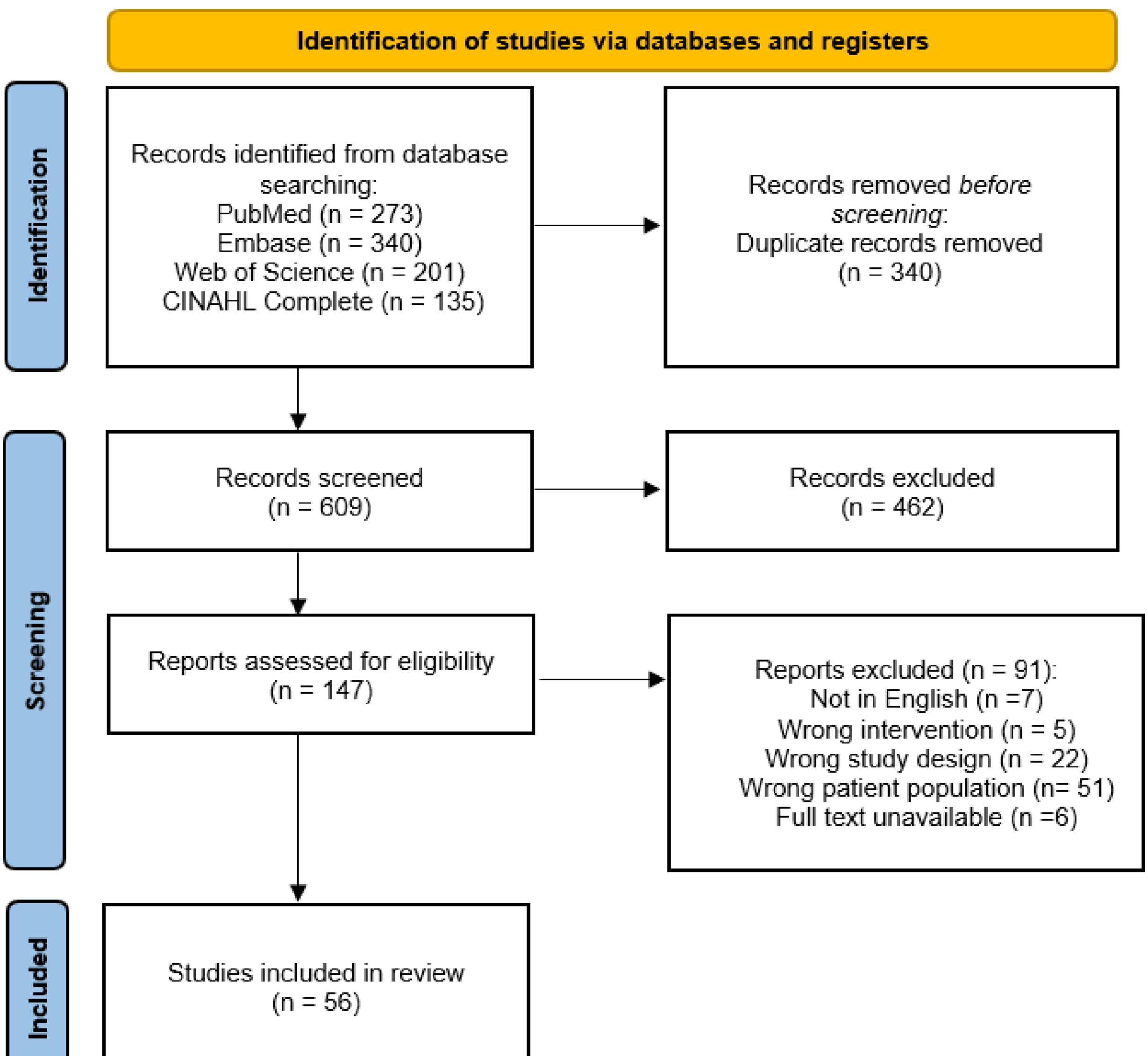

Figure 1 Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram showing article selection process.

and 12 level V (21.4%). The highest number of studies were published from Europe (n=27; Italy=9, Germany=5, Netherlands=5, Poland=3, Belgium=1, Denmark=1, Spain=1, UK=1, Sweden=1) followed by Asia (n=12; China=5, Japan=5, Hong Kong=1, Taiwan=1), North America (n=12; the USA=10, Canada=2), Africa (n=2; Egypt=2), South America (n=2; Brazil=1, Colombia=1) and Oceania (n=1; Australia=1). The characteristics of individual studies including study design, population, pathologies, ESWT parameters, outcome measures, follow-up durations and adverse events are summarised in online supplemental tables 2–3. A brief summary of main findings and return to sports/activity outcomes are presented in online supplemental table 4.

Among the studies that included single sport athletes rather than varied sports participation, runners were the most commonly studied athletes (n=10). For physically active occupations, one study with military cadets[34] and one case report with fitness instructor[35] were identified. The use of ESWT has been reported among athletes and physically active populations in the following injuries: patellar tendinopathy (n=17; level I studies=8), plantar fasciitis (n=8; level I studies=2), medial tibial stress syndrome (n=5; level I studies=1), proximal hamstring tendinopathy/hamstring pain (n=5; level I studies=1), Achilles tendinopathy (n=5; level I studies=2), lateral epicondylitis (n=2; level I studies=2), rotator cuff injury (n=2), distal biceps tendinopathy (n=1), IT band syndrome (n=1; level I study=1), tibialis posterior tendinopathy (n=1), bone injuries (n=10; level I study=1), myositis ossificans (n=2) and other muscle injuries (n=2).

Risk-of-bias assessment

Among 19 RCTs, 6 RCTs were deemed low, 6 RCTs had some concerns and 7 RCTs were deemed high risk of bias (figure 2). Among 12 non-randomised comparative studies, 3 studies were deemed moderate, 6 studies serious and 3 studies critical risk of bias (figure 3). The assessments for case series and case reports are presented in online supplemental tables 5–6.

Patellar tendinopathy

In total, 17 studies reported outcomes in patients with patellar tendinopathy following ESWT. Eight RCTs evaluated ESWT with different comparisons over different time periods. Three RCTs reported favourable outcomes of ESWT over comparison conditions.[36–38] One RCT with high risk of bias composed of mixed national-level athletes compared 16 weekly sessions of R-SWT to a control group receiving weekly acupuncture, ultrasonic wave therapy and microwave therapy and identified that R-SWT resulted in 62.7% reduction in pain, 8.8% and 5.8% increase in 60°/s and 240°/s knee extension peak torques respectively and 12.5% increase in extensor endurance compared with the control group at 16 weeks.[36] In a separate RCT with low risk of bias studying athletes of mixed sport types, three sessions of ESWT in addition to rehabilitation protocol (strengthening including eccentric training, stretching and coordination) were more effective in pain reduction while walking (numeric rating scale 0–10) over rehabilitation protocol alone with sham ESWT at 2 weeks (MD 2.3; 95% CI 0.8 to 3.8), 4 weeks (MD 1.4; 95% CI 0.2 to 2.6) and 12 weeks (MD 1.4; 95% CI 0.4 to 2.5) without statistically significant difference in return to sport outcomes at 12 weeks.[37] In an RCT with some concerns for risk of bias, participants were composed of local university and community volleyball and basketball players with outcomes assessed immediately following application of a single session of F-SWT. Investigators reported a reduction in patellar tendon stiffness in F-SWT group over sham group (tendon shear modulus reduction by mean and SD: 26.7%±19.1% in F-SWT vs 8.4%±24.7% in sham).[38]

In contrast, four RCTs did not show additional benefits of ESWT over control or alternative treatment comparisons in jumping athletes or physically active individuals.[39–42] Among local competitive volleyball, basketball and handball athletes participating in an RCT with high risk of bias, significant reduction in tendon stiffness, increase in tendon strain as well as reduction of pain and dysfunction were observed in both combined F-SWT with eccentric exercise group and eccentric exercise group alone, but there was no significant difference between the groups at 12 weeks.[39] Likewise, another RCT with low risk of bias suggested no additional benefit with three sessions of F-SWT in physically active patients treated with eccentric exercises in terms of pain and Victorian Institute of Sports Assessment-Patellar Tendon (VISA-P) at 6 weeks (MD −1.4; 95% CI −9.0 to 6.2), 12 weeks (MD −3.0; 95% CI −12.3 to 6.3) and 24 weeks (MD −4.8; 95% CI −12.7 to 3.0) after the start of F-SWT.[40] In one RCT with low risk of bias comparing three sessions of F-SWT with placebo (no exercise interventions were prescribed in both groups) in jumping athletes, both groups had similar improvements in pain and VISA-P scores over time at 1 week (MD 3.6; 95% CI −0.3.2 to 10.4), 2 weeks (MD 0.8; 95% CI −7.7 to 9.3) and 22 weeks (MD 0.7; 95% CI −8.0 to 9.4) following treatment.[41] A separate RCT with low risk of bias comparing F-SWT (three sessions at 2–3 days of intervals) with platelet-rich plasma (PRP) in athletes over 2 weeks (one injection per week) demonstrated improved pain Visual Analogue Scale (VAS) and VISA-P at 8, 24 and 52 weeks compared with baseline in both groups, but PRP injections resulted in significantly better results in terms of pain VAS and VISA-P at 24 and 52 weeks (VAS mean and SD: 2.4±1.9 vs 3.9±2.3 at 24 weeks; 1.5±1.7 vs 3.2±2.4 at 52 weeks; VISA-P mean and SD: 86.7±14.2 vs 73.7±19.9 at 24 weeks; VISA-P 91.3±9.9 vs 77.6±19.9 at 52 weeks) and modified Blazina scale at 52 weeks.[42]

One RCT with low risk of bias compared three sessions of R-SWT with three sessions of F-SWT in athletes who underwent eccentric training 2 weeks after their final ESWT and found that while both types of ESWT resulted in similar improvement in VISA-P and VAS scores at 14 weeks, the mean improvement in VISA-P did not surpass minimal clinically important difference (MCID) of 15 in both groups.[43]

An observational study with critical risk of bias evaluated a mixed population of athletes and reported that the outcomes of VISA-P and VAS with ESWT at 24 weeks and at 2 years were comparable to the outcomes following surgery at 2 years. None of the patients experienced any incapacity to work in ESWT group, but patients in surgery group returned to work after an average of 6.1 weeks postoperatively.[44] Other case series[45–52] reported ESWT to be effective in improving pain and function including two studies reporting return to sport at approximately 6 weeks[49] and continued participation at 5-year follow-up.[46]

Plantar fasciitis

Eight studies reported outcomes following ESWT in plantar fasciitis. One RCT with high risk of bias studied runners and found that three sessions of ESWT were more effective in pain reduction than sham at 24 weeks and 52 weeks (VAS mean and SD 2.1±2.0 vs 4.7±1.9 at 24 weeks and 1.5±1.7 vs 4.4±1.7 at 52 weeks).[53] Another RCT in runners with a high risk of bias compared ESWT alone and ESWT with ultrasound and laser

Figure 2 Risk-of-bias assessment for randomised controlled trials.

treatments 2 weeks prior to ESWT. Investigators reported that both treatments resulted in significant improvement in pain and American Orthopaedic Foot and Ankle Society (AOFAS) scores at 5-year follow-up.[54] A prospective cohort study with high risk of bias compared endoscopic plantar fasciotomy (EPF) with ESWT and sham ESWT (patients were randomised into ESWT or sham ESWT) in a mixed athlete population. The study showed that EPF resulted in statistically better pain VAS and Roles and Maudsley scores, while there was no significant difference between ESWT and sham ESWT. However, 7 out of 11 patients (1 patient with no return to sport and 3 patients with missing information) receiving ESWT could return to activities at range of 4.5±3.4 weeks (range: 2–9 weeks), while the patients who elected EPF took longer to return to play of an average 12 weeks (range: 8–16 weeks).[55]

Three case series[45 56 57] composed of mostly runners demonstrated significant improvements in pain and function with 1 study reporting 50 of 54 runners returning to prior athletic level at the mean time of 5 weeks after treatment initiation.[57] One case series that included primarily runners (with an overlapping cohort with Mitchkash *et al*[45]) found that both R-SWT and combined (radial and focused) ESWT were effective in

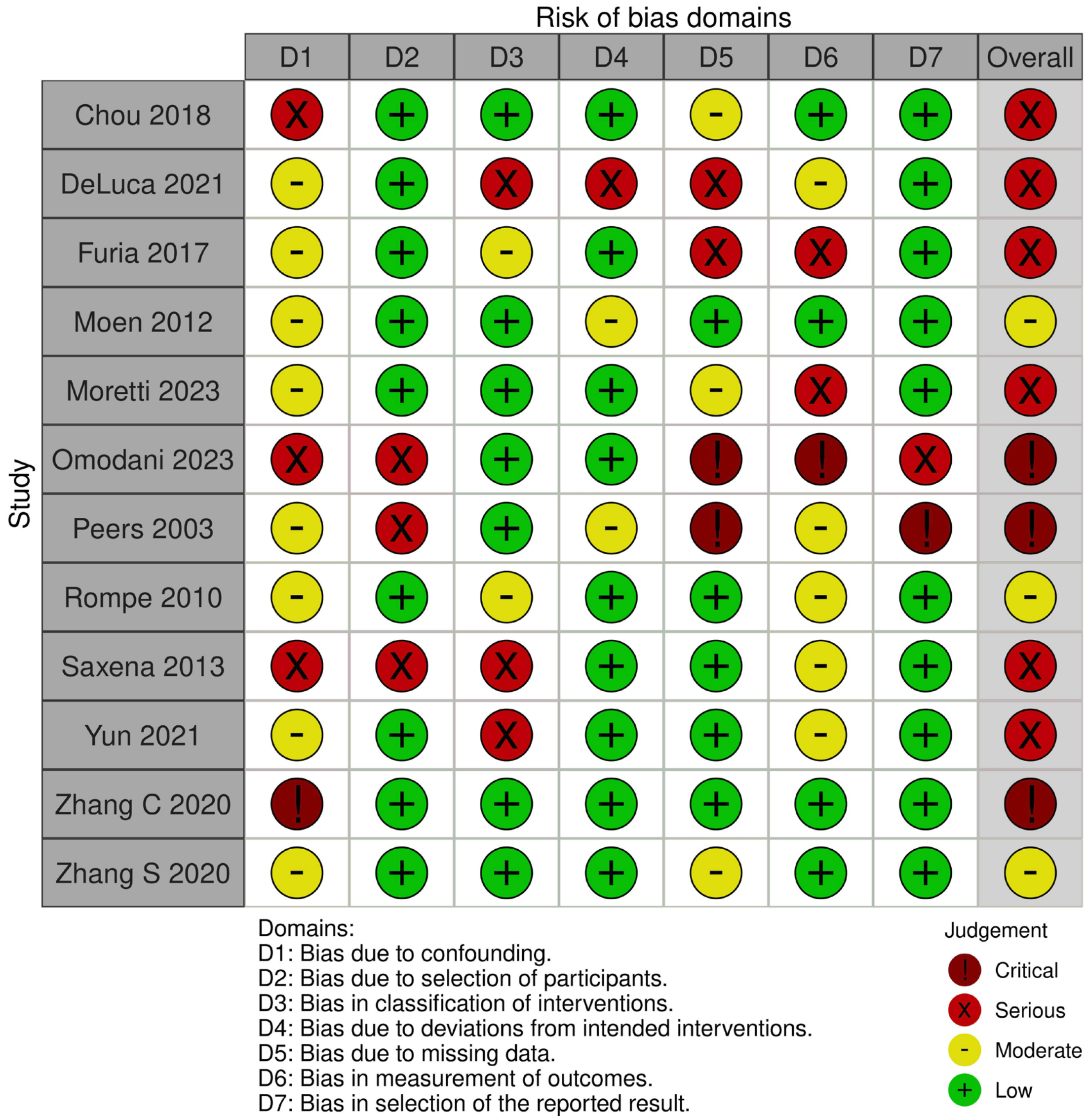

Figure 3 Risk-of-bias assessment for non-randomised controlled trials.

improving Foot and Ankle Ability Measure (FAAM) scores.[58] A case report described a recreational athlete returning to all activities after two times per week for 5 weeks of low-energy F-SWT.[59]

Medial tibial stress syndrome

Five studies reported outcomes following ESWT in MTSS. An RCT composed of military cadets with low risk of bias found one session of ESWT with exercise programme resulted in significantly greater pain improvement and longer pain-free running time compared with those assigned exercise programme alone at 4 weeks (pain VAS at rest mean and SEM: 0.56 and 0.206 in ESWT with exercise vs 1.47 and 0.309 in exercise alone; pain-free running time mean and SE 17 min 33 s and 2.36 s in ESWT with exercise vs 4 min 48 s and 1.03 s in exercise alone).[34] In contrast, one small pilot RCT with some concerns for risk of bias composed of runners reported no significant difference in pain-limited distance run between the group receiving five sessions of ESWT and control receiving sham ESWT at 10 weeks (−583 m 95% CI −1260 to 94).[60]

In a prospective cohort study including recreational athletes with moderate risk of bias, five sessions of F-SWT along with graded running programme resulted in faster recovery (approximately 8 weeks) compared with graded running programme alone (approximately 13 weeks).[61] In a retrospective cohort study including mixed athletes with moderate risk of bias, three sessions of R-SWT along with home training programme was superior to home training programme alone in terms of pain score and subjective recovery based on Likert scale at 4 weeks (VAS mean and SD: 5.8±0.9 vs 7.3±2.9), 16 weeks (VAS 3.8±1.1 vs 6.9±0.8) and 1.25 year (VAS 2.7±0.9 vs 5.3±2.6). Furthermore, 40 out of 47 patients returned to their preferred sport at 1.25 year.[62] A case report described two high-level athletes treated with R-SWT who could continue to compete during the treatment period. One runner won a national championship at 11 weeks after injury and an Olympic gold medal at 17 weeks after injury.[63]

Hamstring tendinopathy

Five studies reported outcomes in management of athletes with proximal hamstring tendinopathy or hamstring pain after ESWT. One RCT with some concerns for risk of bias investigated the efficacy of ESWT in professional athletes with proximal hamstring tendinopathy and found that four sessions of ESWT resulted in significant improvement in VAS and Nirschl Phase Rating Scale at 1 week (MD 3.5; 95% CI 2.3 to 4.7),3 months (MD 4.7; 95% CI 1.3 to 7.2), 6 months (MD 5.4; 95% CI 4.3 to 6.5) and 12 months (MD 5.4; 95% CI 4.3 to 6.5) compared with the control condition which consisted of rest, non-steroidal anti-inflammatory drug (NSAID), physiotherapy (ultrasound and friction massage) and exercise programme (stretching and strengthening hamstring muscles). At 3 months, 16 of 20 in ESWT group returned to their preinjury professional level of sports activity (mean time was 9 weeks with the range of 6–15 weeks) in contrast to none in the control group. None of the athletes who returned to sports had recurrence of injury during the 1-year follow-up.[64]

One case series showed that 22 of 32 runners with proximal hamstring tendinopathy and 3 of 4 runners with distal/mid-hamstring tendinopathy met MCID after ESWT treatment.[45] Another case series with some overlapping participants with Mitchkash *et al*[45] demonstrated that both R-SWT and combined ESWT (focused and radial) resulted in similar gains in VISA-Hamstring in management of proximal hamstring tendinopathy.[65] Two case reports described an elite female para swimming athlete with bilateral hamstring pain[66] and a female ultramarathon runner[67] successfully returning to sport following ESWT.

Achilles tendinopathy

Five studies reported outcomes in patients with Achilles tendinopathy after ESWT. In an RCT of athletes with high risk of bias comparing ESWT with mesotherapy in Achilles tendinopathy (insertional and non-insertional), both four sessions of ESWT and mesotherapy (microinjections with a mixture composed of betamethasone, normal saline and lidocaine along the tendon) improved VAS and AOFAS hindfoot scores at 4 and 12 weeks without between-group difference. ESWT group showed further improvement in tendon thickness, heterogeneity and calcifications at 12 weeks while mesotherapy reporting improvement limited to tendon thickness.[68] In another RCT with high risk of bias including recreationally active individuals with non-insertional Achilles tendinopathy, three sessions of R-SWT resulted in greater reduction in activity-related pain compared with ultrasound therapy or placebo ultrasound (VAS mean and SD 1.42±1.32, 2.85±2.03 and 4.23±1.5, respectively).[69]

One retrospective cohort study with moderate risk of bias compared outcomes following five sessions of R-SWT in runners and non-sports active group with insertional Achilles tendinopathy and found that while ESWT improved VISA-Achilles (VISA-A) and VAS scores in both groups, runners were found to have a significantly lower VAS score (mean and SD: 0.3±0.8 vs 1.6±1.3) and higher VISA-A score (mean and SD: 90±4 vs 78±7) at 5-year follow-up.[70]

A case series study demonstrated that 10 of 11 of runners with insertional Achilles tendinopathy and 13 of 16 of runners with non-insertional Achilles tendinopathy achieved MCID in VISA-A after being treated with ESWT.[45] A case report described a female runner successfully competing in a marathon 6 weeks after the initiation of ESWT.[67]

Lateral epicondylitis

Two RCTs assessed the efficacy of ESWT in tennis and squash players with lateral epicondylitis. One RCT with high risk of bias compared three sessions of R-SWT with one 40 mg methylprednisolone injection at the location with most tenderness around the lateral epicondyle area. While corticosteroid injection seemed to offer faster improvement in pain VAS (mean and SD 4.33±7.6 vs 5.8±1.7 at 2 weeks), patient-rated tennis elbow evaluation (PRTEE; mean and SD: 35.67±16.92 vs 61.33±11.21 at 2 weeks; 14.93±18.65 vs 32.07±20.17 at 4 weeks), and quick Disability of the Arm, Shoulder, and Hand scores (DASH; 35.6±16.96 vs 54.53±12.55 at 2 weeks; 13.33±16.83 vs 27.87±17.46 at 4 weeks) at 2–4 weeks, ESWT group showed better outcomes in PRTEE (1.47±1.3 vs 9.07±8.74) and quick DASH (2.2±2.24 vs 9.73±9.21) at 12 weeks.[71] Another RCT with some concerns for risk of bias compared three sessions of ESWT with placebo in tennis players and found that at 12 weeks after the last ESWT, patients in the ESWT group showed significantly higher improvement in pain during resisted wrist extension (MD 1.5; 95% CI 0.6 to 2.4) and Upper Extremity Functional Scale (MD 12.4; 95% CI 5.7 to 19.1). Moreover, at 12 weeks, 65% (25 of 38 patients) of the ESWT group and 35% (14 of 40 patients) in the placebo group returned to activities at the desired level and tennis (MD 0.3; 95% CI 0.1 to 0.5).[72]

Rotator cuff injuries

Two studies reported outcomes following ESWT in athletes with rotator cuff injuries. One retrospective study with serious risk of bias compared outcomes after three sessions of ESWT versus single PRP injection in amateur athletes with supraspinatus tendinosis. While pain VAS improved over time compared with baseline in both groups, there was no statistically significant difference in pain VAS between PRP and ESWT at 4, 12 and 24 weeks.[73] Another retrospective cohort study including patients with rotator cuff tendinopathy or partial-thickness rotator cuff tear with serious risk of bias compared outcomes between professional athletes (baseball and weightlifting) and non-athletes who completed one session of ESWT and the second one if needed at 3 months. This study showed that both groups improved in VAS and Constant scores at 12, 24 and 52 weeks follow-up without group difference, and within 12 weeks following ESWT all athletes returned to their previous competitive level. However, high rate of recurrence was observed in athletes (8 of 13) versus non-athletes (4 of 23).[74]

Distal biceps tendinopathy

One retrospective case–control study with serious risk of bias compared one session of R-SWT with control group which primarily received pain control (NSAIDs) and physical therapy (PT) exercises in recreational athletes with distal biceps tendinopathy. Patients in the R-SWT group had significantly lower VAS pain scores than those of control group at 4, 12 and 52 weeks compared with control. All patients in the R-SWT group returned to preinjury activity level and sports at 2–6 weeks while 20 of 24 patients in control group were able to return to preinjury status.[75]

IT band syndrome

One RCT with some concerns for risk of bias compared R-SWT to manual therapy in recreational runners with IT band syndrome. Both groups underwent a home exercise programme for 4 weeks. There was no significant difference between three sessions of R-SWT and manual therapy at 4 and 8 weeks although statistically significant improvement of pain was only achieved in R-SWT group and not in manual therapy group at four and 8 weeks. All patients were pain-free during 30 min treadmill tests at 8 weeks. At 24 weeks, 7 of 11 patients in R-SWT and 6 of 9 patients in manual therapy group reported a pain-free activity level.[76]

Tibialis posterior tendinopathy

One case series reported that six of seven and five of seven runners who received a minimum of 3 weekly sessions of ESWT achieved MCID of FAAM-Activities of Daily Living and FAAM-Sport, respectively.[45]

Bone-related injuries

In total, 10 studies reported outcomes following ESWT in bone-related injuries. In amateur male soccer players with osteitis pubis, an RCT with some concerns for risk of bias demonstrated that three sessions of F-SWT with PT led to faster return to play (approximately 10 weeks) than PT (approximately 14.5 weeks) or control group who stopped physical activity (approximately 34.3 weeks).[77]

In a study including high-level youth gymnasts with ischial apophysitis with critical risk of bias, F-SWT along with PT appeared more effective than PT alone in improving pain and fully returning to play and training.[78]

In 10 male elite and subelite soccer players with delayed union/non-union of tibial or fifth metatarsal stress fractures, 3–4 sessions of F-SWT were effective in pain relief and bony union and allowed them to return to full competition at ten weeks to 24 weeks after treatment with one patient requiring repeat treatment to achieve bony union.[79] Based on the seven case reports, ESWT was found to be effective in relieving pain and facilitating in return to play in osteochondritis dissecans of bilateral medial femoral condyle,[80] scaphoid delayed union,[81] resistant stress fractures (base of the fifth metatarsal bone, medial malleolus of the ankle, middle third tibia and inferior pubic ramus),[82] avulsion fracture of the sublime tubercle of ulna,[83] sesamoid osteonecrosis,[84] delayed union of midshaft clavicle fracture[85] and symptomatic bilateral bipartite patella.[35]

Myositis ossificans

One case series[86] and one case report[87] reported outcomes following ESWT in the treatment of myositis ossificans. In 24 athletes with myositis ossificans in lower extremity muscles caused by sports trauma, 3 sessions of F-SWT with rehabilitation programme improved pain VAS score and range of motion (ROM) at 1 month which sustained at 8, 24 and 52 weeks. After 7.2±3.1 weeks, 21 of 24 athletes were able to return to sport-specific training, after 11.3±4.1 weeks to sports-specific activity and after 13.1±4.2 weeks to competitive activity.[86] In a semi-professional rugby player, three sessions of R-SWT resulted in improvement of pain, ROM, strength, running distance and sprints and helped fully return to play at preinjury level at 17 weeks post injury.[87]

Other muscle injuries

Two case series reported outcomes following ESWT in acute[88] and chronic[89] muscle injuries. In professional soccer players with acute muscle injuries, R-SWT applied daily along with other therapeutic modalities such as resistance training, cryotherapy, manual therapy improved pain and facilitated return to soccer. Players were able to return at the mean of 3.3 days for type 1a muscle injury, 6.2 days for type 2b muscle injury and 13 days for type 3a muscle injury.[88] In eight amateur athletes with chronic muscle injuries, low energy ESWT with PT resulted in improvement of pain, muscle strength and Tegner score at the end of treatment (~6–8 weeks). The mean time to return to sports activities was 8.1 weeks after the first ESWT.[89]

Activity restriction following ESWT

Except for bone-related injuries, there was no strict activity restriction during the treatment period or following ESWT. Athletes were allowed to continue training and competing as long as pain was tolerated. Some of the activity restrictions imposed by the authors are summarised in online supplemental table 3.

Adverse events

Among 56 studies, 20 studies (35.7%) reported adverse events associated with ESWT. Common adverse events associated with ESWT in athletes were pain and temporary erythema at the site of application. Nausea was also reported in one study.[72] There was one case of plantar fascial rupture 6 weeks after treatment in one patient which authors likely attributed to use of oral steroids for symptomatic plantar fasciitis when training for a marathon and rather than receiving ESWT.[45] Reported adverse events are summarised in online supplemental table 3.

DISCUSSION

The purpose of this review was to determine the efficacy of ESWT and synthesise current research evaluating the use of ESWT for athletes and physically active individuals. We found that patellar tendinopathy was the most commonly studied pathology with the highest number of level I studies and that runners were the most commonly studied populations.

The included RCTs and comparative studies had different comparison groups that require caution when interpreting the results. The main study designs can be categorised into (1) ESWT versus standard of care, (2) ESWT+standard of care versus sham ESWT+standard of care and (3) ESWT versus other treatments.

ESWT versus sham ESWT or standard of care

The positive results of this type of study design suggest that ESWT may be more effective than no treatment (when compared with sham ESWT) or standard of care. In plantar fasciitis[53] and lateral epicondylitis,[72] the RCTs demonstrated superior outcomes with ESWT over sham ESWT, while in patellar tendinopathy[41] and MTSS,[60] the RCTs found no significant differences between the two groups. In proximal hamstring tendinopathy, one RCT showed more favourable results over standard of care including pain control and an exercise programme. In distal biceps tendinopathy, one retrospective study found that ESWT resulted in more favourable outcomes than those undergoing PT.[75] Therefore, in plantar fasciitis, lateral epicondylitis, proximal hamstring tendinopathy and distal biceps tendinopathy, ESWT may be considered an initial treatment option.

ESWT+standard of care versus sham ESWT+standard of care

The positive results of this type of study design may suggest that ESWT has additional benefits to standard of care. Three RCTs in patellar tendinopathy compared ESWT+exercise intervention with sham ESWT+exercise intervention[37 39 40] and had mixed results. In MTSS, on the other hand, ESWT showed more favourable outcomes when added to exercise programmes in one RCT[34] and two comparative studies.[61 62] In osteitis pubis and ischial apophysitis, one RCT[77] and observational study,[78] respectively, demonstrated that ESWT along with PT facilitated return to play in athletes when compared with PT alone. These results suggest that adding ESWT can be considered a therapeutic modality in injuries such as MTSS, osteitis pubis and ischial apophysitis, but may have less effectiveness as added treatment of patellar tendinopathy.

ESWT versus other treatments

The results of this type of study can help clinicians make informed decisions with patients by discussing other treatment options along with ESWT. In patellar tendinopathy, one RCT showed that ESWT resulted in more favourable outcomes than the control group receiving acupuncture, ultrasonic wave therapy and microwave therapy,[36] while in another RCT, PRP appeared to have more benefits in terms of pain and functional improvement at 24 and 52 weeks.[42] An observational study showed that pain and functional outcomes following ESWT at 24 weeks and 2 years were comparable to the outcomes following surgery at 2 years. In plantar fasciitis, a prospective study found that surgery resulted in better VAS and Roles and Maudsley scores although return to activities tended to be faster with ESWT.[55] ESWT appeared to have similar efficacy with mesotherapy when added with exercise programme in Achilles tendinopathy[68] but allowed better activity-related pain relief than ultrasound therapy in non-insertional Achilles tendinopathy based on the RCTs.[69] In IT band syndrome, ESWT and manual therapy seemed to have comparable outcomes in terms of pain relief and return to activity level when added with an exercise programme.[76] In one RCT investigating lateral epicondylitis, corticosteroid injections offered faster pain and functional relief but ESWT eventually resulted in better functional outcomes at 12 weeks.[71] In one retrospective study, there was no difference in VAS between PRP and ESWT for supraspinatus tendinosis.[73] Given these findings, while choosing a treatment option for athletes and physically active individuals, benefits and risks associated with ESWT should be discussed.

Clinical tolerance of ESWT

The primary benefits of ESWT is that athletes may continue activities, training or even compete as tolerated in most conditions excluding bone stress injuries.[90] As demonstrated in online supplemental table 3, most of the studies allowed activities as tolerated following ESWT. In one study with elite soccer players, R-SWT was well tolerated even when applied on a daily basis.[88] Moreover, although F-SWT alone was not shown to be effective in jumping athletes in one RCT, the athletes could continue to participate in both training and competitions without adverse events during the treatment period.[41] Limited loss of participation in sport is an advantage of ESWT over PRP. PRP is a common intervention for sports injuries but imposes activity or weight-bearing limitations for up to 7 days and return to sport restriction for up to 4–6 weeks according to a previous systematic review.[91] In patellar tendinopathy[44] and plantar fasciitis,[55] surgical treatment provided improvement in pain and function in athletes but required longer periods than ESWT to return to work or activities.

While the minority of included studies (20 out of 56 studies) reported adverse events, another potential advantage of ESWT is the safety profile. As seen in online supplemental table 3, the procedure was well tolerated with the most common adverse events being temporary erythema and pain at the site of application. Moreover, based on some of the studies[48 78 80 82 83] included in our review, ESWT was well tolerated in youth athletes. Corticosteroid injections, which are another common treatment in sports injuries, may provide rapid relief but have risks including tissue atrophy and tendon or soft tissue rupture[92] and should be limited in use for youth athletes. In addition, any type of needle-based intervention accompanies potential complications such as bleeding, infection and potential for a prolonged recovery time.[92 93]

Patient selection for ESWT

Our review also identified specific athletic populations including runners, soccer players, jumping athletes and youth athletes that should be considered when selecting ESWT as a treatment. In studies that specifically included runners, ESWT was studied in various pathologies including plantar fasciitis,[53 54 57 58] insertional Achilles tendinopathy,[70] IT band syndrome[76] and other running-related injuries.[45 67] However, there is only one level I evidence study in plantar fasciitis that showed superior outcomes over sham ESWT.[53] Another RCT in IT band syndrome showed no difference between ESWT and manual therapy, but all patients underwent exercise programmes, and therefore, it is unclear whether there was an intervention effect versus improvement from the exercise alone.[76] While one RCT identified ESWT alone as effective over conservative treatment including exercise treatment for proximal hamstring tendinopathy in a population of sports involving running, the evidence for other pathologies specifically in running populations, derive from lower-level studies, and therefore, caution is needed when interpreting results for Achilles tendinopathy,[67 70] hamstring tendinopathy[45 67] and tibialis posterior tendinopathy.[45]

In soccer players, studies with low level of evidence suggested that multimodal treatment including ESWT and exercise treatment may be beneficial for muscle injuries,[88] delayed stress fractures[79] and patellar tendinopathy,[46] while one level I study showed additional benefit of ESWT over standardised rehabilitation programme alone in osteitis pubis.[77]

In jumping athletes, patellar tendinopathy was the most commonly studied pathology with the highest number of level I studies. However, the results were conflicting, and meta-analysis was not possible due to heterogeneity in study design and outcome measures. According to the previous systematic reviews,[94 95] eccentric exercise seems to be most effective for patellar tendinopathy, and the addition of ESWT may not offer additional benefits.[96] Consistent with these systematic reviews, in jumping athletes, our review found that ESWT may not be effective alone, and the benefit of adding ESWT to eccentric exercises is uncertain.

While there is a lack of high-quality studies, it is worthwhile mentioning that there were some cases in which ESWT had promising results in youth athletes with patellar tendinopathy,[48] ischial apophysitis,[78] osteochondritis dissecans,[80] resistant stress fractures[82] and a delayed union of avulsion fracture[83] in terms of improving pain and facilitating return to sport.

Future research directions

Based on the limited number of level I studies, ESWT may be effective alone in plantar fasciitis, lateral epicondylitis and proximal hamstring tendinopathy and as an adjunct to exercise treatment in MTSS and osteitis pubis in athletes or physically active individuals. However, given the limited number of RCTs with low risk of bias, these findings should be further evaluated through high quality research including larger, well-designed clinical trials. Some studies compared ESWT added to standard of care with standard of care alone, and this type of study design may measure the additional benefit of ESWT. Further head-to-head trials comparing ESWT to standard of care would be needed to demonstrate the true effect of ESWT as monotherapy, and when the standard of care includes exercise treatment, more efforts are needed to follow evidence-based guidelines. Furthermore, there is a need for more RCTs for athletes in pathologies such as rotator cuff injuries, tibialis posterior tendinopathy, bone stress injuries and muscle injuries in which the current evidence derives from low evidence studies. Given the associated financial costs with ESWT, a cost-effective analysis would also inform clinical decisions.

In addition, whether ESWT is used alone or an adjunct to standard of care, reporting early outcomes such as 1 or 2 months as well as return to activity or sport outcomes and reinjury rates would provide more valuable information for athletes and physically active individuals with injuries who wish to return to competition or activities as soon as possible. As previous research has attempted, it would be worthwhile exploring the role of ESWT in postoperative recovery in common athletic injuries such as anterior cruciate ligament reconstruction.[97–99] Lastly, future research may investigate the role of ESWT to hasten recovery and prevent recurrent overuse injuries in active populations.

Limitation

Our review has several limitations. First, we were not able to conduct a quantitative analysis due to the heterogeneity across the studies in the populations studied, outcomes reported and comparison groups. Specifically, the dose, type and frequency of ESWT differed across the pathologies and even within the same pathology. Future research is warranted to establish standard ESWT protocols for each pathology. Second, only 20 of 56 studies reported the absence or presence of adverse events associated with ESWT. While ESWT appears safe without major complications based on the studies that reported adverse events, there needs to be better reporting of adverse events (including the absence of adverse events) in order to confidently draw conclusions related to the safety profile of ESWT. Third, there is a possibility of selection bias as we restricted the studies to those published in the English language although previous literature have suggested that such bias is low.[25 26] Last, 25 of the included 56 studies were case series or case reports with positive outcomes, and therefore, the findings from these studies need to be interpreted with caution.

CONCLUSION

Based on limited high-level studies, ESWT, alone or as an adjunct to exercise treatment, may offer the potential to facilitate athletes and physically active individuals to return to sport or activity in selected injuries given its efficacy and safety profile. Further, large, high-quality studies are needed to identify the optimal indications and dose–response relationships.

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