



DOSSIER · THERAPY

Extracorporeal Shock Wave Therapy (ESWT)

The page compiles the research on extracorporeal shock wave therapy. The majority of the studies in humans are controlled and focus on the musculoskeletal system. However, the most cited controlled trial does not address a tendon but penile rehabilitation after radical prostatectomy.

827

STUDIES IN
TOTAL

585

IN HUMANS

304

OF WHICH
CONTROLLED

37

IN ANIMALS

10

IN THE LAB

Figures from the IHR study database · Last updated 2026-10-15

How to Read This Dossier

ESTABLISHED

measured in humans, with a comparison group

PLAUSIBLE

supported by mechanism, animal studies or observation

HYPOTHESIS

a likely connection that still needs to be tested

Extracorporeal Shock Wave Therapy (ESWT) at a Glance

ORIGIN:
Extracorporeal shock wave therapy transmits shock waves from outside to the tissue. Three energy sources are mentioned: electromagnetic, electrohydraulic and piezoelectric; the energy density of the devices ranges from 0.09 to 0.55 mJ/mm². The studies in humans predominantly concern the musculoskeletal system; controlled studies are somewhat more numerous than observational studies, and the most frequently cited controlled trial addresses penile rehabilitation after radical prostatectomy.

EVIDENCE BASE:
827 evaluated papers · 304 controlled studies in humans · 281 observational studies · 56 review papers · 37 animal studies · 9 cell culture studies

- STRONGEST EVIDENCE:**
- **Proven:** Knee osteoarthritis — a meta-analysis with 782 participants and 877 knees: VAS mean difference 1.7 cm (95 % CI 1.1 to 2.3), WOMAC 13.9 points (95 % CI 6.9 to 20.8), evidence quality moderate.
 - **Proven:** Lateral epicondylopathy — a meta-analysis with 1871 patients found a medium-term reduction in pain intensity versus sham treatment (SMD -1.21; 95 % CI -1.53 to -0.89; P < 0.001).
 - A randomised study showed a response rate on the modified Ashworth scale of 70.4 % (agonists) and 63.3 % (antagonists) versus 16.0 % with physiotherapy alone in elbow spasticity.
 - Erectile dysfunction — in the reviewed literature the improvement in the International Index of Erectile Function was 3.54 (range 1.99 to 6.40); a statistically significant short-term effect is reported.
 - **Proven:** Myofascial pain syndrome of the trapezius — a meta-analysis of ten papers with 477 patients shows a significant pain reduction versus sham shock wave or ultrasound.

- LIMITATIONS:**
- In patellar tendinopathy shock wave therapy does not appear superior to sham shock wave in pairwise meta-analyses of two studies (pain MD +0.1; 95 % CI -0.8 to 1; p = 0.84).
 - In insertional Achilles tendinopathy no significant long-term difference was found between shock wave and sham treatment on the visual analogue scale and its domains.
 - For children with cerebral palsy four studies met the inclusion criteria; the authors conclude that further research is needed and a pooled analysis of the spasticity data is still outstanding.

CLASSIFICATION:
Extracorporeal shock wave therapy is best studied in the musculoskeletal system; at tendon insertions and in spasticity energy density and comparator group remain open questions.

1. What Extracorporeal Shock Wave Therapy Is

Extracorporeal shock wave therapy introduces acoustic pressure waves into circumscribed tissue from outside the body. It is performed without skin incision; the treatment field is coupled to the applicator via coupling gel, sessions last a few minutes and are repeated in series over several weeks. A distinction is made between focused systems, which bundle energy at a single point, and radial systems, which deliver pressure waves over an area. Depending on the indication the treatment field is located by palpation, ultrasound or imaging. The range of applications extends from tendon insertions and joints through bone to urological and regenerative questions.

For the understanding of all papers it is crucial that the term encompasses several procedures. Focused and radial systems differ in the physics of the pressure wave, and within both a distinction is made between low-energy and high-energy protocols. The studies employ different energy densities, session numbers and treatment intervals, partly with and partly without imaging guidance. Anyone comparing results is therefore comparing not a single procedure but a family of protocols. Added to this is the measurement level: most controlled papers record pain and function via scales and questionnaires, that is, markers, not the course of a disease.

The key human studies and the most important reviews — by application area, with population, duration, preparation, outcome measure and result as reported in the original papers. Numbers appear only where the paper states them.

Distribution of **controlled studies in humans** by application area — the numbers are not additive because one paper may be assigned to several areas:

APPLICATION AREA	CONTROLLED STUDIES
Musculoskeletal system	121
Safety and tolerability	81
Bone and joints	47
Metabolism	20
Inflammatory processes	18
Cognition and psyche	14

APPLICATION AREA	CONTROLLED STUDIES
Skin	11
Fatigue and stress	11

Under the name ESWT several procedures are grouped together

Anyone reading the evidence base must draw two dividing lines. The first runs between focused and radial shock wave, the second between low-energy and high-energy protocols. Both dividing lines are physically justified and not merely gradual. A meta-analysis that pools studies of both designs and both energy ranges does not answer the question of the effect of a specific procedure. It shows only that the sum of the protocols examined points in one direction.

The second difficulty is the control. A sham treatment for shock wave can be produced, and individual randomised, double-blind, sham-controlled trials exist, for example on erectile dysfunction after PDE5 inhibitors. In many other papers such a control is absent or only single-blinded. As long as the comparator group is chosen with varying rigour, effect sizes are not directly comparable between studies.

HYPOTHESIS:

Part of the observed effect in unblinded papers is attributable to the expectation of the treated person. The open question is therefore not whether shock wave does something, but which protocol was tested against which comparator condition.

2. What the Studies Show in Detail

Musculoskeletal System

After radical prostatectomy, a randomised, open-label study with two parallel arms in a 1:1 ratio examined whether early administration of the PDE-5 inhibitor tadalafil alone is inferior to a combination of early tadalafil administration and low-intensity extracorporeal shock wave therapy (LIESWT). The primary clinical endpoint was a difference of at least 4 points in the International Index of Erectile Function (short form IIEF-5) in favour of the experimental group at the final follow-up; any statistical difference in the IIEF-5 between the arms counted as the primary statistical endpoint. Between 25 September 2017 and 3 December 2018, 92 men were enrolled. The results of this study are still pending ¹.

In patients after stroke with elbow spasticity, a randomised, single-blind study investigated the effect of radial extracorporeal shock wave therapy (rESWT) on agonist and antagonist muscles as well as the duration of the effect and the influence on function. 25 patients formed the control group (A), 27 received rESWT to the agonists (B) and 30 to the antagonists (C). All three groups received conventional physiotherapy six times a week for three weeks; in addition, rESWT was applied at four-day intervals in five consecutive treatments. The primary endpoint was the modified Ashworth Scale (MAS); secondary measures included the modified Tardieu Scale, visual analogue scale (VAS), Fugl-Meyer Assessment and a swelling scale at baseline, after five treatments and after four weeks of follow-up. The response rate, measured by MAS change, was 16.0 % (A), 70.4 % (B) and 63.3 % (C) after the rESWT treatments and 24.0 % (A), 74.1 % (B) and 66.7 % (C) after four weeks. Improvements were seen for R1 ($P < 0.01$), R2 ($P < 0.01$) and VAS ($P < 0.01$) after five rESWT interventions; after four weeks significant improvements remained for R1 ($P < 0.01$) and VAS ($P < 0.01$) ¹⁴.

In children with cerebral palsy, a systematic review examined the literature on treatment of muscle spasticity with extracorporeal shock wave therapy and assessed its quality according to the Oxford Centre for Evidence-based Medicine guidelines. Four studies met the inclusion criteria: one low-quality randomised controlled trial, two individual case-control studies and one case series. In all selected papers, reduction of muscle stiffness and improvement of joint range of motion were the target variables. The authors conclude that further research is needed to support the use of extracorporeal shock wave therapy in muscular spasticity of children with cerebral palsy ¹⁶.

A review compared the energy spectra of six currently commercially available shock wave devices and contrasted them with personal experience with these six devices in 350 patients. According to the author, all published preclinical and clinical studies on penile shock wave therapy were evaluated; main target variables were success rates in erectile dysfunction (change in International Index of Erectile Function-erectile function, conversion of non-responders to PDE-5 inhibitors) and in Peyronie's disease (change in deviation and plaque size). Three energy sources are used: electromagnetic, electrohydraulic and piezoelectric; the devices differ markedly in the available spectrum of energy flux density between 0.09 and 0.55 mJ/mm². The author names the -6-dB value and the 5-MPa focus as biologically relevant energy parameters, which differ substantially between the devices. The announced presentation of results from the 350 patients is still pending ³⁰. What remains to be clarified: the results of penile rehabilitation after radical prostatectomy ¹, a pooled analysis of the spasticity data in children ¹⁶ and a uniform reference quantity for the energy parameters of the devices ³⁰.

Bones and Joints

63 volunteers with knee osteoarthritis (Kellgren-Lawrence grade II or III) were assigned to two groups in a placebo-controlled randomised study. The experimental group received low-dose extracorporeal shock wave therapy for four weeks, the placebo group received sham treatment; both groups continued their usual home exercise programme. Knee pain and physical function were assessed with visual analogue scale (VAS), Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) and Lequesne Index at baseline, after five and after twelve weeks; cartilage change was determined via transverse relaxation time (T2-mapping). VAS, WOMAC and Lequesne Index of the shock wave group were significantly better than in the placebo group after five and after twelve weeks ($P < 0.05$); both groups improved over the twelve weeks ($P < 0.05$). No significant difference in T2 values was found between the groups in the imaging data ².

PROVEN

A meta-analysis of randomised studies up to 30 September 2019 included fourteen studies with 782 participants and 877 knees. For pain on the VAS a mean difference of 1.7 cm (95 % confidence interval 1.1 to 2.3) was obtained, for the WOMAC 13.9 points (95 % CI 6.9 to 20.8); the quality of evidence was rated moderate. The effect of shock wave therapy with medium energy flux density was greater on the WOMAC than with low or high

density ($\text{Chi}^2 = 9.8$, $p = 0.002$) and reached borderline significance on the VAS ($\text{Chi}^2 = 3.8$, $p = 0.05$). At very low evidence quality a moderate improvement in knee joint range of motion was shown (MD = 17.5°; 95 % CI 9.4 to 25.5)³.

In a meta-analysis three randomised controlled trials and three cohort studies with 589 patients were summarised. Pain scores decreased after four weeks (WMD = -0.436; 95 % CI -0.604 to -0.269), after eight weeks (WMD = -0.234; 95 % CI -0.447 to -0.022) and after twelve weeks (WMD = -0.239; 95 % CI -0.436 to -0.043). A third review with meta-analysis reports that the shock wave group showed significant pain relief versus the control group over twelve months, measured with WOMAC and VAS, and that the patients improved versus baseline at most follow-up time points (one week to twelve months). Physical function was better than in the control group after six and twelve months and better than at baseline across all follow-up time points (one to twelve months); only minor complications were observed after treatment^{13, 29}.

An overview is available on the mechanisms of fracture healing. Clinical efficacy of extracorporeal shock wave therapy in bone non-union is described therein as widely recognised, yet the biological mechanism of healing promotion remains unclear. It is described that the shock wave, via mechanical transmission, produces a microfracture of the old callus, forms a subperiosteal haematoma, releases bioactive factors, reactivates the fracture healing mechanism, rebalances the activity of osteoblasts and osteoclasts, promotes angiogenesis at the fracture site and accelerates non-union healing³⁵.

Hypothesis: If this chain of mechanically transmitted steps is confirmed, the effect would not be limited to a superficial stimulus but would be linked to reactivation of a tissue repair programme; this chain has so far been tested predominantly mechanistically and preclinically, not at controlled clinical endpoints in humans. What remains to be clarified: direct comparisons between low, medium and high energy flux density and an analysis linking cartilage changes in imaging follow-up with clinical endpoints^{2, 3}.

Further Investigations

In chronic insertional Achilles tendinopathy, 16 patients received low-energy shock wave therapy and 15 received sham treatment in a double-blind, randomised, sham-controlled study. Baseline values did not differ significantly (VAS 6.0 ± 2.6 versus 5.2 ± 2.2; VAS for foot and ankle 64.8 ± 16.6 versus 65.3 ± 12.7). Pain, function and further complaints were assessed before the intervention and at weeks 2, 3, 4, 6, 12 and 24. Long-term no significant difference was found between the groups in VAS, VAS for foot and ankle or their domains; the shock wave group showed a significant improvement in VAS in weeks 4 to 12 (2.9 ± 2.2)⁴. In a further double-blind randomised study in 119 patients with insertional Achilles tendinopathy (February 2017 to February 2019) one group received eccentric exercises plus extracorporeal shock wave therapy, the other eccentric exercises plus sham shock wave. Three sessions with radial shock waves were performed at two-week intervals, the eccentric exercises ran for three months; the primary endpoint was the Victorian Institute of Sport Assessment-Achilles questionnaire at 24 weeks, secondary measures included visual analogue scale, algometry, Foot and Ankle Outcome Score and the 12-Item Short Form Health Survey¹².

In non-insertional Achilles tendinopathy, twenty-two men and twenty-eight women aged 18 to 40 years were randomised to two equal groups in a double-blind randomised study between 2018 and 2020: eccentric loading programme with stretching exercises plus shock wave therapy or plus sham treatment. Function and pain were measured at baseline, after one month and after 16 months with VISA-A and VAS. At baseline the groups did not differ (VISA-A 22.2 ± 6.5 versus 21.0 ± 5.2; VAS 8 ± 1 versus 8 ± 1). After treatment both groups improved markedly (VISA-A 85 ± 6.2 versus 53.4 ± 7.7; VAS 1 ± 2 versus 7 ± 2). At the 16-month follow-up the values declined slightly but significantly¹⁷.

In symptomatic calcifying tendinitis of the rotator cuff unresponsive to conservative treatment, a randomised controlled study compared two procedures: extracorporeal shock wave therapy with 2000 impulses and an energy flux density of 0.35 mJ/mm² in four sessions at one-week intervals versus ultrasound-guided needling technique combined with a subacromial corticosteroid injection. After one year the needling group showed similar results to the shock wave group regarding change in Constant-Murley Score from baseline. A systematic review with meta-analysis of randomised controlled studies compared operative and non-operative procedures in chronic calcifying tendinitis of the rotator cuff; 7 % to 17 % of persons with shoulder pain exhibit calcific deposits of the rotator cuff. Pain on the visual analogue scale, Constant-Murley Score and resolution of the calcific deposits were evaluated¹⁵. In a prospective cohort of 80 patients with long-standing calcifying tendinitis of the rotator cuff treated with high-energy extracorporeal shock wave therapy and ultrasound-guided needling, the minimal clinically important difference and substantial clinical benefit of two questionnaires were determined: for the Constant-Murley Score 9.8 and 19.9 by the mean change method and 5.5 and 10.5 by ROC analysis, for the Disabilities of the Arm, Shoulder and Hand score -8.2 and -19.6²⁷.

Ten articles with 477 patients were included in a meta-analysis on myofascial pain syndrome of the trapezius. Shock wave therapy improved pain reduction significantly compared with sham shock wave or ultrasound treatment, but showed no significant effect compared with conventional treatments (dry needling, trigger point injection, laser therapy) regarding pain intensity and Neck Disability Index⁹. In a meta-analysis on lateral epicondylopathy twenty-seven studies with 1871 patients were evaluated. Versus sham treatment shock wave therapy reduced pain intensity in the medium term (standardised mean difference -1.21; 95 % CI -1.53 to -0.89; $P < 0.001$) and improved grip strength very short-term (MD 3.92; 95 % CI 0.91 to 6.94; $P = 0.01$) and short-term (MD 4.87; 95 % CI 2.24 to 7.50; $P < 0.001$). No clinically meaningful differences were found between the comparison groups at all endpoints and follow-up times¹¹. A network meta-analysis on patellar tendinopathy included 37 randomised controlled studies with 33 different interventions, most represented by single studies; on the basis of pairwise meta-analyses of two studies shock wave therapy does not appear superior to sham shock wave (eccentric exercises in both groups): short-term pain MD +0.1 (95 % CI -0.8 to 1; $p = 0.84$), function MD -1.8 (95 % CI -8 to 4.4; $p = 0.57$)³¹. A further systematic review with meta-analysis on patellar tendinopathy, Achilles tendinopathy and plantar fasciitis found a negligible short-term effect of shock wave therapy alone or in combination with eccentric exercises on pain and function compared with placebo or placebo plus eccentric exercises in patellar tendinopathy; versus conservative treatment, however, a significant effect on pain was shown³². A narrative review on the combination of shock wave therapy and exercise treatment in five tendinopathies concludes that the combination with eccentric training, tissue-specific stretching or heavy slow resistance training is effective in certain tendinopathies; the number of studies on the combination is currently limited, and in patellar tendinopathy the combination has not yet been demonstrated³³.

An overview of newer treatments for erectile dysfunction reviewed, for the section on low-intensity shock wave therapy, one randomised controlled study, two prospective studies, one animal study and two meta-analyses; the improvement in the International Index of Erectile Function amounted to 3.54 (range 1.99 to 6.40). The authors concluded a statistically significant short-term effect and an improvement in erectile function⁶. A systematic review on spasticity in cerebral palsy evaluated 489 identified articles, of which 48 studies met the inclusion criteria; 54 % of the papers reported on selective dorsal rhizotomy,

29 % on intrathecal baclofen pumps and 17 % on extracorporeal shock wave therapy. A statistically significant improvement in spasticity was reported for each procedure²⁸. What remains to be clarified: head-to-head comparisons between shock wave therapy and conventional procedures in myofascial pain as well as pooled analyses reporting pain and function separately by energy flux density and number of sessions^{9, 31, 32}.

Safety and Tolerability

76 patients with vascular erectile dysfunction unresponsive to PDE-5 inhibitors completed a randomised, double-blind, sham-controlled study; 40 men were treated with low-intensity shock wave therapy (one session per week over four weeks, 5000 impulses per session, energy flux density 0.09 mJ/mm²), 36 with a sham probe. Erectile function was assessed before and after treatment (after one, three and six months) with validated questionnaires (IIEF-EF, EHS, SEP2, SEP3 and GAQ1); comparisons were made with Mann-Whitney-Wilcoxon and Chi-square tests, statistical significance was assumed at $p < 0.05$. After three months the median change in IIEF-EF was 3.5 (interquartile range 0 to 10) in the active group and -0.5 (interquartile range -11 to 1; $p < 0.05$) in the sham group. Six months after treatment 52.5 % of patients (21 of 40) in the active group and 27.8 % (10 of 36) in the sham group had an EHS > 2 ($p < 0.05$); 40.0 % (16 of 40) and 13.9 % (5 of 36) answered GAQ-1 positively⁷.

In a randomised controlled study in 59 patients with chronic plantar fasciitis three sessions of radial shock wave therapy (29 patients) were compared with two sessions of ultrasound-guided intrafascial injection of 2 ml 20 % dextrose solution (30 patients). Pain intensity on the visual analogue scale, daily and sports activity on the Foot and Ankle Ability Measure and plantar fascia thickness on ultrasound were assessed before as well as six and twelve weeks after treatment. VAS and FAAM showed significant improvements in pain and function in both groups after six and twelve weeks, and plantar fascia thickness decreased significantly at both time points (all $p < 0.05$). In the group comparison, apart from the FAAM sports subscale which favoured shock wave therapy, the interaction effects of group and time for the remaining endpoints were not significant¹⁰.

HYPOTHESIS Since both procedures acted in the same order of magnitude, shock wave therapy could be considered as an alternative in chronic plantar fasciitis for patients in whom an injection is not an option; the study with 29 and 30 patients per arm was not designed for a non-inferiority proof. What remains to be clarified: follow-ups beyond six months⁷ and a survey of adverse events with uniform recording method across the studies^{10, 34}.

Metabolism

42 patients aged 41 to 55 years with confirmed erectile dysfunction and diabetic polyneuropathy were randomised to two groups: 21 received low-intensity shock wave therapy plus pelvic floor training, 21 pelvic floor exercises plus sham shock wave. The diagnosis was confirmed by nerve conduction and Doppler examinations, erectile function was assessed with the five-item short form of the International Index of Erectile Function (IIEF-5), penile perfusion of the two cavernosal arteries by colour-coded duplex sonography; the examination was performed before and three months after treatment. Systolic peak velocity increased significantly in both groups; after treatment it was significantly higher in the study group than in the control group ($p < 0.001$ for both arteries)⁸.

HYPOTHESIS Since systolic peak velocity increased in both groups but IIEF-EF only in the study group, the additional effect may not be mediated solely via perfusion; with 21 patients per arm the study was too small to separate the vascular and neural components. What remains to be clarified: a sham-controlled trial without concomitant training in both arms and follow-ups beyond three months⁸.

Inflammatory Processes

104 patients (10 men, 94 women, mean age 61.5 years) with greater trochanteric pain syndrome were enrolled in a prospective, two-arm, single-blind randomised controlled study; 53 were assigned to focused shock wave therapy, 51 to ultrasound-guided corticosteroid injection, 11 patients were lost to follow-up. The primary endpoint was pain on the visual analogue scale, secondary Harris Hip Score and Trendelenburg test for function, SF-36 for quality of life and a Likert question on subjective improvement of complaints. Baseline values did not differ between the groups. After three months pain, function and quality of life had improved in both groups, but not statistically significantly. The Trendelenburg test was significantly improved in the shock wave group, with 80 % negative tests versus 20 % at baseline¹⁸.

A systematic review on biological effects of shock wave therapy in tendons describes that for each species and each tendon an optimal dose is adjusted and that exceeding the optimal dose can lead to structural damage. The effects are grouped into induction of neovascularisation, changes in cellularity and extracellular matrix, modulation of metalloproteases and cytokines as well as production of lubricin; in the examined models the remodelled tendon showed improved biomechanical properties under load. Examined were preclinical models on animal and human tendons; a corresponding effect in humans was therefore not investigated³⁴.

HYPOTHESIS From the dose dependence it follows that results of different studies can only be compared with comparable energy density and impulse number; the review provides no uniform reference value for this. What needs to be clarified next: human studies that directly link the described tissue changes with pain and function courses³⁴, as well as courses beyond three months in greater trochanteric pain syndrome¹⁸.

Skin

A review on keloids places extracorporeal shock wave therapy among a range of multimodal procedures that, in addition to classic corticosteroid therapy, include injections, cryotherapy, laser, irradiation and radiofrequency ablation. According to the presentation, keloids arise through excessive granulation tissue or collagen type III during the healing process, have a genetic component, and a predisposition can be inherited; they impair quality of life through psychological burden resulting from cosmetic impairment and functional limitation. The review describes newer treatment approaches such as stem cell therapy, mitomycin C, bleomycin, interferon, botulinum toxin type A, calcium channel blockers, ACE inhibitors and fat grafting as well as epigenetic and gene therapy approaches²⁵.

The review mentions shock wave therapy only as one of the listed approaches; results on effect, dose or course in keloids are not reported therein.

Hypothesis: Since keloids are described via excessive collagen deposition and recurrences after excision, it would be necessary to examine whether shock wave treatment on scar tissue influences remodelling of the extracellular matrix; this has not been investigated in the evaluated works. What needs to be clarified next: controlled studies with keloids as a separate target variable, in which deviation, scar height and recurrence rate are recorded over a defined period²⁵.

Cognition and Psyche

A narrative review on the treatment of erectile dysfunction in men with diabetes who do not respond to PDE-5 inhibitors cites an estimated prevalence of erectile dysfunction of 52.5 % in the diabetic population. PDE-5 inhibitors are considered first-line therapy, with the data suggesting that diabetic men respond less; further options mentioned are intracavernous injections, intraurethral prostaglandin, vacuum erection devices and penile prosthesis surgery. In addition, combinations of PDE-5 inhibitors and other oral treatments such as arginine or L-carnitine are mentioned, which could have synergistic effects with better outcomes. Low-intensity shock wave therapy is listed among the newer therapies that could be effective in targeted treatment modalities ²⁶.

HYPOTHESIS If the effect is confirmed in the presence of concurrent diabetic polyneuropathy and vascular component, shock wave therapy would need to be examined less as a substitute than as a component in a combined approach; the review reports no own figures on this. What needs to be clarified next: studies in diabetic erectile dysfunction that record perfusion parameters, nerve conduction findings and subjective function scales in the same cohort ^{8, 26}.

Fatigue and Stress

A systematic review included 56 studies with 1874 athletes or physically active persons and evaluated the efficacy of extracorporeal shock wave therapy in this cohort. According to the Oxford evidence scale, 18 studies (32.1 %) were level I, 3 (5.4 %) level II, 10 (17.9 %) level III, 13 (23.2 %) level IV and 12 (21.4 %) level V. On the basis of the level-I studies, shock wave therapy alone could be effective in plantar fasciitis, lateral epicondylitis and proximal hamstring tendinopathy and as an adjunct to exercise therapy in medial tibial stress syndrome and osteitis pubis. In most studies the athletes were allowed to continue activity and training and tolerated shock wave therapy ³⁶.

HYPOTHESIS If athletes tolerate the treatment without interrupting training, the procedure could be compatible with the competition calendar; the review does not report downtime or time to return to sport as a separate target variable. What needs to be clarified next: studies with uniformly defined return to sport, recorded training volumes and follow-up beyond the season ³⁶.

Overall Picture

Across the areas, meta-analyses with several concordant randomised studies contribute to the picture in knee osteoarthritis and lateral epicondylopathy: there, pain and function improvements versus sham treatment are available with pooled effect sizes ^{3, 11, 13, 29}. In Achilles tendon complaints, myofascial pain of the trapezius and patellar tendinopathy, studies with clear effect ^{4, 17} stand against evaluations without superiority versus sham treatment ^{9, 31, 32}. Part of these differences is due to different energy densities and session numbers that are not reported uniformly in the works ^{3, 30}.

Where individual randomised studies form the sole basis, questions remain open: the results of penile rehabilitation after radical prostatectomy are not reported in the evaluated works ¹, in greater trochanteric pain syndrome both groups improved without statistical significance ¹⁸, and in chronic plantar fasciitis shock wave therapy and dextrose injection did not differ except in one subscale ¹⁰. In keloids and in spasticity in children the examination is at the beginning ^{16, 25}; the review consulted on keloids addresses many treatment approaches and not shock wave therapy alone. Across all areas there is a lack of uniform reporting of energy density, impulse number, device type and follow-up duration, although precisely these parameters co-determine the results ^{30, 34}.

Methodology of the Evidence Base

The supporting works are controlled studies in humans as well as meta-analyses; participant numbers range from 31 in the smallest sham-controlled study on the Achilles tendon ⁴ to 1874 in the review on athletes ³⁶. Typical are treatment blocks of three to eight weeks with sessions at intervals of four days to two weeks ^{1, 12, 14}, and follow-ups between one month and twelve months ^{2, 17, 29}. Endpoints are almost invariably pain scales (visual analogue scale), function questionnaires (WOMAC, VISA-A, Constant-Murley score) and imaging (T2-mapping, calcification size, plantar fascia thickness); tissue parameters come predominantly from tendon models ³⁴. Systematically lacking is a standardised specification of energy density, impulse number and device type, without which studies cannot be pooled ³⁰.

3. How Robust the Research Is

The research is distributed clearly. The musculoskeletal system constitutes the largest field, followed by bone. A separate, unusually large block is devoted expressly to safety. In addition there are smaller areas such as metabolism, inflammation, cognition, skin, fatigue, immune system and oncology. Striking is the urological line: the most frequently cited controlled works address penile rehabilitation after radical prostatectomy, erectile dysfunction in diabetes and treatment failure after PDE5 inhibitors. The citation foci are therefore not where most studies are located.

PROVEN For tendon disorders and gonarthrosis, systematic reviews and network meta-analyses combine several randomised studies; there the evidence is densest. Mechanistic reviews and preclinical works on animals and cell cultures contribute to the understanding of the tissue response, but are not evidence in humans. Many works in humans are observational. The methodological weakness of the field lies less in the number of trials than in their comparability: devices, protocols and target variables change, and a blinded sham treatment is technically demanding.

4. What Is Frequently Claimed — and What the Data Provide

STATEMENT	EVIDENCE BASE
ESWT helps in tendon disorders	Systematic reviews and network meta-analyses are available for the patellar tendon, Achilles tendon and plantar fascia. They pool several randomised studies; 1
ESWT stimulates tissue regeneration	Mechanistic reviews and preclinical work on tendons describe biological effects. These findings stem predominantly from animal and cell models and are to be
ESWT is effective in erectile dysfunction	Several randomised studies, including sham-controlled ones, investigate low-energy protocols in diabetes, after prostatectomy and in PDE5 failure. The results .
ESWT is a uniform procedure	Focused and radial systems, low- and high-energy protocols as well as differing numbers of sessions are grouped under a single name. Vergleiche zwischen St

5. The Most Robust Studies

Ordered by strength of evidence, not by prominence. The complete evaluation includes significantly more studies; the most robust ones are listed here.

Controlled Studies in Humans

- ¹ The Role of the Low-Intensity Extracorporeal Shockwave Therapy on Penile Rehabilitation After Radical Prostatectomy: A Randomized Clinical Trial (2020)
- ² A Randomized Controlled Trial on the Effects of Low-Dose Extracorporeal Shockwave Therapy in Patients With Knee Osteoarthritis (2019)
- ³ Extracorporeal shockwave therapy improves pain and function in subjects with knee osteoarthritis: A systematic review and meta-analysis of randomized ... (2020)
- ⁴ Effectiveness of Extracorporeal Shockwave Therapy in the Treatment of Chronic Insertional Achilles Tendinopathy (2020)
- ⁵ Comparing Ultrasound-Guided Needling Combined With a Subacromial Corticosteroid Injection Versus High-Energy Extracorporeal Shockwave Therapy for ... (2020)
- ⁶ Novel Treatments of Erectile Dysfunction: Review of the Current Literature (2021)
- ⁷ Penile low intensity shock wave treatment for PDE5I refractory erectile dysfunction: a randomized double-blind sham-controlled clinical trial (2021)
- ⁸ Effect of low-intensity extracorporeal shock wave therapy on diabetic erectile dysfunction: Randomised control trial (2021)
- ⁹ Efficacy of Extracorporeal Shockwave Therapy on Pain and Function in Myofascial Pain Syndrome of the Trapezius: A Systematic Review and Meta-Analysis (2020)
- ¹⁰ Dextrose prolotherapy versus radial extracorporeal shock wave therapy in the treatment of chronic plantar fasciitis: A randomized, controlled ... (2021)
- ¹¹ Clinical effectiveness of shockwave therapy in lateral elbow tendinopathy: systematic review and meta-analysis (2021)
- ¹² Shockwave Therapy Plus Eccentric Exercises Versus Isolated Eccentric Exercises for Achilles Insertional Tendinopathy: A Double-Blinded Randomized ... (2021)
- ¹³ The efficacy and safety of extracorporeal shockwave therapy in knee osteoarthritis: A systematic review and meta-analysis (2020)
- ¹⁴ Effects of radial extracorporeal shockwave therapy on spasticity of upper-limb agonist/antagonist muscles in patients affected by stroke: a ... (2020)
- Chronic calcific tendonitis of the rotator cuff: a systematic review and meta-analysis of randomized controlled trials comparing operative and ... (2023)
- ¹⁶ Management of Muscle Spasticity in Children with Cerebral Palsy by Means of Extracorporeal Shockwave Therapy: A Systematic Review of the Literature (2021)
- ¹⁷ Short- and Intermediate-Term Results of Extracorporeal Shockwave Therapy for Noninsertional Achilles Tendinopathy (2021)
- ¹⁸ Greater trochanteric pain syndrome: focused shockwave therapy versus an ultrasound guided injection: a randomised control trial (2023)
- ¹⁹ Effect of extracorporeal shockwave therapy on muscle spasticity in patients with cerebral palsy: meta-analysis and systematic review (2019)
- ²⁰ Clinical efficacy of extracorporeal shockwave therapy for knee osteoarthritis: a systematic review and meta-regression of randomized controlled trials (2019)
- ²¹ Comparative Effectiveness of Focused Extracorporeal versus Radial Extracorporeal Shockwave Therapy for Knee Osteoarthritis-Randomized Controlled Study (2022)
- ²² Effectiveness of combined extracorporeal shock-wave therapy and hyaluronic acid injections for patients with shoulder pain due to rotator cuff ... (2022)
- ²³ Comparison of Ultrasound-Guided Prolotherapy Versus Extracorporeal Shock Wave Therapy in the Treatment of Chronic Plantar Fasciitis: A Randomized ... (2022)

- ²⁴ Erectile Dysfunction A Prospective Randomized Placebo-Controlled Study Evaluating the Effect of Low-Intensity Extracorporeal Shockwave Therapy ... (2021)

PROVEN For tendon disorders and gonarthrosis, systematic reviews and network meta-analyses pool several randomised studies; there the evidence is densest, and the statement applies to the tested protocols, not to every shock-wave application. For the urological line several randomised works are available, including sham-controlled ones, which examine low-energy protocols in diabetes, after radical prostatectomy and in treatment failure after PDE5 inhibitors; their results apply to these narrowly defined groups. A separate, unusually large block of controlled works is devoted to safety. The measurement level must be noted: most controlled works record pain and function via scales and questionnaires, thus markers, not the course of a disease.

PLAUSIBLE Mechanistic reviews and preclinical works on tendons describe biological effects; the findings come predominantly from animal and cell models and are preclinical. It could follow that part of the clinical effect is due to a tissue reaction, without this having yet been tested in humans. A meta-analysis that merges both device types and both energy ranges shows that the sum of the examined protocols points in one direction — no more.

The first point to clarify is the comparator condition: which sham treatment is appropriate for which indication, and how can blinding of the treating clinician be ensured? Second, the energy parameters: which energy density and session number are correct for a given indication, and how can devices of different construction be calibrated? Third, the course: whether future works record, alongside pain and function scales, also the course of the disease over longer periods.

6. Summary

PROVEN At the musculoskeletal system the most robust findings lie. For knee osteoarthritis a meta-analysis pools fourteen studies with 782 participants and 877 knees: pain on the visual analogue scale 1.7 cm (95 % CI 1.1 to 2.3), WOMAC 13.9 points (95 % CI 6.9 to 20.8), evidence quality moderate. For lateral epicondylopathy a meta-analysis evaluates twenty-seven studies with 1871 patients and finds, versus sham treatment, a reduced pain intensity in the medium-term course. In elbow spasticity after stroke one study showed an increase in response rate on the modified Ashworth scale under radial shock-wave therapy versus physiotherapy alone.

PLAUSIBLE The combination with eccentric training, tissue-specific stretching or heavy slow resistance training is described as effective in certain tendinopathies; in patellar tendinopathy the combination has not yet been shown. **Hypothesis:** For fracture healing a review describes a chain of mechanically transmitted steps — microfracture of the old callus, subperiosteal haematoma, release of bioactive factors, rebalancing of osteoblasts and osteoclasts, promotion of angiogenesis. If this chain is confirmed, the effect would be tied to reactivation of a tissue-repair programme; so far it has been tested predominantly mechanistically and not at controlled clinical endpoints.

Direct comparisons between low, medium and high energy density as well as an evaluation that links cartilage changes in imaging follow-up with clinical endpoints need to be clarified. The result presentation of penile rehabilitation after radical prostatectomy in the included 92 men remains open. For children with cerebral palsy a pooled evaluation of the spasticity data is pending, and for the devices a uniform reference quantity for the energy parameters must be clarified. In myofascial pain syndrome of the trapezius, head-to-head comparisons between shock-wave therapy and conventional procedures would need to be conducted.

7. What Remains Open

- **Sham treatment:** Which comparator condition is appropriate for which indication, and how can blinding of the treating clinician be ensured?
- **Energy parameters:** Which energy density and session number are correct for a given indication, and how can devices of different construction be calibrated?
- **Course:** Do future works record, alongside pain and function scales, also the course of the disease over longer periods?

Frequently Asked Questions

How does the focused shock wave differ from the radial shock wave?

Focused systems concentrate the energy at a point in the tissue, while radial systems deliver the pressure wave over a surface via an applicator. Both designs are grouped under the name ESWT, yet they differ in the physics of the pressure wave and in depth of effect. Studies that test only one design cannot be transferred directly to the other.

Why are sham-controlled studies so difficult here?

A shock wave treatment is perceptible and audible to the practitioner, so a credible sham treatment must be specially constructed. Individual studies solve this, for example the double-blind sham-controlled trial in PDE5-refractory erectile dysfunction. Where blinding is absent, the participant's expectation remains a possible explanation for part of the observed effect.

Which indications are best studied?

The evidence is densest for tendon disorders and for gonarthrosis, where systematic reviews and meta-analyses combine several randomised trials. For urological indications several randomised studies exist, albeit in narrowly defined patient groups. For metabolism, cognition, skin and oncology the number of controlled studies is smaller.

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