

# The Effectiveness of Extracorporeal Shock Wave Therapy in Lower Limb Tendinopathy

## A Systematic Review

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**Background:** There is accumulating evidence for the effectiveness of extracorporeal shock wave therapy (ESWT) when treating lower limb tendinopathies including greater trochanteric pain syndrome (GTPS), patellar tendinopathy (PT), and Achilles tendinopathy (AT).

**Purpose:** To evaluate the effectiveness of ESWT for lower limb tendinopathies.

**Study Design:** Systematic review and meta-analysis.

**Methods:** PubMed (Medline), Embase, Web of Knowledge, Cochrane, and CINAHL were searched from inception to February 2013 for studies of any design investigating the effectiveness of ESWT in GTPS, PT, and AT. Citation tracking was performed using PubMed and Google Scholar. Animal and non-English language studies were excluded. A quality assessment was performed by 2 independent reviewers, and effect size calculations were computed when sufficient data were provided.

**Results:** A total of 20 studies were identified, with 13 providing sufficient data to compute effect size calculations. The energy level, number of impulses, number of sessions, and use of a local anesthetic varied between studies. Additionally, current evidence is limited by low participant numbers and a number of methodological weaknesses including inadequate randomization. Moderate evidence indicates that ESWT is more effective than home training and corticosteroid injection in the short (<12 months) and long (>12 months) term for GTPS. Limited evidence indicates that ESWT is more effective than alternative non-operative treatments including nonsteroidal anti-inflammatory drugs, physical therapy, and an exercise program and equal to patellar tenotomy surgery in the long term for PT. Moderate evidence indicates that ESWT is more effective than eccentric loading for insertional AT and equal to eccentric loading for midportion AT in the short term. Additionally, there is moderate evidence that combining ESWT and eccentric loading in midportion AT may produce superior outcomes to eccentric loading alone.

**Conclusion:** Extracorporeal shock wave therapy is an effective intervention and should be considered for GTPS, PT, and AT particularly when other nonoperative treatments have failed.

**Keywords:** extracorporeal shock wave therapy; greater trochanteric pain syndrome; patellar tendinopathy; Achilles tendinopathy

Tendinopathies are clinically characterized by localized, painful, and tender tendon thickening, which causes a loss of function.<sup>27</sup> Lower limb tendinopathies, including greater trochanteric pain syndrome<sup>2,26</sup> (GTPS; commonly due to gluteal tendinopathy),<sup>3</sup> patellar tendinopathy<sup>15</sup> (PT), and Achilles tendinopathy<sup>16</sup> (AT), are prevalent among both athletes and sedentary patients. Tendinopathies are often difficult to treat, leading to substantial impacts on health, sporting activity, physical activity for health, and occupation.<sup>4,27</sup>

There is no agreement on the best form of management, with extracorporeal shock wave therapy (ESWT) recently being proposed as a viable treatment option for lower

limb tendinopathies with varying reports of effectiveness. Originally used for the treatment of kidney stones, ESWT is now being used for several orthopaedic conditions, with level 1a evidence recently established for the treatment of calcific rotator cuff tendinosis.<sup>12</sup> Despite this early indication of its potential benefit in treating tendinopathies, the true potential for pain reduction and improved function remains unclear.

Decision making about whether to use ESWT and the energy levels, number of treatment sessions, and number of impulses to choose is hindered by the diversity of published works. The benefits of using a local anesthetic are also disputed.<sup>14,22</sup> Considering the growing popularity of ESWT as an intervention for lower limb tendinopathies in a clinical setting, this review aimed to assess the short-term (<12 months) and long-term (>12 months) effectiveness of ESWT in treating GTPS, PT, and AT.

## MATERIALS AND METHODS

### References

A search of PubMed (Medline), Embase, Web of Knowledge, Cochrane, and CINAHL was performed in February 2013 (for search strategy details, see Appendix 1 [available in the online version of this article at <http://ajsm.sagepub.com/supplemental>]). Studies involving animals and those not available in English were excluded. No limit on the publication year was imposed. The titles and abstracts of all articles identified from this search were independently screened by 2 reviewers (S.M.-B. and C.B.) and the full texts of relevant articles retrieved for further evaluation. Article reference lists were also searched for relevant articles not identified from the search strategy, and citation tracking was performed using PubMed and Google Scholar in February 2013.

### Quality Assessment

The quality of each article was assessed independently by 2 raters (S.M.-B. and C.W.) using a modified Downs and Black checklist,<sup>6</sup> and the van Tulder criteria<sup>30</sup> were used to grade the level of evidence (Appendix 2, available online).

### Data Extraction and Analysis

The study design, population, interventions, outcome measures, and outcomes were extracted from each study. Using Review Manager,<sup>19</sup> effect sizes were calculated and presented in forest plots for individual findings, and data pooling was performed whenever possible.

## RESULTS

### Literature Search

The initial search yielded 255 articles, of which 19 were identified as relevant after screening of titles/abstracts and removal of duplicates (Figure 1). Full texts were retrieved, and 1 further article was added from searching reference lists and citation tracking.

The 20 studies included 2 evaluating ESWT in GTPS,<sup>11,24</sup> 7 in PT,<sup>10,17,29,32-35</sup> and 11 in AT.<sup>#</sup> There were 9 randomized controlled trials (RCTs),\*\* 6 single-cohort

#References 5, 7-9, 13, 18, 20, 21, 23, 25, 31.

\*\*References 5, 18, 20, 21, 23, 24, 29, 33, 35.

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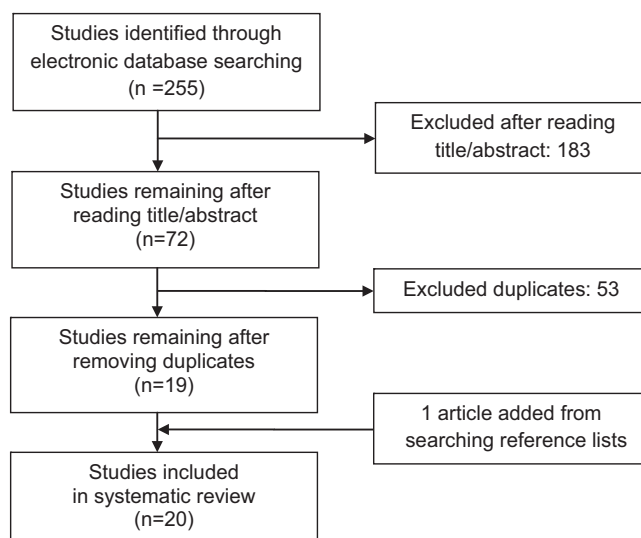
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**Figure 1.** Flow diagram of study selection.

prospective studies,<sup>7,13,25,31,32,34</sup> and 5 retrospective studies.<sup>8-11,17</sup> A summary of the characteristics of each study is shown in Table 1 and Appendix 3 (available online).

### Greater Trochanteric Pain Syndrome

Two studies<sup>11,24</sup> evaluated the effectiveness of ESWT for GTPS (Figure 2). Effect size calculations indicated that ESWT was superior to various other nonoperative treatments including rest, anti-inflammatory medication, stretching and strengthening exercises, and corticosteroid injections in reducing pain and improving function.<sup>11</sup> Additionally, ESWT produced superior outcomes to home training at 4 months.<sup>24</sup> When compared with corticosteroid injections, ESWT produced inferior outcomes at 1 month (Figure 2, A and C) but superior outcomes beyond 12 months (Figure 2, B and D) in relation to pain reduction.<sup>24</sup>

### Patellar Tendinopathy

Seven studies evaluated the effectiveness of ESWT for PT.<sup>10,17,29,32-35</sup> Four studies<sup>10,17,33,35</sup> comparing the effectiveness of ESWT to an alternative intervention for PT were included in effect size calculations (Figure 3). There was no difference in outcomes between ESWT and placebo ESWT at 1, 12, or 22 weeks in the study by Zwerver et al<sup>35</sup> (Figure 3A). In the study by Furia et al,<sup>10</sup> ESWT was

TABLE 1  
Study Design Characteristics and Main Results<sup>a</sup>

Study (Year)	Design	Intervention and ESWT Protocol	Average Length of Follow-up	Outcome Measures and Results
<b>Greater trochanteric pain syndrome</b>				
Rompe et al <sup>24</sup> (2009)	Quasi-RCT	ESWT vs corticosteroid injection vs home training 2000 impulses at 3 bar (0.12 mJ/mm <sup>2</sup> ) at 8 Hz 3 sessions (weekly interval)	15 mo	Degree of recovery (Likert scale) and VAS score at 1, 4, and 15 mo after treatment ESWT inferior to corticosteroid injection at 1 mo, significantly better than home training at 4 mo, and equal with home training and better than corticosteroid injection at 15 mo
Furia et al <sup>11</sup> (2009)	Case control	ESWT vs control (nonoperative) 2000 impulses at 4 bar (0.18 mJ/mm <sup>2</sup> ) at 10 Hz 1 session	12 mo	VAS score, Harris Hip Score, and RM score at 1, 3, and 12 mo after treatment Improvement in all outcomes for both groups; however, ESWT significantly better than control at each time point
<b>Patellar tendinopathy</b>				
Peers et al <sup>17</sup> (2003)	Retrospective cross-sectional outcome analysis	ESWT vs surgery 1000 impulses (0.08 mJ/mm <sup>2</sup> ) at 4 Hz 3 sessions (interval not specified)	ESWT: 22.1 mo (range, 17-27 mo) Surgery: 26.3 mo (range, 16-48 mo)	VAS score, VISA-P score, and RM score ESWT equal to surgery Greater working incapacity for surgical patients after treatment
Taunton et al <sup>29</sup> (2003)	RCT	ESWT vs placebo ESWT 2000 impulses (0.17 mJ/mm <sup>2</sup> ) 3-5 sessions (weekly interval)	12 wk	VISA-P score and vertical jump test Significant difference for both outcomes between groups; ESWT better than placebo ESWT
Vulpiani et al <sup>32</sup> (2007)	Prospective study	ESWT follow-up 1500-2500 impulses (0.08-0.44 mJ/mm <sup>2</sup> ) Average of 4 sessions (min, 3; max, 5) 2- to 7-day interval	>24 mo	VAS score and subjective clinical evaluation range For both outcome measures, significant differences at 1 mo after treatment as well as short (<12 mo) and long term (>24 mo) but not medium term (12 mo < x < 24 mo)
Wang et al <sup>33</sup> (2007)	Quasi-RCT	ESWT vs control (conservative treatment) 1500 impulses (0.18 mJ/mm <sup>2</sup> ) at 1-2 Hz 1 session; some received second sessions if not improving sufficiently	ESWT: 32.7 ± 10.8 mo Control: 28.6 ± 9.8 mo	VAS score, VISA-P score, and ultrasound assessment Significant reduction in VAS score and increase in VISA-P score with ESWT
Zwerver et al <sup>34</sup> (2010)	Prospective pilot study	ESWT follow-up 2000 impulses (session 1: 0.35 mJ/mm <sup>2</sup> ; session 2: 0.52 mJ/mm <sup>2</sup> ; session 3: 0.65 mJ/mm <sup>2</sup> ) at 4 Hz Weekly interval	3 mo	VAS score and VISA-P score Significant improvement for both outcome measures
Zwerver et al <sup>35</sup> (2011)	RCT	ESWT vs placebo ESWT 2000 impulses (0.1-0.58 mJ/mm <sup>2</sup> ) at 4 Hz 3 sessions (weekly interval)	22 wk	VAS score and VISA-P score No significant difference between the 2 groups; ESWT not better
Furia et al <sup>10</sup> (2013)	Case control	ESWT vs control (conservative treatment) 2000 impulses (0.18 mJ/mm <sup>2</sup> ) Single session	12 mo	VAS score, VISA-P score, and RM score Significant improvement in all outcome measures for both groups; significant difference between groups at each time point
<b>Achilles tendinopathy</b>				
Lakshmanan and O'Doherty <sup>13</sup> (2004)	Prospective study	ESWT follow-up 2000 impulses at 2.5 bar at 6-10 Hz 3 sessions (weekly interval)	20.7 mo (range, 20-22 mo)	VISA-A score and AOFAS score Significant differences in both scores after treatment
Costa et al <sup>5</sup> (2005)	RCT	ESWT vs placebo ESWT 1500 impulses (maximum, 0.2 mJ/mm <sup>2</sup> ) 3 sessions (monthly interval)	Primary outcome at 3 mo	VAS score, Functional Index of Lower Limb Activity, and EQoL score No significant differences between groups
Furia <sup>9</sup> (2006)	Case control	ESWT vs control 3000 impulses for a total energy flux density of 604 mJ/mm <sup>2</sup> ; 50 shocks were given at each power level from 1-4 for a total of 200 shocks; the final 2800 shocks were given at power level 5, which corresponds to 0.21 mJ/mm <sup>2</sup> 1 session	12 mo	VAS score and RM score at 1, 3, and 12 mo after treatment Significant improvement in VAS and RM scores at all time points for ESWT when compared with baseline At each time point, improvement in VAS score was less in local anesthetic group compared with nonlocal anesthetic group Significant difference for RM score between groups, favoring ESWT
Rompe et al <sup>23</sup> (2007)	RCT	Eccentric loading vs ESWT vs wait-and-see 2000 impulses at 3 bar (0.1 mJ/mm <sup>2</sup> ) at 8 Hz 3 sessions (weekly interval)	4 mo	VISA-A score, general assessment, and pain assessment Significant differences for ESWT and eccentric loading for VISA-A score, general assessment, and pain assessment but no difference between treatments ESWT and eccentric loading better than wait-and-see policy

continued

TABLE 1  
(continued)

Study (Year)	Design	Intervention and ESWT Protocol	Average Length of Follow-up	Outcome Measures and Results
Furia <sup>8</sup> (2008)	Case control	ESWT vs control Ankle block with or without sedation 3000 impulses for a total energy flux density of 604 mJ/mm <sup>2</sup> ; 50 shocks were given at each power level from 1-4 for a total of 200 shocks; the final 2800 shocks were given at power level 5, which corresponds to 0.21 mJ/mm <sup>2</sup> 1 session	12 mo	VAS score and RM score at 1, 3, and 12 mo after treatment Significant differences in VAS and RM scores at all time points for ESWT Significant differences between groups for VAS and RM scores at all time points
Rompe et al <sup>20</sup> (2008)	RCT	Eccentric loading vs ESWT 2000 impulses at 2.5 bar (0.12 mJ/mm <sup>2</sup> ) at 8 Hz 3 sessions (weekly interval)	4 mo	VISA-A score, general assessment, and pain assessment Improvement in all 3 outcomes for both groups; however, ESWT significantly better than eccentric loading
Rasmussen et al <sup>18</sup> (2008)	RCT	ESWT vs placebo ESWT 2000 impulses (0.12-0.51 mJ/mm <sup>2</sup> ) at 50 Hz 4 sessions 1-2 weeks between sessions	3 mo	VAS score and AOFAS score Improvement in AOFAS score in both groups; significant differences between groups; ESWT better VAS score reduced in both groups; no difference between groups
Fridman et al <sup>7</sup> (2008)	Prospective study	ESWT follow-up Under intravenous sedation and local anesthesia 2000 impulses (21 kV) at 2 Hz 1 session	20 mo (range, 4-35 mo)	VAS score, improved condition, patient satisfaction, and willingness to repeat procedure Significant reduction in VAS score for morning pain as well as activity pain 4 mo after ESWT
Rompe et al <sup>21</sup> (2009)	RCT	Eccentric loading vs eccentric loading + ESWT 2000 impulses at 3 bar (0.1 mJ/mm <sup>2</sup> ) at 8 Hz 3 sessions (weekly interval)	4 mo	VISA-A score, general assessment, and pain assessment Improvement in all 3 outcome measures for both groups Significant differences between groups for all 3 outcome measures, favoring combined treatment
Vulpiani et al <sup>31</sup> (2009)	Prospective study	ESWT follow-up 1500-2500 impulses (midportion: 0.08-0.33 mJ/mm <sup>2</sup> ; insertional: 0.12-0.40 mJ/mm <sup>2</sup> ) Average of 4 sessions (between 3-5) 2- to 7-day interval	24 mo	VAS score, subjective clinical evaluation range Significant improvement in outcome measures over short (2 mo) and medium term (6-12 mo)
Saxena et al <sup>25</sup> (2011)	Prospective study	ESWT follow-up 2500 impulses at 2.4 bar at 11-13 Hz 3 sessions 4- to 10-day interval	12-24 mo	RM score Significant improvement in score for proximal, insertional, and paratendinosis

<sup>a</sup>For the ESWT protocol, the number of impulses, the energy level (in bar, mJ/mm<sup>2</sup>, or kV), the frequency of impulses (in Hz), the number of sessions, and the interval between sessions are reported if stated in the study. AOFAS, American Orthopaedic Foot and Ankle Society; EQoL, Euro Quality of Life; ESWT, extra-corporeal shock wave therapy; RCT, randomized controlled trial; RM, Roles and Maudsley; VAS, visual analog scale; VISA-A, Victorian Institute of Sport Assessment Questionnaire–Achilles; VISA-P, Victorian Institute of Sport Assessment Questionnaire–Patellar.

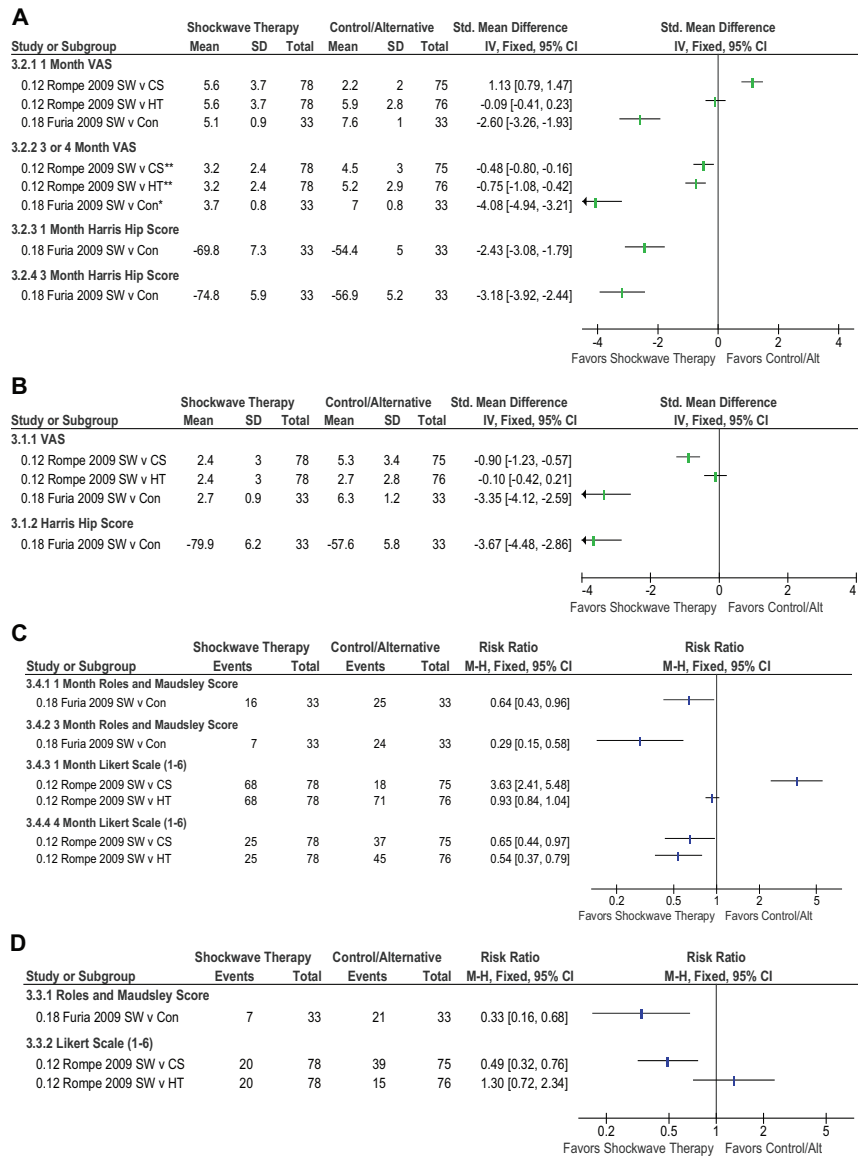
superior to alternative nonoperative treatments at 1, 3, and 12 months. Two studies, which examined the effect of ESWT beyond 24 months, showed ESWT to be comparable with patellar tenotomy surgery and better than nonoperative treatments including nonsteroidal anti-inflammatory drugs, physical therapy, an exercise program, use of a knee strap, and modification of activity levels in reducing pain and improving function<sup>17,33</sup> (Figure 3, B and C).

### Achilles Tendinopathy

Eleven studies evaluated the effectiveness of ESWT for AT.<sup>††</sup> Four studies concerned patients with midportion tendinopathy,<sup>8,13,21,23</sup> 2 concerned patients with insertional tendinopathy,<sup>9,20</sup> and 5 included both.<sup>5,7,18,25,31</sup> Seven

studies<sup>5,8,9,18,20,21,23</sup> compared the effectiveness of ESWT to an alternative intervention (Figure 4). Effect size calculations indicated that ESWT produces greater short-term (<12 months) (Figure 4, A and C) and long-term (>12 months) (Figure 4, B and D) improvements in pain and function compared with nonoperative treatments including rest, footwear modification, anti-inflammatory medication, and gastrocnemius-soleus stretching and strengthening, with the exception being a short-term RCT by Costa et al,<sup>5</sup> which indicated no difference. Short-term studies by Rompe et al,<sup>20,21,23</sup> where primary outcomes were measured at 4 months, indicated similar outcomes between ESWT and eccentric loading in midportion AT (tendinopathy 2 to 6 cm from the insertion into the calcaneus) and superior outcomes to eccentric loading in insertional AT (tendinopathy up to 2 cm from the insertion into the calcaneus). Combining ESWT and eccentric loading in

<sup>††</sup>References 5, 7-9, 13, 18, 20, 21, 23, 25, 31.



**Figure 2.** Greater trochanteric pain syndrome: Comparison of (A) VAS score for pain (10-point rating scale) and Harris Hip Score (hip function) at <12 months, (B) VAS score and Harris Hip Score at >12 months, (C) successful outcomes at <12 months, and (D) successful outcomes at >12 months. Alt, alternative treatment; Con, conservative treatment; CS, corticosteroid injection; HT, home training; SW, extracorporeal shock wave therapy; VAS, visual analog scale. \*3 months. \*\*4 months.

midportion AT produced greater improvement in pain and function compared with eccentric loading alone (Figure 4A).<sup>21</sup>

**DISCUSSION**

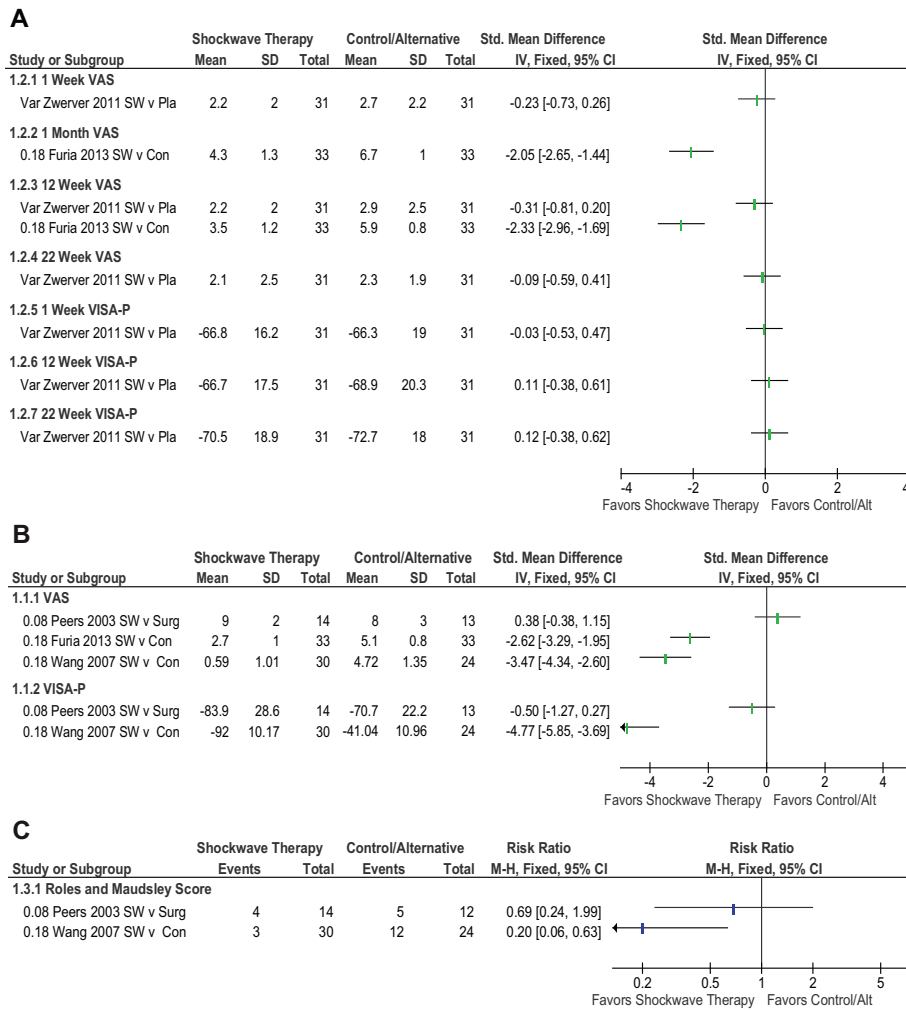
The aims of this review were to assess the effectiveness of ESWT for 3 lower limb tendinopathies.

**Greater Trochanteric Pain Syndrome**

From the results of the high-quality study by Furia et al,<sup>11</sup> there is moderate evidence that ESWT may be more

effective than nonoperative treatments including rest, anti-inflammatory medication, stretching and strengthening exercises, and corticosteroid injections in the short- and long-term management of GTPS. When ESWT was compared with a home training regimen, there was moderate evidence that it was as effective at 1 and 15 months in relieving pain and improving function, but effectiveness was better at 4 months.<sup>24</sup> In the same study, Rompe et al<sup>24</sup> provided moderate evidence that ESWT was less effective than corticosteroid injections at 1 month, but with time, it became more effective at 4 and 15 months after intervention. Moreover, ESWT had a 74% success rate at 15 months compared with 35% for the injection.





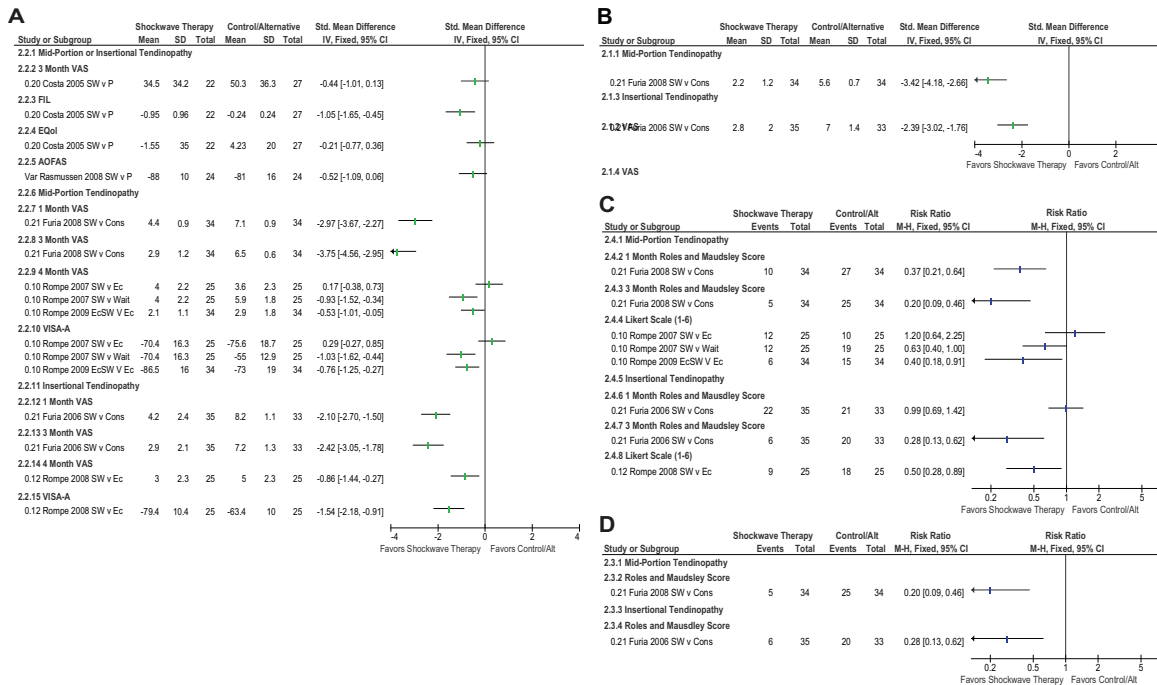
**Figure 3.** Patellar tendinopathy: (A) Comparison between ESWT and placebo using the VAS score (pain rating scale) and VISA-P score (questionnaire assessing symptoms, function, and ability to participate in sport; maximum score = 100) at <12 months. (B) Comparison of ESWT and surgery and usual conservative care using the VAS and VISA-P scores at >12 months. (C) Comparison of successful outcomes at >12 months. Alt, alternative treatment; Con, conservative treatment including nonsteroidal anti-inflammatory drugs, physical therapy, an exercise program, use of a knee strap, and modification of activity levels; Pla, placebo ESWT; Surg, surgery; SW, extracorporeal shock wave therapy; Var, variable energy level from 0.10-0.58 mJ/mm<sup>2</sup>; VAS, visual analog scale; VISA-P, Victorian Institute of Sport Assessment Questionnaire-Patellar.

These results indicate that ESWT is a viable short- and long-term treatment option for GTPS and may be used as an alternative to home training and corticosteroid injections.

### Patellar Tendinopathy

The 5 studies presenting evidence of the short-term effectiveness of ESWT consisted of 2 RCTs,<sup>29,35</sup> 2 prospective studies,<sup>32,34</sup> and 1 retrospective study.<sup>10</sup> Taunton et al<sup>29</sup> noted significantly greater improvements with ESWT compared with sham ESWT, with an 8-point difference in the Victorian Institute of Sport Assessment Questionnaire-Achilles/Patellar (VISA-A/P) score and a 1.5-inch difference in the vertical jump test score between groups. In comparison, Zwerver et al<sup>35</sup> found no difference in VISA-P or visual

analog scale (VAS) scores between treatment groups. The vertical jump test, a functional test used for assessing the impairment of tendinopathy, is one of the few objective outcomes found by this review, highlighting the need for a greater emphasis on objective outcome measures in future research evaluating the effectiveness of ESWT. Zwerver et al<sup>34</sup> and Vulpiani et al<sup>32</sup> conducted prospective studies that both demonstrated clinically significant short-term improvements in pain and function, noted by a 3-cm reduction in the VAS score and a 14-point increase in the VISA-P score. The retrospective study by Furia et al<sup>10</sup> showed that ESWT produced a clinically significant improvement in the VAS and VISA-P scores at 1 and 3 months in comparison to alternative nonoperative treatments, which did not. Overall, these results show that ESWT may be an effective intervention in the short term for PT.



**Figure 4.** Achilles tendinopathy: Comparison of (A) pain and functional outcomes at <12 months, (B) pain outcomes at >12 months, (C) successful outcomes at <12 months, and (D) successful outcomes at >12 months. Alt, alternative treatment; AOFAS, American Orthopaedic Foot and Ankle Society; Cons, conservative treatment; Ec, eccentric loading; EcSW, combined extracorporeal shock wave therapy and eccentric loading; EQoL, Euro Quality of Life; FIL, Functional Index of Lower Limb Activity; P, placebo; SW, extracorporeal shock wave therapy; Var, variable energy level from 0.12-0.51 mJ/mm<sup>2</sup>; VAS, visual analog scale; VISA-A, Victorian Institute of Sport Assessment Questionnaire–Achilles (questionnaire assessing severity of Achilles tendinopathy); Wait, wait-and-see policy.

The results from Vulpiani et al<sup>32</sup> indicated that ESWT was effective at reducing pain in the long term for PT, with a satisfactory result in 68.8% of cases. However, it is unclear whether the improvements were purely as a result of ESWT, as there was no documentation of co-interventions. The long-term results from the study by Furia et al<sup>10</sup> mirrored the short-term results, with clinically significant changes in the VAS and VISA-P scores. There is some evidence that ESWT is a more effective long-term intervention than nonoperative treatments and as effective as surgery for PT. Wang et al<sup>33</sup> showed that patients treated with ESWT had clinically significant improvements in the VAS and VISA-P scores after 12 months compared with patients who received a combination of anti-inflammatory medication, physical therapy, and an exercise intervention. However, ESWT treatment was not standardized, as 3 patients whose response was deemed inadequate after a single treatment received an additional ESWT treatment session. Peers et al<sup>17</sup> showed ESWT to be comparable with patellar tenotomy surgery in improving pain and function, providing an equivalent successful outcome score in the long term. This would indicate that ESWT may be a viable alternative to surgery for long-term sufferers of PT.

Even though these studies indicate that ESWT may be a promising short- and long-term treatment option for

treating PT, the majority of evidence is limited. Further research with a more robust study design will help to identify the true effectiveness of ESWT for patients with PT.

### Achilles Tendinopathy

There is conflicting evidence for the effectiveness of ESWT in comparison to sham ESWT for AT. Costa et al<sup>5</sup> found no difference in pain or function between patients treated with ESWT or sham ESWT. However, an important potential confounding factor is that the average age of patients in the ESWT group was 10 years older than those in the sham ESWT group. Considering that increasing age is associated with lower tendon healing rates,<sup>28</sup> the absence of a difference between groups may be explained. Conversely, Rasmussen et al,<sup>18</sup> who used the same intervention treatments as Costa et al<sup>5</sup> but used a higher energy level and an extra treatment session, found that patients in the group treated with ESWT improved their American Orthopaedic Foot and Ankle Society score to a significantly greater extent than those in the sham group, with an increase of 18 points in the ESWT group and 7 points in the sham group. These findings were reported at 3 months, suggesting that ESWT may be an effective short-term intervention.

Eccentric loading is considered the gold-standard nonoperative treatment for midportion AT.<sup>1</sup> However, moderate

evidence exists to suggest that ESWT may be a more effective short-term intervention than eccentric loading for insertional tendinopathy and equal to eccentric loading in midportion AT. Furthermore, RCTs conducted by Rompe et al<sup>20,23</sup> showed that ESWT was effective at relieving pain and improving function in both midportion and insertional AT. In addition, when combining ESWT and eccentric loading, patients with midportion AT showed a significantly greater improvement in pain and function than with eccentric loading alone, reporting a difference of 1.5 cm in the VAS score and 14 points in the VISA-A score.<sup>21</sup> Further research is needed to confirm this finding; however, these results indicate that combining ESWT and eccentric loading should be considered in clinical practice, particularly if a patient is slow to respond to eccentric loading.

There is limited evidence for the effectiveness of ESWT in comparison to other nonoperative interventions for the treatment of AT. Retrospective studies by Furia<sup>8,9</sup> showed ESWT to be significantly better at relieving pain in both insertional and midportion AT and improving outcomes, as assessed by the Roles and Maudsley score, than other nonoperative therapies including rest, footwear modification, anti-inflammatory medication, and gastrocnemius-soleus stretching and strengthening. Also for patients with insertional AT,<sup>9</sup> the pain-reducing effect of ESWT was diminished when a local anesthetic was administered before treatment. Further studies examining the effect of anesthetics on the outcomes of ESWT are needed to build upon this finding. Altogether, these short-term results show that ESWT can be beneficial for both midportion and insertional AT.

The 6 studies looking at long-term ESWT effects included 2 retrospective<sup>8,9</sup> and 4 prospective studies.<sup>7,13,25,31</sup> Furia<sup>8,9</sup> showed that the differences in pain and functional outcomes between the patient groups receiving ESWT and other nonoperative therapies were similar at 3 months. The 4 low-quality prospective studies by Lakshmanan and O'Doherty,<sup>13</sup> Fridman et al,<sup>7</sup> Vulpiani et al,<sup>31</sup> and Saxena et al<sup>25</sup> all reported patient improvements in pain and function after ESWT treatment. Hence, ESWT may also be considered a suitable long-term intervention for AT.

Overall, the results indicate ESWT to be an effective short-term intervention for both midportion and insertional AT and that it can be used as an alternative to other nonoperative forms of management in clinical practice. However, RCTs with longer term follow-ups are needed to build upon the evidence for long-term AT management.

### Quality Assessment

Scores from the Downs and Black quality index<sup>6</sup> ranged from 9 to 26 (of a maximum score of 28) (Appendix 3). Ten studies were classified as high quality. The primary differences between low- and high-quality studies included the following: the absence of a control group, meaning that it was difficult to say whether it was solely the intervention that led to the observed results<sup>7,13,25,31,32,34</sup>, informal randomization, which increased the risk of selection bias<sup>24,33</sup>, and the difficulty in identifying whether patients were representative of the population or whether the treatment was

representative of what patients are normally offered.<sup>††</sup> In addition, as there was a great degree of heterogeneity in the protocols used (energy level of treatment, number of impulses, and number of treatment sessions as well as number of days between treatment sessions), it was difficult to directly compare the results of different studies.

For a number of studies, the outcome measures used were not specific to the condition, unlike the VISA-A/P, which focus on the clinical severity of AT and PT, respectively. The validity of the results to translate to clinical practice from these studies may therefore be questioned.<sup>5,11,18,24</sup> A few studies used suboptimal statistical tests; therefore, the results of these studies may not be accurate and indeed misleading.<sup>7,29</sup>

### Clinical Relevance

From analysis of the higher quality studies, it is evident that ESWT can play a role in the treatment of patients with lower limb tendinopathies alongside progressive loading and flexibility management. Both forms of treatment serve to induce tendon regeneration, with rehabilitation exercises tending to be carried out over a period of many weeks, whereas ESWT treatment is typically administered weekly for 3 weeks. A suitable pathway may be using ESWT early in the treatment phase, alongside a progressive loading program, based on some evidence that this combination confers additional benefits.<sup>21</sup> Hence, it is also important for clinicians to be aware of combining treatment modalities when a patient presents with a tendinopathy.

### Future Directions

From this systematic review, it is evident that there are enough high-quality studies evaluating the effectiveness of ESWT for lower limb tendinopathies to make initial level 1 recommendations. Further, the evidence allows us to suggest key areas for further work. More robust RCTs with larger sample sizes and control groups that include objective functional tests are needed to build upon the limited/moderate evidence that currently exists for ESWT's effectiveness in lower limb tendinopathies. Additionally, further RCTs specifically comparing the different elements of ESWT, energy levels, number of applications, and number of days between applications, are needed to identify the optimum protocol. Work on mechanisms underpinning observed effects is warranted.

### CONCLUSION

Extracorporeal shock wave therapy appears to be an effective intervention for lower limb tendinopathies, with moderate-level evidence of efficacy for all 3 tendinopathies reviewed. Further, ESWT seems to be a suitable alternative to home training and corticosteroid injection in the short- and long-term management of GTPS. For PT, ESWT seems to be superior to other nonoperative

††References 5, 7, 8, 10, 13, 20, 21, 25, 29, 31-34.



treatments and equal to surgery in the long term. For AT, the results suggest that ESWT is superior to eccentric loading in the short term for insertional tendinopathy, effective when combined with eccentric loading in midportion tendinopathy, and superior to various alternative non-operative treatments, particularly in recalcitrant presentations.

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