Extracorporeal Shockwave Therapy in the Management of Sports Medicine Injuries

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Abstract

Treatment of musculoskeletal conditions in athletes with extracorporeal shockwave therapy (ESWT) is gaining popularity as greater evidence supports its use. ESWT protocols (describing energy flux density, number of impulses, type of shockwave (focused or radial), number/frequency/duration of treatment session, area of application, and postprocedural therapy protocols) can be adjusted in the clinical setting. Protocols vary across studies, and optimal protocols for most indications are yet to be determined. ESWT can safely be used to treat various musculoskeletal conditions in athletes, including rotator cuff tendinopathy, lateral elbow epicondlyopathy, greater trochanteric pain syndrome, hamstring tendinopathy, patellar tendinopathy, Achilles tendinopathy, other tendinopathies, plantar fasciopathy, bone stress injuries, and medial tibial stress syndrome. ESWT can be used to treat in-season athletes, as it often requires no/minimal time away from sport and may result in rapid benefits. ESWT should be used in conjunction with physical therapy to facilitate longer-term gains in function and to optimize healing.

Introduction

The best documented initial use for extracorporeal shockwave therapy (ESWT) was reported in 1980 by Dr. Christian Chaussy to treat kidney stones in a lithotripsy procedure and ESWT continues to be used for this indication today (1–3). Serendipitously, a lithotripsy procedure in the pelvic region in 1992 led to the discovery of the effects of ESWT on bone stimulation of the iliac crest by Dr. Gerald Haupt (4). Subsequently, ESWT was studied in orthopedics, where shockwaves were shown to augment fracture healing (5,6) and could be used to treat overuse conditions of tendon (7) and fascia (8,9). The evidence in support of the use of ESWT is growing, and sports medicine clinicians may find this to be a useful tool to treat musculoskeletal injuries in athletes. However, optimal evidence-based, standardized protocols specific to a given condition using ESWT have not been determined for most indications and ESWT parameters can be adjusted (energy flux density [EFD], number of impulses, type of shockwave, number/frequency/duration of treatment session, area of application, use of analgesia, and postprocedural therapy protocols). The purpose of this review is to describe the clinical use of ESWT by discussing treatment parameters, synthesizing the recent literature, and offering our clinical experience and recommendations on the use of ESWT to treat musculoskeletal conditions in athletes.

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What Is ESWT?

Types of Shockwaves

Shockwaves are a form of energy that can develop a peak pressure about 1000 times higher than that of ultrasound (10). There are two primary forms of ESWT used in clinical practice: focused shockwave and radial shockwave, the latter also referred to as radial pressure waves (Table 1).

Mechanism of ESWT

The mechanisms of ESWT for treatment of musculoskeletal conditions are not completely understood, but shockwaves are thought to have mechanical and cellular effects that improve tissue healing and alter pain signaling. It has been hypothesized that the biological effects of ESWT are a consequence of mechanotransduction, where the vibrations of tissues lead to regeneration and healing (11). Shockwaves produce a positive pressure to cause absorption, reflection, refraction, and transmission of energy in tissues and cells, which may lead to destruction of calcifications in tissue (12–14). Shockwaves have been shown to have effects at the cellular level by triggering the release of adenosine triphosphate for the activation of cell signaling pathways (15) and altering the function of ion channels in the cell membrane (16). Shockwaves also may cause microcavitation and the release of nitric oxide leading to downstream analgesic, angiogenic, and anti-inflammatory

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Table 1.
Comparison of the two primary types of shockwave therapy used in clinical practice.

	Focused Shockwave	Radial Shockwave
Source[a]	Electrohydraulic, electromagnetic, piezoelectric devices	Pneumatic/ballistic devices
Maximal Energy level	Higher	Lower
Depth of maximal force	Deeper (can be selected)	Peak force at superficial structures, attenuated energy at greater depths
Pain with application	High energy can be more painful; low energy can be less painful	High energy can be more painful; low energy can be less painful
Examples of commercial devices[b]	• Dornier Aries device (Dornier MedTech, Germany)[EM] • Duolith SD (Storz Medical, EU)[EM] • Electrohydraulic lithotripter (MFL 5000; Philips, Hamburg, Germany)[EH] • Epos Ultra (Dornier MedTech, Wessling, Germany)[EM] • Evotron1 (SwiTech, Kreuzlingen, Swizerland)[EH] • Modulith SLK (Storz Medical AG, Tagerwilen, Switzerland)[EM] • Minilith (Stroz Medical, Switzerland)[EM] • Orthima (Direx Medical System Ltd)[EM] • Orthospec (Medispec Ltd, Germantown, MD, USA)[EH] • OrthoWave machine (MTS, Konstanz, Germany)[NA] • Ossastron (Sanuwave, Swanee, Georgia)[EH] • Piezoson100 (Richard Wolf, Knittlingen, Germany)[PE] • Piezowave2 system (Richard Wolf GmbH, Knittlingen, Germany)[PE] • Sonocur Plus Unit (Siemens, Munich, Germany)[EM] • Storz Minilith SL1 lithotrypter machine (Storz Medical, Switzerland) [EM]	• Duolith SD (Storz Medical, EU) • EMS Swiss Dolor-Clast (EMS Electro Medical Systems, Nyon, Switzerland) • Masterpuls MP 100 (Storz Medical, • Tagerwilen, Switzerland) • Pain Treatment System of Radial shock wave Device (Sonothera, Hanil Tm Co. Ltd, Korea) • ShockMaster 500 device (GymnaUniphy NV, Bilzen, Belgium) • Storz Extracorporeal pulse activation technology (EPAT) device (Storz Medical, T€agerwilen, Switzerland).

[a]The energy flux densities emitted by each type of focused shockwave device may not necessarily equate to the same EFD emitted by another type of focused shockwave device.

[b]The listed commercial devices are those that were used in the studies cited in this article. The following superscripts denote the type of focused shockwave device: EH, electrohydrolic; EM, electromagnetic; PE, piezoelectric; NA, not available.

effects (17,18). Shockwave also may increase collagen synthesis through several mechanisms, including increased TGF-B1 and IGF-1 (19); increased IL-6, IL-8, MMP-2, and MMP-9 (20); and increased glycosaminoglycans (21). In addition, they can increase tenocyte proliferation (19) and osteoprogenitor differentiation (22). Finally, ESWT may have an analgesic effect through stimulation of nociceptive c-fibers (23), increase in pain-inhibiting substances (*i.e.*, substance P) (24,25), and nociceptor hyperstimulation (via the gate-control theory) (26).

ESWT Parameters

There are several parameters that can be adjusted with each ESWT treatment. The machine settings should be reported when performing ESWT in the clinical setting. There are few accepted machine settings or delivery method for each musculoskeletal indication and the optimal protocol likely often varies by indication. EFD, number of impulses, type of wave (focused or radial), number of treatment sessions, days between sessions, area of application, use of coupling gel, and use of analgesia during application should all be considered when interpreting literature regarding effectiveness of ESWT. These parameters are listed in Table 2 with evidence from the literature and suggestions based on our clinical practice. EFD, which is defined as the energy per impulse at the focal point of a shockwave, is the parameter that is most commonly adjusted with ESWT application. EFD is often reported in mJ·mm^2 for focused ESWT and in bar for radial ESWT (for comparison, typical measures of radial shockwave 2 bar is approximately 0.09 mJ·mm^2 and 4 bar is approximately 0.18 mJ·mm^2). It is important to note that the EFD of one type of focused ESWT device does not necessarily equate to the same EFD of a different type of focused ESWT device (*i.e.*, EFD of an electrohydraulic device does not equate to that of a piezoelectric device). One study classified EFD as high (0.6 mJ·mm^2), medium (0.28 mJ·mm^2), and low (0.08 mJ·mm^2) and identified high EFD leading to histopathologic changes including inflammation, necrosis, and disorganized fibrocytes based on histopathological specimens in an animal model of tendinopathy (27).

Utility of ESWT in Sports Medicine Practice

Indications/Contraindications

The International Society for Medical Shockwave Treatment (35) has outlined numerous indications and contraindications for the use of ESWT. Musculoskeletal indications and contraindications for the use of ESWT pertinent to a sports medicine practice are listed in Table 3. ESWT is often used when patients fail conservative treatments (rest, ice, nonsteroidal medications). It is a noninvasive option with minimal side effects and often allows athletes to continue to participate in

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Table 2.
Literature evidence and clinical recommendations for ESWT parameters.

Parameter	Literature Evidence	Clinical Recommendations/Practice
EFD	*In vivo* studies report 0.06 to 0.40 mJ·mm^2; an *in vitro* study (27) recommended not exceeding 0.28 mJ·mm^2	Typically administer as high as the patient can tolerate. Often, nerve tissue requires low energy (less than 0.10 mJ·mm^2, tendon/fascia require moderate energy (0.10 to 0.25 mJ·mm^2) and bone requires higher energy (often in excess of 0.25 mJ·mm^2)
Impulse # and frequency	Reported from 600 to 4000 impulses up to 7 to 8 Hz, with most studies utilizing impulses at 1 to 7 Hz.	Typically administer 2000 to 3000 impulses at 12 to 15 Hz; lower Hz can be used if too painful for patient to tolerate
Type of wave	Both are reported in the literature; unclear how type of wave relates to clinical effectiveness (28)	Radial may be more commonly used due to lower cost of machine operation
Number of treatment sessions	Reported from 1 (29) to 16 (30), with mean number reported to be 3 to 4 in most studies	Typically start with 3 and perform additional treatments if symptoms persist
Time between treatment sessions	Most studies report 1 wk between treatments	Frequency depends on patient preference, but typically perform treatments weekly
Locating area of application	Use of sonographic guidance (31) is reported but has not been shown to improve clinical efficacy (32). Most studies target the maximal area of tenderness to palpation.	Follow the "principle of clinical focusing", targeting the site of maximal tenderness to palpation.
Use of coupling agent	Ultrasound gel is optimal (33)	Use ultrasound gel
Use of analgesia	Use of local anesthesia with nerve block may lead to worse outcomes (34). Use of local anesthesia prevents utilization of the "principle of clinical focusing".	Not used
Person performing treatment	Focused shockwave is more commonly performed by a physician, but radial shockwave can be performed by a physician or other trained personnel.	Physician or another medical provider guided by a physician (typically physician will perform the initial treatment and guide the protocol).

sport for most conditions as pain levels allow. Therefore, it may be preferred to more-invasive treatment options, such as corticosteroid, tenotomy, or platelet-rich plasma injections, which carry the risk of tendon rupture or require variable amounts of time away from sport. ESWT also is an excellent treatment option in patients who are needle phobic. As discussed previously, there is a lack of standardization in ESWT protocols, and optimum ESWT parameters have not yet been determined. The current literature on ESWT will be reviewed in the subsequent text, and we will offer clinical pearls pertinent to the use of ESWT in the treatment of musculoskeletal conditions. It is important to note that most studies were performed on populations that had failed other conservative management options. Many studies did not report the athletic activity of the population at baseline, so the results of these studies are extrapolated to an athletic population.

Rotator Cuff Tendinopathy (Calcific and Noncalcific)

A recent Cochrane review and meta-analysis of 32 randomized and quasirandomized controlled trials compared ESWT to placebo (12 studies), compared high-dose ESWT (EFD, 0.2 to 0.4 mJ·mm^2) to low-dose ESWT (EFD <0.2 mJ·mm^2) (11 studies) or compared ESWT with various other interventions (ultrasound-guided glucocorticoid or hyaluronic acid injections, transcutaneous nerve stimulation, exercise, or no treatment) for the treatment of rotator cuff disease in nonathletic populations (36). A total of 2281 participants were included with 25 trials examining patients with calcific tendinopathy only, five trials examining patients with noncalcific tendinopathy only, and two examining patients with either calcific or noncalcific tendinopathy (36). All trials were susceptible to bias (36). Focused ESWT was used in 26 studies and radial ESWT was used in six studies with variable ESWT protocols (36). When comparing ESWT with placebo at 3 months, visual analog pain scale (of 10) was 0.78 points better in the ESWT group (did not meet minimal clinically important difference of 1.5 points) (36). In addition, functional measures (of 100) were 7.9 points better in the ESWT group (did not meet minimal clinically important difference of 10 points) (36). There was no difference in adverse events between ESWT and control groups (36). A recent study comparing focused (electromagnetic) ESWT (four sessions, EFD 0.09 ± 0.018 mJ·mm^2, impulse #3000) to radial ESWT (four sessions, EFD 4 ± 0.35 bar, impulse #3000) showed significantly greater improvement in pain and function in the focused ESWT group at 24 and 48 wk, despite both groups improving from baseline (37).

The utility of ESWT for calcific rotator cuff tendinopathy has not specifically been studied in the athletic population. In the Cochrane review, subgroup analyses found no difference in outcomes based on presence or absence of calcific deposits in the rotator cuff (36). In contrast, Wu et al. (38) showed that those treated with focused ESWT (one session, EFD 0.32 mJ·mm^2, impulse #3000) who had translucent calcifications in the rotator cuff had significantly improved

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Table 3.

Indications and contraindications for the use of shockwave in treating musculoskeletal conditions.

Indications	
Tendon pathologies	Rotator cuff tendinopathy Lateral epicondylopathy of the elbow[a] Distal biceps tendinopathy GTPS Hamstring tendinopathy Adductor tendinopathy Patellar tendinopathy Pes anserine tendinopathy Achilles tendinopathy Peroneal tendinopathy Plantar fasciopathy[a]
Bone pathologies	Delayed healing/nonunion Stress fracture Osgood Schlatter disease Medial tibial stress syndrome Bone marrow edema Avascular necrosis Osteochondritis dissecans
Muscle pathologies	Myofascial pain Muscle strain without discontinuity
Contraindications	
Radial and focused waves with low energy	Malignant tumor in treatment area Pregnancy
High energy focused waves	Malignant tumor in treatment area Pregnancy Lung tissue in the treatment area Epiphyseal plate in the treatment area Brain or spine in the treatment area Severe coagulopathy

[a]United States Food and Drug Administration approved indications.

pain, strength, and range of motion with higher satisfaction at 12 months compared with those without evidence of calcification or those whose calcifications were dense. Resolution of calcific deposits after treatment was not examined in this study (38). In patients with rotator cuff calcific tendinopathy, when high-energy focused ESTW (four weekly sessions, EFD 0.35 mJ·mm^2, impulse #2000) was directly compared with ultrasound-guided needling plus subacromial bursa corticosteroid injection, both groups showed statistically significant improvement in pain and function at 1 year, but the size of the calcification decreased more significantly in the ultrasound-guided interventional group than the ESWT group (31). Furthermore, those in the ESWT group more commonly received additional treatment during follow-up because of persistent symptoms (41% in ESWT group vs 22% in ultrasound interventional group) (31). Tornese et al. (39) found that positioning the shoulder in hyperextension and internal rotation during focused ESWT (three weekly sessions, EFD 0.22 mJ·mm^2, impulse #1200) treatment resulted in significantly more reabsorption of calcific deposits (opaque deposits measuring >1 cm, tendon location not specified) with improved clinical outcomes compared with neutral positioning. More studies are needed to determine if use of ESWT results in reabsorption of calcific deposits, if the size, density, and location of the calcific deposit matters, and if there is clinical relevance of change in appearance of calcific deposits after the use of ESWT.

Pearl: ESWT appears safe, but the optimum ESWT parameters and efficacy are unknown for treatment of rotator cuff tendinopathy. ESWT may be most successful when treating rotator cuff calcific tendinopathy when translucent calcifications are present using high energy flux density values.

Lateral Elbow Epicondylopathy

Despite lateral epicondylopathy being an approved indication for the use of ESWT by the United States Food and Drug Administration (FDA), studies show mixed treatment efficacy of ESWT. The literature discussed is not specifically in an athletic population, so results of these studies must be extrapolated to an athletic population. A meta-analysis of five randomized controlled trials comparing ESWT to ultrasound therapy showed statistically significant improvement in short term pain (1, 3, and 6 months) and grip strength (3 months), but no difference in function (1 to 3 months) in the ESWT group compared with ultrasound (40). However, a subsequent meta-analysis of nine randomized controlled trials comparing ESWT to placebo (two studies), sham (two studies), ultrasound (one study), laser (one study), or lower-dose ESWT (one study) found that more subjects reported a 50% pain reduction in the ESWT group than in the placebo group; there was no difference in the overall average pain reduction (four studies pooled), but improved grip strength (three studies pooled) in the ESWT group at 3 months (41). A single study by Park et al. (42) compared calcific and noncalcific lateral epicondylopathy treated with focused ESWT (four weekly sessions; EFD, 0.06 to 0.12 mJ·mm^2; impulse #2000) and found no significant difference in improvement in pain in patients with calcific versus noncalcific tendinopathy; however, those with calcific tendinopathy with concomitant tendon tearing had the worst outcomes.

Pearl: ESWT is approved by the U.S. FDA for treatment of lateral epicondylopathy. In our experience, ESWT over the lateral epicondyle is not always tolerated due to pain. Always adjust your energy levels to keep the patient's pain tolerable during ESWT. As such, consider a lower starting EFD and frequency and slowly titrate higher. One can consider use of a softer applicator, such as a plastic tip or silicon tip for radial ESWT.

Greater Trochanteric Pain Syndrome

Early studies examined the use of radial ESWT in athletic populations (43,44), while subsequent studies examined the use of focused ESWT, but did not report the activity levels of their subjects (45–47). Furia et al. (43) assessed the utility of radial ESWT (one session, four bars, impulse #2000) for greater trochanteric pain syndrome (GTPS) and showed improved short- (3 months) and long-term (12 months)

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outcomes compared with baseline, with 76% of athletes who received ESWT returning to sport within 1 wk to 3 months. The study by Rompe et al. (44), where the majority of patients were involved in frequent sport activities, also showed long-term superiority of radial ESWT (three sessions, three bars, impulse #2000) when compared with corticosteroid injections at 15 months. More recent studies have examined the utility of focused ESWT (utilized different protocols) in patients with an average age in their late 50s and unknown activity levels (45–47). Focused ESWT (three weekly sessions, EFD 0.20 mJ·mm^2, impulse #2000) resulted in improved pain at 2 months and improved function at 6 months when compared with sham (47). Carlisi et al. (46) showed improved pain reduction at 2 and 6 months with focused ESWT when compared to ultrasound therapy (three weekly sessions, EFD 0.15 mJ·mm^2, impulse #1800) in a randomized controlled trial. A small cohort study of low energy and short duration focused ESWT (up to 12 sessions, EFD 0.10 mJ·mm^2, impulse #600) by Seo et al. (45) showed pain improvement at 1 wk that declined by average follow-up time of 27 wk. Two of the studies on focused ESWT included patients with calcific tendinopathy but did not compare outcomes based on the presence or absence of calcific deposits (45,46).

Pearl: Both radial and focused ESWT may be efficacious in treating greater trochanteric pain syndrome. However, given the typical depth of the gluteal tendons in certain patients, use of high energy focused ESWT may be preferred to achieve adequate energy flux density at site of deeper penetration.

Proximal Hamstring Tendinopathy

One of the few randomized controlled trials on the use of ESWT to treat athletes examined the use of ESWT to treat proximal hamstring tendinopathy (48). In this study, Cacchio et al. (48) compared conservative management (nonsteroid anti-inflammatory medications, physical therapy, and an exercise program) to radial ESWT (four weekly sessions, EFD 0.18 mJ·mm^2, impulse #2500) for the treatment of proximal hamstring tendinopathy in a randomized controlled trial of 40 professional athletes. They found a significant improvement in pain and function at 3 months in the ESWT group compared with the conservative management group with 85% of the ESWT group and only 10% of the conservative group receiving at least a 50% reduction in pain (48). Most strikingly, in the study by Cacchio et al. (48), 80% of athletes treated with ESWT returned to preinjury level of sports participation by 3 months, with 0% of those in the conservative treatment group returning to sport at 3 months. Mitchkash et al. (49) reported on the use of radial ESWT (average, four sessions, EFD 2 to 5 bar) to treat a cohort of 94 runners, 32 of whom had proximal hamstring tendinopathy and showed similar results to Cacchio et al., with 69% achieving the minimal clinically important difference in the measured functional outcome (Victorian Institute of Sport Assessment-Proximal Hamstring Tendons).

Pearl: The ESWT protocol used to treat proximal hamstring tendinopathy is one of the most widely used and well-established ESWT protocols, given its reported success in the randomized controlled trial by Cacchio et al. in an athletic population (48). Treatment often consists of four sessions of radial ESWT with EFD of 0.18 mJ·mm^2, although more sessions can be performed if needed and EFD can be adjusted based on patient tolerance of the treatment.

Patellar Tendinopathy

Early studies on the use of ESWT to treat patellar tendinopathy examined the use of focused ESWT using variable protocols (50,51), while one cohort study evaluated the effects of radial ESWT for this condition (30). A meta-analysis of 7 studies examining the effects of focused ESWT on patellar tendinopathy concluded that ESWT may be a superior alternative to other nonoperative treatments (physical therapy, nonsteroidal anti-inflammatory drugs, exercise) and equal to patellar tenotomy surgery at up to 24 months, despite the use of varying ESWT protocols (50). Zwerver et al. (51) compared focused ESWT (three weekly sessions, EFD 0.07 ± 11.7 mJ·mm^2, impulse #2000) to placebo to treat in-season athletes (volleyball, basketball, handball) and found that significantly more athletes noted subjective symptom improvement at 1 wk, but no differences in pain and function at 12 and 22 wk. Cheng et al. (30) performed a randomized control trial in athletes with patellar tendinopathy and compared one group who received radial ESWT (16 weekly sessions, EFD 1.5 to 3 bar, impulse #2000) to a control group (received physical therapy modalities such as acupuncture, ultrasonic wave, and microwave therapy) and showed improved pain and strength in both treatment groups at 16 wk, but did not report shorter-term outcomes.

Pearl: ESWT appears to be an effective nonoperative treatment for patellar tendinopathy. ESWT may be utilized safely for in-season athletes with patellar tendinopathy with more immediate gains in pain relief and function.

Achilles Tendinopathy

In multiple comparison studies ESWT has been shown to be superior to eccentric exercises alone and sham ESWT for management of chronic midportion Achilles tendinopathy, although study design to determine maximal efficacy was variable (1 to 12 months follow-up) and studies did not completely capture baseline activity levels of participants (52–54). Rasmussen et al. (53) compared focused ESWT (three sessions every 1 to 2 wk, EFD 0.12 to 0.51 mJ·mm^2, impulse #2000) to sham in patients with chronic midportion Achilles tendinopathy and found improvements in pain and functional outcomes at 8 and 12 wk. Vahdatpour et al. (54) also compared focused ESWT (four weekly sessions, EFD 0.25 to 0.4 mJ·mm^2, impulse #1500 plus EFD 1.8 to 2.6 mJ·mm^2, impulse #3000) to sham, but only noted superiority of ESWT at improving pain and function at 16 wk but not 4 wk. Rompe et al. (52) compared treatment with radial ESWT (three weekly sessions, EFD 3 bar, impulse #2000) plus eccentric exercises to eccentric exercise alone in patients with chronic midportion Achilles tendinopathy that was refractory to nonoperative management and found that those who received both ESWT and eccentric exercise had improved pain and function at 4 and 12 months. Abdelkader et al. (55) followed 40 randomized patients up to 16 months and found that radial ESWT (four weekly sessions, EFD 3 bar, impulse #2000) plus eccentric exercise resulted in statistically and clinically significant improvements in pain and function compared with eccentric exercise alone. When radial ESWT (three weekly sessions, average EFD 2.1 to 2.9 bar, impulse #2000) was compared with image-guided high-volume

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Table 4.
ESWT postprocedural recommendations.

Postprocedure recommendations
• Pain may increase slightly on the day of the procedure
• Can often continue activities as tolerated (with pain $< 3/10$)[a], unless a stress fracture or tendon tear is present and it is anticipated that the injury will progress with continued participation in sport
• ESWT is not a substitute but a supplement for physical therapy
• Can continue analgesic medication (acetaminophen) as needed, but avoid NSAIDs during and after treatments
• Can have ESWT concurrently with other treatment interventions

[a]If athletes are able to rest based on timing in their sports season, that is recommended.

injection in a small randomized controlled trial, no difference in functional outcomes was noted between the two groups (56). A network meta-analysis of treatments for midportion Achilles tendinopathy showed that, two treatment combinations, eccentric exercises with ESWT and eccentric exercises with high-volume injection plus corticosteroid injection, resulted in the largest improvement in pain and function in patients with midportion Achilles tendinopathy when compared with various other treatment options, suggesting that ESWT can be considered a noninvasive, synergistic treatment option to eccentric exercises (57).

Insertional Achilles tendinopathy is historically more difficult to treat than midportion tendinopathy, and only two studies have examined the use of ESWT for this indication in both athletes and nonathletes (58,59). Pinitkwamde et al. (58) compared radial ESWT (four weekly sessions, EFD 2.5 to 3.5 bar, impulse #2000) to sham in a population where only 12% to 13% were involved in sporting activities and 60% to 68% had underlying medical conditions. They found significantly greater improvements in pain and function in the ESWT group at 4 and 12 wk but no significant difference long term (12 and 24 wk) (58). Zhang et al. (59) found that of those who received radial ESWT (five weekly sessions, EFD 0.06 to 0.1 mJ·mm^2, impulse #2000) and those who self-reported to be "sports active" had better 5-year pain and functional outcomes suggesting that athletes may have a better response to ESWT than the general population. In addition, the same authors concluded that the use of ESWT did not have any effect on the sonographic presence of intratendinous calcification or neovascularization in patients with insertional Achilles tendinopathy (59).

Pearl: Eccentric exercises should be a part of the treatment regimen for Achilles tendinopathy and can (and should) be performed in conjunction with ESWT. ESWT may allow for short-term pain and functional improvements that permit patients to better tolerate an eccentric Achilles tendon loading rehabilitation program.

Plantar Fasciopathy

ESWT is FDA approved to treat plantar fasciopathy, and the greatest amount of evidence supports its use for this indication, although most studies do not include athletic populations. Several recent meta-analyses show superiority of ESWT to placebo and other treatments (ultrasound, low-level laser, pulsed radiofrequency treatment, and corticosteroid injections) but the type of ESWT and ESWT protocols varied among included studies (60–62). In a network meta-analysis, radial ESWT was the only treatment modality (compared with ultrasound, ultrasound-guided pulsed radiofrequency treatment, low level laser therapy and noninvasive interactive neurostimulation), which showed improvements in pain and function compared with placebo (60). Other meta-analyses did not separate studies that utilized radial ESWT from focused ESWT, but showed ESWT was efficacious, and may be more efficacious at higher intensity (EFD >0.36 mJ·mm^2), in the short term (0 to 6 wk) (61,62). In addition, a meta-analysis of nine randomized controlled trials comparing ESWT to corticosteroid injections also showed that ESWT success was related to energy levels. In this meta-analysis higher intensity ESWT (defined as EFD >0.2 mJ·mm^2) was more effective than corticosteroid injections which was more effective than lower intensity ESWT in the treatment of plantar fasciopathy at 3 months (63). However, there was a similar recurrence rate among all groups at 1 year and this meta-analysis lacked robust long-term outcomes (63).

Pearl: ESWT has been shown to be effective for the treatment of plantar fasciopathy. It is approved by the U.S. FDA for treatment of plantar fasciopathy. It is generally not covered by most insurance plans. However, the authors note that some patients have recently reported that they have been reimbursed for ESWT when it is used to treat plantar fasciopathy.

Other Tendinopathies

Although studies are limited, ESWT has been shown to be beneficial in the treatment of tendinopathies in athletic populations that were not discussed above, including distal biceps tendinopathy (64) and tibialis posterior tendinopathy (65). Furia et al. (64) compared a cohort of recreational athletes and labors with distal biceps tendinopathy treated with conservative management (avoid aggravating activities, topical and oral anti-inflammatory, physical therapy) to those who elected to be treated with radial ESWT (1 session, EFD 0.18 mJ·mm^2, impulse #2000) and found that those treated with ESWT had a significantly greater improvement in pain and function at 3 months but similar return to sports and work at 12 months. Robinson et al. (65) described the use of radial ESWT (four to eight sessions, EFD minimum 1.8 bar, impulse #3000 over the tendon and EFD minimum 2 bar, impulse #3000 over the muscle) and a foot intrinsic progression exercise regimen on 10 patients with tibialis posterior tendinopathy that had failed conservative management and found that function significantly improved, both statistically and clinically, in most patients on average at 4 months after initiation of ESWT. These studies highlight the wide applicability of radial ESWT in an athletic population with tendinopathy.

Pearl: Radial ESWT has been shown to be effective in treatment of athletic populations with various overuse

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tendon injuries including distal biceps tendinopathy and tibialis posterior tendinopathy.

Adverse Effects

ESWT has been shown to be relatively safe. The main adverse effects occur at the site of application and include pain (primarily during application), skin irritation (transient reddening, bruising, swelling), or nerve irritation (transient paresthesias) (36,58,65,66). No major adverse events, including tendon rupture or hematomas, have been reported (66). Achilles tendon rupture (two cases, both patients over 60 years old) (67) and plantar fascia rupture (one case, patient was able to return to running after 6 wk) (68) also have been reported following ESWT. Tolerability of ESWT should be discussed with patients, as many patients report that ESWT is "unpleasant but tolerable" (46). If needed, the EFD can be decreased on the ESWT machine when patients are not able to tolerate higher energy levels. As with any intervention, there is always a possibility that ESWT will not provide a patient with the relief they desire or it may worsen symptoms (14,58). This should always be discussed with patients, because ESWT is often an out-of-pocket expense for patients.

Postprocedural Guidelines

Few studies describe the postprocedure guidelines (rest, use of medications, physical therapy) after ESWT administration. ESWT likely works best when combined with adequate rest and an optimal rehabilitation protocol. Only a few studies have examined the efficacy of concurrent physical therapy and ESWT, but these studies have shown good efficacy of combined treatments (47,52,65,69). The use of concurrent nonsteroidal anti-inflammatory (NSAID) medications and analgesics is infrequently described in the literature. There is one study that discontinued NSAIDs and analgesics for 2 wk before and 4 wk after ESWT treatment (38), but there is not additional evidence to support this. It is generally believed that ESWT can be safely used as a treatment option for in-season athletes, without necessitating time away from sport. A study on the use of ESWT for in-season athletes with patellar tendinopathy showed that ESWT could safely be used for athletes during the competitive season with subjective short-term benefits, although long-term efficacy was not achieved (51). Our postprocedural recommendations are briefly outlined in Table 4.

Conclusions

ESWT is a safe treatment option for peripheral musculoskeletal conditions in athletes. Treatment with ESWT requires no, to minimal, time away from sport. Various protocols have shown efficacy in reducing pain and improving function but no single optimal ESWT protocol has been identified. Across studies and body regions, ESWT appears to have the most efficacy in the short term. ESWT can be combined with other treatment modalities and should be used as a supplement to, rather than a substitute for, physical therapy, with the goal of achieving longer-term benefits.

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References

1. Chaussy C, Schmiedt E, Jocham D, *et al.* First clinical experience with extracorporeally induced destruction of kidney stones by shock waves. *J. Urol.* 2017; 197(2S):S160–s3.
2. Argyropoulos AN, Tolley DA. Optimizing shock wave lithotripsy in the 21st century. *Eur. Urol.* 2007; 52:344–52.
3. Chaussy C, Brendel W, Schmiedt E. Extracorporeally induced destruction of kidney stones by shock waves. *Lancet.* 1980; 2:1265–8.
4. Haupt G, Haupt A, Ekkernkamp A, *et al.* Influence of shock waves on fracture healing. *Urology.* 1992; 39:529–32.
5. Cacchio A, Giordano L, Colafarina O, *et al.* Extracorporeal shock-wave therapy compared with surgery for hypertrophic long-bone nonunions. *J. Bone Joint Surg. Am.* 2009; 91:2589–97.
6. Taki M, Iwata O, Shiono M, *et al.* Extracorporeal shock wave therapy for resistant stress fracture in athletes: a report of 5 cases. *Am. J. Sports Med.* 2007; 35:1188–92.
7. Reilly JM, Bluman E, Tenforde AS. Effect of shockwave treatment for management of upper and lower extremity musculoskeletal conditions: a narrative review. *PM R.* 2018; 10:1385–403.
8. Aqil A, Siddiqui MR, Solan M, *et al.* Extracorporeal shock wave therapy is effective in treating chronic plantar fasciitis: a meta-analysis of RCTs. *Clin. Orthop. Relat. Res.* 2013; 471:3645–52.
9. Wang YC, Chen SJ, Huang PJ, *et al.* Efficacy of different energy levels used in focused and radial extracorporeal shockwave therapy in the treatment of plantar fasciitis: a meta-analysis of randomized placebo-controlled trials. *J. Clin. Med.* 2019; 8:1497.
10. Wang CJ. Extracorporeal shockwave therapy in musculoskeletal disorders. *J. Orthop. Surg. Res.* 2012; 7:11.
11. d'Agostino MC, Craig K, Tibalt E, Respizzi S. Shock wave as biological therapeutic tool: From mechanical stimulation to recovery and healing, through mechanotransduction. *Int. J. Surg.* 2015; 24(Pt B):147–53.
12. Simplicio CL, Purita J, Murrell W, *et al.* Extracorporeal shock wave therapy mechanisms in musculoskeletal regenerative medicine. *J. Clin. Orthop. Trauma.* 2020; 11(Suppl. 3):S309–s18.
13. Perlick L, Luring C, Bathis H, *et al.* Efficacy of extracorporal shock-wave treatment for calcific tendinitis of the shoulder: experimental and clinical results. *J. Orthop. Sci.* 2003; 8:777–83.
14. Peters J, Luboldt W, Schwarz W, *et al.* Extracorporeal shock wave therapy in calcific tendinitis of the shoulder. *Skelet. Radiol.* 2004; 33:712–8.
15. Weihs AM, Fuchs C, Teuschl AH, *et al.* Shock wave treatment enhances cell proliferation and improves wound healing by ATP release-coupled extracellular signal-regulated kinase (ERK) activation. *J. Biol. Chem.* 2014; 289:27090–104.
16. Frairia R, Berta L. Biological effects of extracorporeal shock waves on fibroblasts. A review. *Muscles Ligaments Tendons J.* 2011; 1:138–47.
17. Wang CJ, Yang YJ, Huang CC. The effects of shockwave on systemic concentrations of nitric oxide level, angiogenesis and osteogenesis factors in hip necrosis. *Rheumatol. Int.* 2011; 31:871–7.
18. Wang C-J, Yang KD, Ko J-Y, *et al.* The effects of shockwave on bone healing and systemic concentrations of nitric oxide (NO), TGF-beta1, VEGF and BMP-2 in long bone non-unions. *Nitric Oxide.* 2009; 20:298–303.
19. Chen YJ, Wang CJ, Yang KD, *et al.* Extracorporeal shock waves promote healing of collagenase-induced Achilles tendinitis and increase TGF-beta1 and IGF-I expression. *J. Orthop. Res.* 2004; 22:854–61.
20. Waugh CM, Morrissey D, Jones E, *et al.* In vivo biological response to extracorporeal shockwave therapy in human tendinopathy. *Eur. Cell. Mater.* 2015; 29:268–80; discussion 80.
21. Bosch G, Lin YL, van Schie HT, *et al.* Effect of extracorporeal shock wave therapy on the biochemical composition and metabolic activity of tenocytes in normal tendinous structures in ponies. *Equine Vet. J.* 2007; 39:226–31.
22. Sun D, Junger WG, Yuan C, *et al.* Shockwaves induce osteogenic differentiation of human mesenchymal stem cells through ATP release and activation of P2X7 receptors. *Stem Cells.* 2013; 31:1170–80.
23. Klonschinski T, Ament SJ, Schlereth T, *et al.* Application of local anesthesia inhibits effects of low-energy extracorporeal shock wave treatment (ESWT) on nociceptors. *Pain Med.* 2011; 12:1532–7.
24. Hausdorf J, Lemmens MA, Kaplan S, *et al.* Extracorporeal shockwave application to the distal femur of rabbits diminishes the number of neurons immunoreactive for substance P in dorsal root ganglia L5. *Brain Res.* 2008; 1207:96–101.
25. Hausdorf J, Lemmens MA, Heck KD, *et al.* Selective loss of unmyelinated nerve fibers after extracorporeal shockwave application to the musculoskeletal system. *Neuroscience.* 2008; 155:138–44.
26. Wess OJ. A neural model for chronic pain and pain relief by extracorporeal shock wave treatment. *Urol. Res.* 2008; 36:327–34.
27. Rompe JD, Kirkpatrick CJ, Küllmer K, *et al.* Dose-related effects of shock waves on rabbit tendo Achilles. A sonographic and histological study. *J. Bone Joint Surg. (Br.).* 1998; 80:546–52.

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28. van der Worp H, van den Akker-Scheek I, van Schie H, *et al.* ESWT for tendinopathy: technology and clinical implications. *Knee Surg. Sports Traumatol. Arthrosc.* 2013; 21:1451–8.

29. Furia JP. High-energy extracorporeal shock wave therapy as a treatment for insertional Achilles tendinopathy. *Am. J. Sports Med.* 2006; 34(5):733–40.

30. Cheng L, Chang S, Qian L, *et al.* Extracorporeal shock wave therapy for isokinetic muscle strength around the knee joint in athletes with patellar tendinopathy. *J. Sports Med. Phys. Fitness.* 2019; 59:822–7.

31. Louwerens JKG, Sierevelt IN, Kramer ET, *et al.* Comparing ultrasound-guided needling combined with a subacromial corticosteroid injection versus high-energy extracorporeal shockwave therapy for calcific tendinitis of the rotator cuff: a randomized controlled trial. *Art Ther.* 2020; 36:1823–33.

32. Njawaya MM, Moses B, Martens D, *et al.* Ultrasound guidance does not improve the results of shock wave for plantar fasciitis or calcific achilles tendinopathy: a randomized control trial. *Clin. J. Sport Med.* 2018; 28:21–27.

33. Cartledge JJ, Cross WR, Lloyd SN, *et al.* The efficacy of a range of contact media as coupling agents in extracorporeal shockwave lithotripsy. *B. J. U. Int.* 2001; 88:321–4.

34. Rompe JD, Meurer A, Nafe B, *et al.* Repetitive low-energy shock wave application without local anesthesia is more efficient than repetitive low-energy shock wave application with local anesthesia in the treatment of chronic plantar fasciitis. *J. Orthop. Res.* 2005; 23:931–41.

35. Eid J. Consensus statement on ESWT indications and contraindications. *Int. Soc. Med. Shockwave Treat.* (ISMST). 2016; 1–4.

36. Surace SJ, Deitch J, Johnston RV, Buchbinder R. Shock wave therapy for rotator cuff disease with or without calcification. *Cochrane Database Syst. Rev.* 2020; 3: Cd008962.

37. Li C, Li Z, Shi L, *et al.* Effectiveness of focused shockwave therapy versus radial shockwave therapy for noncalcific rotator cuff tendinopathies: a randomized clinical trial. *Biomed. Res. Int.* 2021; 2021:6687094.

38. Wu KT, Chou WY, Wang CJ, *et al.* Efficacy of extracorporeal shockwave therapy on calcified and noncalcified shoulder tendinosis: a propensity score matched analysis. *Biomed. Res. Int.* 2019; 2019:2958251.

39. Tornese D, Mattei E, Bandi M, *et al.* Arm position during extracorporeal shock wave therapy for calcifying tendinitis of the shoulder: a randomized study. *Clin. Rehabil.* 2011; 25:731–9.

40. Yan C, Xiong Y, Chen L, *et al.* A comparative study of the efficacy of ultrasonics and extracorporeal shock wave in the treatment of tennis elbow: a meta-analysis of randomized controlled trials. *J. Orthop. Surg. Res.* 2019; 14:248.

41. Zheng C, Zeng D, Chen J, *et al.* Effectiveness of extracorporeal shock wave therapy in patients with tennis elbow: a meta-analysis of randomized controlled trials. *Medicine.* 2020; 99:e21189.

42. Park JW, Hwang JH, Choi YS, Kim SJ. Comparison of therapeutic effect of extracorporeal shock wave in calcific versus noncalcific lateral epicondylopathy. *Ann. Rehabil. Med.* 2016; 40:294–300.

43. Furia JP, Rompe JD, Maffulli N. Low-energy extracorporeal shock wave therapy as a treatment for greater trochanteric pain syndrome. *Am. J. Sports Med.* 2009; 37:1806–13.

44. Rompe JD, Segal NA, Cacchio A, *et al.* Home training, local corticosteroid injection, or radial shock wave therapy for greater trochanter pain syndrome. *Am. J. Sports Med.* 2009; 37:1981–90.

45. Seo KH, Lee JY, Yoon K, *et al.* Long-term outcome of low-energy extracorporeal shockwave therapy on gluteal tendinopathy documented by magnetic resonance imaging. *PLoS One.* 2018; 13:e0197460.

46. Carlisi E, Cecini M, Di Natali G, *et al.* Focused extracorporeal shock wave therapy for greater trochanteric pain syndrome with gluteal tendinopathy: a randomized controlled trial. *Clin. Rehabil.* 2019; 33:670–80.

47. Ramon S, Russo S, Santoboni F, *et al.* Focused shockwave treatment for greater trochanteric pain syndrome: a multicenter, randomized, controlled clinical trial. *J. Bone Joint Surg. Am.* 2020; 102:1305–11.

48. Cacchio A, Rompe JD, Furia JP, *et al.* Shockwave therapy for the treatment of chronic proximal hamstring tendinopathy in professional athletes. *Am. J. Sports Med.* 2011; 39:146–53.

49. Mitchkash M, Robinson D, Tenforde AS. Efficacy of extracorporeal pulse-activated therapy in the management of lower-extremity running-related injuries: findings from a large case cohort. *J. Foot Ankle Surg.* 2020; 59:795–800.

50. Mani-Babu S, Morrissey D, Waugh C, *et al.* The effectiveness of extracorporeal shock wave therapy in lower limb tendinopathy: a systematic review. *Am. J. Sports Med.* 2015; 43:752–61.

51. Zwerver J, Hartgens F, Verhagen E, *et al.* No effect of extracorporeal shockwave therapy on patellar tendinopathy in jumping athletes during the competitive season: a randomized clinical trial. *Am. J. Sports Med.* 2011; 39:1191–9.

52. Rompe JD, Furia J, Maffulli N. Eccentric loading versus eccentric loading plus shock-wave treatment for midportion Achilles tendinopathy: a randomized controlled trial. *Am. J. Sports Med.* 2009; 37:463–70.

53. Rasmussen S, Christensen M, Mathiesen I, Simonson O. Shockwave therapy for chronic Achilles tendinopathy: a double-blind, randomized clinical trial of efficacy. *Acta Orthop.* 2008; 79:249–56.

54. Vahdatpour B, Forouzan H, Momeni F, *et al.* Effectiveness of extracorporeal shockwave therapy for chronic Achilles tendinopathy: a randomized clinical trial. *J. Res. Med. Sci.* 2018; 23:37.

55. Abdelkader NA, Helmy MNK, Fayaz NA, Saweeres ESB. Short- and intermediate-term results of extracorporeal shockwave therapy for noninsertional Achilles tendinopathy. *Foot Ankle Int.* 2021; 1071100720982613.

56. Wheeler PC, Tattersall C. Novel interventions for recalcitrant Achilles tendinopathy: benefits seen following high-volume image-guided injection or extracorporeal shockwave therapy—a prospective cohort study. *Clin. J. Sport Med.* 2020; 30:14–9.

57. Rhim HC, Kim MS, Choi S, Tenforde AS. Comparative efficacy and tolerability of nonsurgical therapies for the treatment of midportion Achilles tendinopathy: a systematic review with network meta-analysis. *Orthop. J. Sports Med.* 2020; 8:2325967120930567.

58. Pinitkwamdee S, Laohajaroensombat S, Orapin J, Woratanarat P. Effectiveness of extracorporeal shockwave therapy in the treatment of chronic insertional Achilles tendinopathy. *Foot Ankle Int.* 2020; 41:403–10.

59. Zhang S, Li H, Yao W, *et al.* Therapeutic response of extracorporeal shock wave therapy for insertional Achilles tendinopathy between sports-active and nonsports-active patients with 5-year follow-up. *Orthop. J. Sports Med.* 2020; 8:2325967119898118.

60. Li X, Zhang L, Gu S, *et al.* Comparative effectiveness of extracorporeal shock wave, ultrasound, low-level laser therapy, noninvasive interactive neurostimulation, and pulsed radiofrequency treatment for treating plantar fasciitis: a systematic review and network meta-analysis. *Medicine.* 2018; 97:e12819.

61. Dizon JN, Gonzalez-Suarez C, Zamora MT, Gambito ED. Effectiveness of extracorporeal shock wave therapy in chronic plantar fasciitis: a meta-analysis. *Am. J. Phys. Med. Rehab.* 2013; 92:606–20.

62. Sun K, Zhou H, Jiang W. Extracorporeal shock wave therapy versus other therapeutic methods for chronic plantar fasciitis. *Foot Ankle Surg.* 2020; 26:33–8.

63. Li S, Wang K, Sun H, *et al.* Clinical effects of extracorporeal shock-wave therapy and ultrasound-guided local corticosteroid injections for plantar fasciitis in adults: a meta-analysis of randomized controlled trials. *Medicine.* 2018; 97: e13687.

64. Furia JP, Rompe JD, Maffulli N, *et al.* Radial extracorporeal shock wave therapy is effective and safe in chronic distal biceps tendinopathy. *Clin. J. Sport Med.* 2017; 27:430–7.

65. Robinson D, Mitchkash M, Wasserman L, Tenforde AS. Nonsurgical approach in management of tibialis posterior tendinopathy with combined radial shockwave and foot core exercises: a case series. *J. Foot Ankle Surg.* 2020; 59:1058–61.

66. Liao CD, Tsauo JY, Chen HC, Liou TH. Efficacy of extracorporeal shock wave therapy for lower-limb tendinopathy: a meta-analysis of randomized controlled trials. *Am. J. Phys. Med. Rehab.* 2018; 97:605–19.

67. Costa ML, Shepstone L, Donell ST, Thomas TL. Shock wave therapy for chronic Achilles tendon pain: a randomized placebo-controlled trial. *Clin. Orthop. Relat. Res.* 2005; 440:199–204.

68. Saxena A, Hong BK, Yun AS, *et al.* Treatment of plantar fasciitis with radial soundwave "early" is better than after 6 months: a pilot study. *J. Foot Ankle Surg.* 2017; 56:950–3.

69. Rompe JD, Furia J, Cacchio A, *et al.* Radial shock wave treatment alone is less efficient than radial shock wave treatment combined with tissue-specific plantar fascia-stretching in patients with chronic plantar heel pain. *Int. J. Surg.* 2015; 24(Pt B):135–42.

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