ASMAR Special Issue: Injury Prevention and Rehabilitation

Extracorporeal Shockwave Therapy Is Associated With Similar Functional Outcomes for Male and Female Runners With Patellar or Quadriceps Tendinopathy: A Pilot Investigation

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Purpose: To characterize functional outcomes in runners with patellar tendinopathy (PT) and quadriceps tendinopathy (QT) following extracorporeal shockwave therapy (ESWT) and explore differences in response by tendinopathy (PT or QT) and by sex (female or male). **Methods:** This is a retrospective cohort study of runners with PT or QT treated with ESWT (radial or combined radial and focused) at a single sports medicine clinic during a 5-year period. Individuals were included if they had a primary diagnosis of PT or QT, self-identified as a runner, and had complete baseline and final functional outcome questionnaires for ESWT with treatment duration defined by response based on best practices. Functional outcome at baseline and following treatment were assessed using the Victorian Institute of Sport Assessment—Patellar Tendon questionnaires. Treatment success was defined as meeting the minimal clinically important difference (MCID) of $\geq$13 points. **Results:** Of the 19 runners included, 26% identified as female and 74% as male; all runners identified as cisgendered. There were 12 runners with PT (17% female, 83% male) and 7 with QT (43% female, 57% male). Median follow-up was 3.0 months (range, 1.0-23.0; interquartile range, 3.0-6.0). Of all runners, 67% with PT and 71% with QT achieved MCID with no significant difference between tendinopathy groups ($P = .90$). There was also no difference in the percentage that achieved MCID between sexes, with 80% of women and 64% of men meeting MCID ($P = .72$). **Conclusions:** Similar functional outcomes were observed in female and male runners with QT or PT following radial and combined ESWT, with most achieving MCID. This study suggests that ESWT, in combination with physical therapy, may be an effective treatment for runners with PT or QT and that ESWT could be considered for PT or QT refractory to physical therapy. **Level of Evidence:** Level IV, retrospective case series.

The knee has been reported to be the most common lower extremity pain generator for runners, and tendinopathies are a frequent cause.[1-3] Patellar tendinopathy (PT) was found to be the second most common injury in female runners and the third most common injury in male runners, accounting for 12.3% of running-related injuries overall.[3] The frequency of quadriceps tendinopathy (QT) in runners has not been well characterized, although it has been found to be less common than PT in athletes of a variety sports.[4] Anterior knee pain caused by PT and/or QT is commonly referred to as "jumper's knee,"[5] and these tendinopathies are often assessed together. However, clinically, these tendinopathies are distinguishable. PT presents as focal pain at the inferior pole of the patella, while QT presents with pain at the superior pole of the patella.[6,7] Since PT alone or in combination with QT has been more extensively researched than QT alone, these tendinopathies are often both treated with rehabilitation programs designed for PT.[6,8,9]

Sex differences have been established for these tendinopathies. When assessed together, PT and QT are more common in male than female nonelite athletes (10.2% and 6.4%, respectively)[10] and elite athletes (13.5% and

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Received July 1, 2024; accepted August 21, 2024.

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2666-061X/241064

https://doi.org/10.1016/j.asmr.2024.101024

5.6%, respectively).[4] Moreover, a significant difference was found between the frequency of male (57%) compared to female (43%) runners who experienced PT ($P < .05$).[2] Despite known differences, current literature and clinical practice favor the same management between sexes, with initial treatment being nonoperative. Patients are recommended activity modification, nonsteroidal anti-inflammatory drugs, and physical therapy with eccentric strengthening exercises.[11,12]

Extracorporeal shockwave therapy (ESWT) is nonoperative treatment effective for knee extensor tendinopathy.[13,14] ESWT improves pain and function in both PT and QT assessed together and PT alone, with success rates ranging from 73.5% to 87.5%.[14] This therapy involves the application of energy, which differs by type of EWST used (radial vs focused) and elicits various physiological and biological healing responses.[15-20] Radial ESWT (R-SWT) involves lower energy pressure waves produced by a pneumatic/ballistic device while focused ESWT (F-SWT) creates a higher amplitude and energy waves from electromagnetic, hydraulic, and piezoelectric devices.[21] R-SWT exerts its greatest pressure at the skin surface while F-SWT exerts maximal force at a selected depth.[22] There are limited data on the use of combined radial and focused ESWT (C-SWT) for tendinopathies and a paucity of data assessing C-SWT for PT and R-SWT, F-SWT, or C-SWT for QT in runners.[23-27]

The purpose of this study is to characterize the functional outcomes in runners with PT and QT following ESWT (R-SWT or C-SWT) with duration defined by response based on best practices and explore differences in response by tendinopathy (PT or QT) and by sex (female or male). We hypothesize that ESWT will be associated with functional outcomes in male and female runners with PT or QT with no significant difference between tendinopathies or sexes.

Methods

Participants

Runners were identified using chart review for those who presented to an outpatient physical medicine and rehabilitation sports medicine clinic and were treated with ESWT between August 2017 and December 2021. Inclusion criteria were (1) a primary diagnosis of PT or QT, (2) self-identification as a current runner, and (3) a completed initial functional outcome questionnaire and a final questionnaire. Participants were excluded if they (1) had primary diagnoses of both PT and QT, (2) received ESWT for multiple primary lower extremity conditions simultaneously, (3) had an additional primary lower extremity injury at the time of treatment for PT or QT, (4) had a prior surgery to the patellar or quadriceps tendon, or (5) had concomitant underlying inflammatory or connective tissue disease.

Intervention

ESWT was offered as a therapeutic modality for individuals presenting with knee pain and diagnosed with patellar and/or quadriceps tendinopathy that was limiting the desired level of activity. R-SWT treatment was performed using the Storz Extracorporeal Pulse Activation Technology device and F-SWT with the Storz Duolith device (Storz Medical). For R-SWT, a minimum of 3,000 shocks was delivered at 15 Hz with pressure ranging from 1.8 to 4.5 bar. For F-SWT used in C-SWT, a minimum of 1,000 shocks were delivered with energy flux density ranging from 0.07 to 0.22 mJ/mm^2. Therapy was applied to the pathologic tendon (quadriceps or patellar) and focused at anatomic sites of increased pain during ESWT treatment. Three to four weekly sessions were performed with follow-up typically at 3 months following treatment. Further shockwave sessions were provided depending on response based on best practices.[28] No topical or systemic anesthetic was used during treatment. Participants were counseled to refrain from taking nonsteroidal anti-inflammatory medications during duration of ESWT treatment series to prevent disruption of the inflammatory cascade stimulated by ESWT that may contribute to healing.[29] Determination of whether participants received R-SWT, F-SWT, or C-SWT and amount was at the discretion of 1 sports medicine physician (A.S.T.), and decisions were made based on clinical course. All participants were prescribed physical therapy to perform during the duration of ESWT treatment and were allowed to continue running as long as pain remained below 5 out of 10 on the visual analog scale.

Data Collection

Chart review identified all runners diagnosed and treated for PT or QT using ESWT by 1 sports medicine physician (A.S.T.) based on history and physical examination. Imaging (X-rays, sonographic, magnetic resonance imaging, computed tomography scan) was obtained as clinically indicated to exclude alternative pathology. Data collected included demographics, treatment protocols, and functional outcome survey scores. Functional outcomes were assessed by Victorian Institute of Sport Assessment—Patellar Tendon (VISA-P) questionnaires prior to ESWT (initial) and at the conclusion of participants' treatment (final). This questionnaire was designed to assess severity of symptoms in participants with "jumper's knee," defined as patellar tendinosis.[30] It includes 8 questions that evaluate participants' abilities to perform routine activities (siting, walking) and exercises with increased demand on the knee (lunging, squatting, single-leg hoping), as well as if/how their pain prevents them from participating in their sport.[30] The maximum score for an asymptomatic participant would be 100 points, and the minimum score for the most severely symptomatic

participant would be 0 points. VISA-P questionnaires were completed by each participant prior to initiation of ESWT (initial) and at the end of the treatment (final). A change in VISA-P score (final − initial) of 13 points was used to determine the minimal clinically important difference (MCID).[31]

Outcome Measures

Tendinopathy. Differences in response to ESWT between runners with PT or QT were assessed. Outcome measures compared between these 2 groups included percentage of runners who achieved MCID, change in VISA-P scores, and the number and type of ESWT sessions.

Sex. In this work, sex is defined by biology of an individual, whereas gender is defined by each individual based on how he/she/they identify. Differences in response to ESWT between female runners and male runners were assessed. Outcome measures compared between these 2 groups included percentage of runners who achieved MCID, change in VISA-P scores, and the number and type of ESWT sessions.

Statistical Analysis

For continuous data, means and standard deviations or median and interquartile range were presented. For categorical data, descriptive statistics were presented. The χ^2 tests, unpaired 2-tailed Student t tests, and Wilcoxon rank-sum tests were used to assess the statistical significance of differences between groups with statistical significance set at $P < .05$.

The data that support the findings of this study are available upon request from the corresponding author.

Institution approval was received for this quality improvement initiative, and institutional review board approval was waived.

Results

Participant Demographics

There were 19 total runners (26% female, n = 5; 74% male, n = 14) with age 34 ± 13 years. All runners were cisgendered. The PT cohort included 12 runners (17% female, n = 2; 83% male, n = 10), and the QT cohort included 7 runners (43% female, n = 3; 57% male, n = 4; Fig 1, Table 1). Runners had experienced anterior knee pain from QT or PT for a median of 13

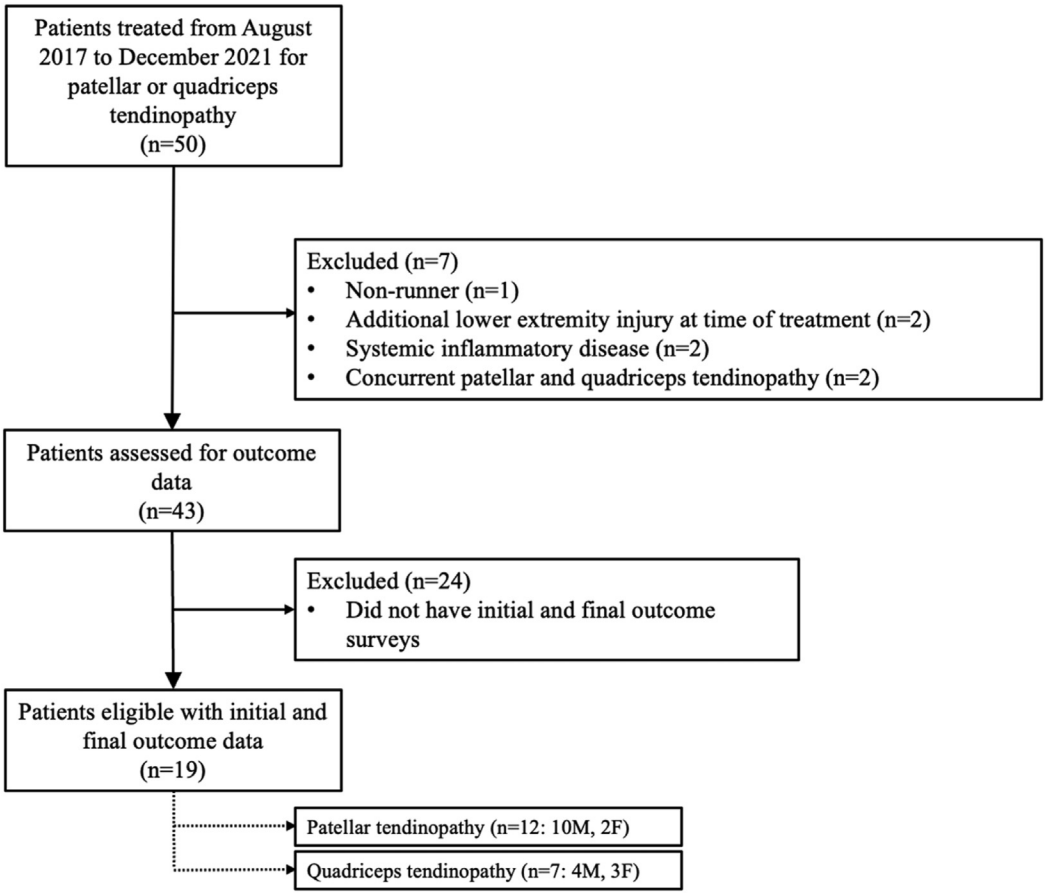

Fig 1. CONSORT diagram for male and female runners with patellar or quadriceps tendinopathy.

Table 1. Demographics and Clinical Characteristics

	Runners		
Characteristic	PT (n = 12)	QT (n = 7)	Total (n = 19)
Female, n (%)	2 (17)	3 (43)	5 (26)
Male, n (%)	10 (83)	4 (57)	14 (74)
Age, mean ± SD, y	33 ± 13	37 ± 13	34 ± 13
Symptom duration before ESWT, median (IQR), mo	15 (12, 62)	12 (10, 14)	13 (12, 22)
Physical therapy prior to ESWT, n (%)	12 (63)	4 (21)	16 (84)
Tendinopathy laterality			
Left, n (%)	4 (33)	1 (14)	5 (26)
Right, n (%)	1 (8)	2 (29)	3 (16)
Bilateral, n (%)	7 (58)	4 (57)	11 (58)

ESWT, extracorporeal shockwave therapy; IQR, interquartile range; PT, patellar tendinopathy; QT, quadriceps tendinopathy.

months (interquartile range [IQR], 12, 22), and 84% had participated in physical therapy prior to ESWT intervention (Table 1). Participants were followed for a median of 3.0 months (range, 1.0-23.0; IQR, 3.0, 6.0; Table 3).

Tendinopathy Comparison

For runners with PT and QT, 67% and 71% achieved MCID, respectively. There was no significant difference in the percentage achieving MCID between groups ($P = .90$; Table 2). For PT, the initial and final VISA-P scores were 42 ± 18 points and 64 ± 14 points, respectively, with a change in VISA-P of 21 ± 18 (Fig 2). For QT, initial and final VISA-P scores were 41 ± 21 points and 60 ± 30 points, respectively, with a change in VISA-P of 20 ± 12 points (Fig 2). There was no significant difference in overall change in VISA-P between PT and QT groups ($P = .81$; Fig 2). Runners with PT or QT received a similar amount of ESWT sessions (5.3 ± 1.8 and 5.4 ± 2.7, respectively, $P = .86$). There was also no significant difference in type of ESWT received between PT and QT groups (R-SWT: $P = .97$, C-SWT: $P = .97$; Table 3).

Sex Comparison

Eighty percent of females and 64% of males met MCID. There was no significant difference in the percentage achieving MCID between groups ($P = .72$; Table 2). Overall, female and male runners received an average of 6.4 ± 3.0 and 4.9 ± 1.6 ESWT sessions, respectively. Female runners with PT or QT compared to male runners with PT or QT received a similar amount of ESWT sessions ($P = .19$) and similar types of ESWT (R-SWT: $P = .47$, C-SWT: $P = .54$; Table 3).

Discussion

In this study, the majority of both female and male runners with PT and QT achieved MCID (Table 2). Additionally, there was no significant difference in the number of ESWT sessions clinically indicated between groups (Table 3). These findings are consistent with existing literature and further support ESWT as an effective noninvasive treatment for PT[13] and suggest that runners with QT may experience similar functional benefits with ESWT. Notably, our reporting of C-SWT, which includes both R-SWT and F-SWT, for PT and QT in runners introduces a therapeutic modality that warrants further exploration in this population.

This work advances the limited literature on ESWT for runners with anterior knee pain due to PT. In this study, runners with chronic PT had an average VISA-P increase of 21 points over 4.0 ± 2.4 months after an average of 5.3 ± 1.8 ESWT sessions (58% R-SWT, 42% C-SWT; Fig 2, Table 3). Similarly, Furia and colleagues[32] found that patients with chronic PT achieved a mean VISA-P score increase of 15.5 points at 1 month, 21.5 points at 3 months, and 25 points at 1 year after 1 session of R-SWT (2,000 impulses, 4 bars). While patients in this study received F-SWT in combination with R-SWT, great variability has been reported for outcomes following F-SWT alone. Zwerver and colleagues[33] observed that male athletes with chronic PT achieved a mean VISA-P score increase of 14 points over 12 weeks after 3 sessions of F-SWT (2,000 impulses, 0.35-0.65 mJ/mm^2 energy flux density), and Wang and colleagues[34] illustrated that patients with chronic PT achieved a 49.43-point improvement in VISA-P after 12 months after an average of 1 session (3 of 30 patients received a second treatment session) of F-SWT (1,500 impulses, 0.18 mJ/mm^2 energy flux density). Thijs and colleagues[35] found that patients with PT achieved a mean VISA-P score increase of 16.4 points over 24 weeks after 3 sessions of F-SWT (1,000 impulses of 4 Hz, 0.2 mJ/mm^2 energy flux density) paired with eccentric strengthening, but this increase did not differ significantly from that observed in a cohort that received sham F-SWT and eccentric strengthening. This

Table 2. Proportion of Female and Male Runners With Patellar or Quadriceps Tendinopathy Achieving Minimal Clinically Important Difference

Patient Groups	Achieved MCID, n (%)
PT female and male	8 (67)
QT female and male	5 (71)
PT female	2 (100)
PT male	6 (60)
QT female	2 (67)
QT male	3 (75)
Female PT and QT	4 (80)
Male PT and QT	9 (64)

NOTE. MCID indicates 13-point improvement between initial and final Victorian Institute of Sport—Patellar Tendon score. All $P > .60$: PT vs QT, PT_F vs PT_M, QT_F vs QT_M, PT_F vs QT_F, PT_M vs QT_M.

MCID, minimal clinically important difference; PT, patellar tendinopathy; QT, quadriceps tendinopathy.

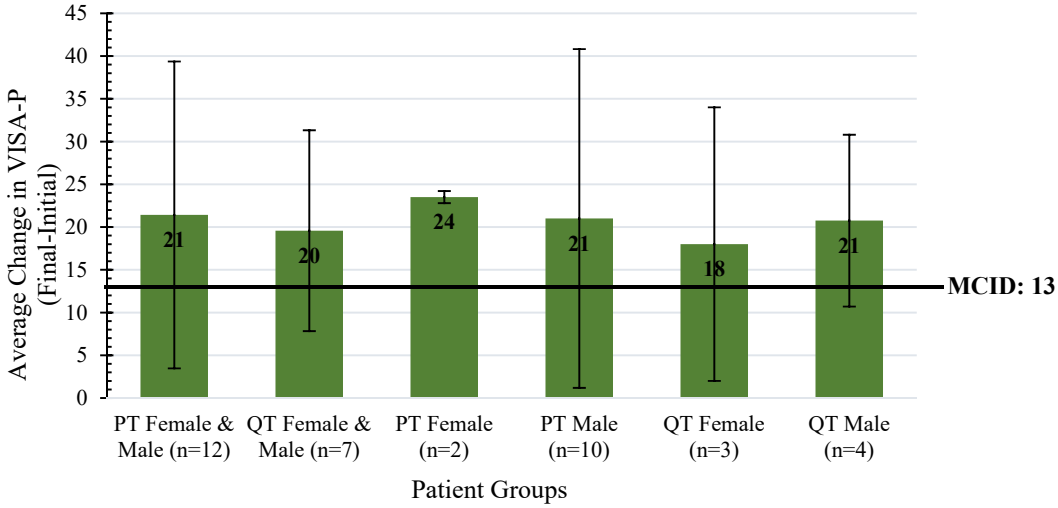

Fig 2. Change in Victorian Institute of Sport—Patellar Tendon for male and female runners with patellar or quadriceps tendinopathy. MCID represents a 13-point difference between initial and final Victorian Institute of Sport—Patellar Tendon score. All $P > .6$: PT vs QT, PT_F vs PT_M, QT_F vs QT_M, PT_F vs QT_F, PT_M vs QT_M. (PT, patellar tendinopathy; QT, quadriceps tendinopathy.)

variability highlights the need for additional research to establish optimized standardized protocols.

This study contributes to our understanding of the utility of R-SWT or C-SWT for QT in runners. We found that runners with chronic QT had an average VISA-P increase of 20 points over 7.1 ± 7.3 months after an average of 5.4 ± 2.7 ESWT sessions (57% R-SWT, 43% C-SWT; Fig 2, Table 3). Vulpiani and colleagues[36] assessed the benefit of F-SWT in a mixed population of athletes with PT (78.3%) and QT (21.7%) and found that after 3 to 5 sessions of F-SWT (1,500-2,500 pulses, 0.08-0.44 mJ/mm^2), there was an overall benefit with significant improvement in visual analog scale pain scores after 1 month, 12 months, and 24 months with 73.5% of patients reporting satisfactory results. This building evidence for the use of ESWT for QT aids in providing clinical care tailored to individuals with QT in lieu of treating with management established for PT. This treatment modality may be particularly helpful for in-season or training athletes, since ESWT does not require a period of inactivity.[37]

Female and male runners appreciated functional improvement with ESWT with no clear sex-based differences. There was no significant difference in the proportion that achieved MCID, number of EWST sessions, or the types of ESWT sessions between sexes (Tables 2 and 3). These findings are consistent with previous literature suggesting no differences in functional outcome following ESWT for PT between male and female athletes.[38] While differences have been established between female and male patellar and quadriceps tendon properties, with female patellar tendons having longer lengths, smaller cross-sectional areas, and rupturing at lower maximal stress,[39-42] and female quadriceps tendons having decreased elasticity at 60° of flexion,[43] these properties do not seem to impact response to ESWT. These findings support the use of ESWT for males and females without concerns of decreased efficacy based on sex. Further research should explore differences in ESWT efficacy based on location of tendinopathy and sex, and studies of large samples and various tendinopathies may substantiate these findings.

Table 3. Extracorporeal Shockwave Therapy Treatment Provided for Female and Male Runners With Patellar or Quadriceps Tendinopathy

Characteristic	Patient Groups	ESWT Sessions, Mean ± SD	*P* Value	R-SWT, n (%)	*P* Value	C-SWT, n (%)	*P* Value	Final- Initial VISA-P, Median (Range; IQR), mo	*P* Value
Female and male	PT	5.3 ± 1.8	.86	7 (58)	.97	5 (42)	.97	3.0 (1.0-10.0; 2.8, 5.3)	*.30*
	QT	5.4 ± 2.7		4 (57)		3 (43)		5.0 (2.0-23.0; 3.0, 7.0)	
PT and QT	Female	6.4 ± 3.0	.19	3 (60)	.47	2 (40)	.54	6.0 (2.0-7.0; 3.0, 7.0)	*.40*
	Male	4.9 ± 1.6		5 (36)		9 (64)		3.0 (1.0-23.0; 2.3, 5.0)	

C-SWT: combined radial and focused extracorporeal shockwave therapy; ESWT, extracorporeal shockwave therapy; IQR, interquartile range; PT, patellar tendinopathy; QT, quadriceps tendinopathy; R-SWT, radial extracorporeal shockwave therapy; VISA-P, Victorian Institute of Sport—Patellar Tendon.

Limitations

Although this study adds valuable data to the limited literature characterizing ESWT for PT and QT in male and female runners, several limitations should be noted. The retrospective cohort design limits the ability to establish causality between the intervention and outcome, and the lack of a control group with sham intervention may introduce the potential for a placebo effect. However, functional improvement in this cohort is unlikely due to the natural history of the pathology given participants had symptoms for a median of 13 months (IQR, 11, 24), and most had symptoms refractory to standard of care, including physical therapy before receiving ESWT. Additionally, the small convenience sample of runners treated at a single outpatient clinic may limit the generalizability, and the sample size may have been underpowered to detect differences. Lastly, VISA-P was used to assess QT, although it was originally designed to assess jumper's knee, defined as patellar tendinosis.[30] However, given that no VISA questionnaire has been designed or validated for QT, the VISA-P has been used to assess jumper's knee, defined more broadly to include QT.[10]

Conclusions

Similar functional outcomes were observed in female and male runners with QT or PT following radial and combined ESWT, with the majority achieving MCID. This study suggests that ESWT, in combination with physical therapy, may be an effective treatment for runners with PT or QT and that ESWT could be considered for PT or QT refractory to physical therapy.

Disclosures

All authors (N.B.K., J.P.F., A.S.N., A.S.T.) declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Funding

This work was supported by the Terrapin Station Foundation.

Acknowledgments

The authors thank the patients who participated in this study.

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