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INVITED REVIEW

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Effects of isometric, eccentric, or heavy slow resistance exercises on pain and function in individuals with patellar tendinopathy: A systematic review

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Abstract

Background and Purpose: The purpose of this study is to evaluate current evidence and provide a review on the effects of isometric, eccentric, or heavy slow resistance (HSR) exercises on pain and function in individuals with patellar tendinopathy (PT).

Methods: Academic journals from CINAHL, Embase, MEDLINE, Scopus, SPORTDiscus™, and The Cochrane Library were searched from inception to August 2017. Screening of reference lists was also performed. Human interventional studies investigating outcomes of pain and function in PT using either isometric, eccentric, or HSR training exercises were included. The McMaster Critical Review Form-Quantitative Studies was used to assess for risk of bias. Levels of evidence were obtained using the National Health and Medical Research Council (NHMRC) evidence hierarchy. The NHMRC Body of Evidence Framework was utilized to formulate recommendations for clinical practice. Extraction of data was performed by two independent reviewers according to predefined data criterion, data were then tabulated, and a descriptive, qualitative data synthesis was performed.

Results: Fifteen studies (3 isometric, 2 HSR, and 10 eccentric) were included for this review. Mean quality score across all studies was 81.6% (range 70% to 93%). Nine studies were of high quality, whereas six studies were of moderate quality. Nine studies were randomized controlled trials, which provided good Level II evidence; four studies were of satisfactory Level III evidence; and two studies were case series (Level IV evidence).

Conclusions: Findings from isometric exercises can be trusted to guide clinical practice (Grade A), whereas eccentric exercises can be trusted to guide clinical practice in most clinical situations (Grade B). It is recommended that HSR exercises should be applied carefully to individual clinical circumstances (Grade C) and interpreted with care. Isometric exercises appear to be more effective during competitive seasons for short-term pain relief, whereas HSR or eccentric exercises are more suitable for long-term pain reduction and improvement in knee function.

KEYWORDS

exercise, pain, patella, tendinopathy

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1 | INTRODUCTION

Patellar tendinopathy (PT) is a repetitive, excessive overload injury to the extensor mechanism of the knee and occurs frequently in sports with explosive jumping (van Ark et al., 2016), such as volleyball and basketball. Hence, "jumper's knee" has also been coined as a term for PT. This condition causes significant pain and reduced function, which is especially debilitating in athletes during the competitive season (Rio et al., 2016).

A recent systematic review by Morgan, Vuuren, and Coetzee (2016) investigated the risk factors of PT and found that common contributing factors are reduced quadriceps strength, inappropriately progressed training load and/or duration, reduced lower limb flexibility, reduced skill set in the sport, and an inferiorly displaced patella. Many of these risk factors are thus modifiable and preventable through appropriate physiotherapy programmes. Rehabilitation of PT includes strengthening exercises of the quadriceps muscle, which has been shown to be effective in reducing pain in the long term (Gaida & Cook, 2011). It has also been shown to improve patellar tendon strength and activation of the quadriceps muscle on electromyography (Kongsgaard et al., 2006). Therefore, conservative management through rehabilitation has been an important cornerstone in the treatment of PT.

Although eccentric exercises have strong evidence supporting its utility in PT rehabilitation, it was not effective in athletes, especially during a competitive season (Gaida & Cook, 2011). A study by Visnes, Hoksrud, Cook, and Bahr (2005) revealed that elite athletes with PT were unable to tolerate or progress their rehabilitation programmes during competitive seasons due to excessive loading of the patellar tendon during matches, ultimately resulting in poor clinical outcomes. Patients with chronic PT have also been shown to respond less when participating in eccentric strengthening programmes, with residual pain plaguing functional activities even after rehabilitation (Bahr, Fossan, Loken, & Engebretsen, 2006). Innovative methods of rehabilitation are thus required to further enhance rehabilitation and recovery in these patients. In most recent studies, isometric and heavy slow resistance (HSR) exercises have demonstrated potential in pain reduction and functional improvement in PT (Kongsgaard et al., 2010; Rio et al., 2015; Rio et al., 2016; Romero-Rodriguez, Gual, & Tesch, 2011; van Ark et al., 2016). In particular, it was reported that a single bout of isometric contraction had immediate tendon pain relief for at least 45 min in athletes during competitive seasons (Rio et al., 2015). Thus, it appears that an alternative contraction-type exercise may have emerged as a promising tool in revolutionizing the management of PT. Hence, it would seem relevant to review the effectiveness of these exercises.

Existing systematic reviews have attempted to evaluate the effectiveness of exercises on PT (Larsson, Käll, & Nilsson-Helander, 2012; Morgan et al., 2016; Rabin, 2006; Visnes & Bahr, 2007). Although these reviews suggested sufficient evidence for the implementation of eccentric exercises in the management of PT, these reviews only included studies with eccentric exercises or HSR exercises and have not considered the effectiveness of isometric exercise protocols. To our knowledge, this is the first systematic review to present current evidence on effectiveness of isometric, eccentric, and HSR exercises on pain and function in PT. The objectives are to evaluate the current evidence and provide a review on the effects of isometric, eccentric, or HSR exercises on pain and function in PT.

2 | METHODS

2.1 | Protocol and registration

The systematic review was undertaken in accordance with the protocol guidelines outlined in the Preferred Reporting Items for Systematic Reviews and Meta-Analyses statement and was registered on August 12, 2017, with the International Prospective Register of Systematic Reviews (PROSPERO# CRD42017074286).

2.2 | Eligibility criteria

Articles reporting at least one of the outcomes of pain and/or function in PT were included. Human interventional studies investigating isometric, eccentric, or HSR training exercises in PT were also included.

Studies that were not written in English language, did not have full text available, or did not include any participants with tendinopathy were excluded. Any studies that had invasive interventions (for example, injections or surgery) were also excluded. Other exclusion criteria included non-peer-reviewed studies, clinical commentaries, and reviews.

2.3 | Information sources and search

An electronic search of CINAHL, Embase, MEDLINE, Scopus, SPORTDiscus™, and The Cochrane Library was performed on August 12, 2017. Articles published from inception to August 2017 were included in the search. Search terms include "Patellar tendinopathy" and all its variants (patella* tendin*), "isometric," "eccentric," and "heavy slow resistance." To supplement the database searches, reference lists of included studies and existing systematic reviews were screened and included if relevant. Table 1 shows the search terms utilized in MEDLINE.

2.4 | Study selection

Two independent reviewers screened the title and abstract of all studies identified by the search strategy for fulfilment of relevant eligibility criteria. Full texts were retrieved if insufficient information was provided in the title and abstract. Any discrepancies between the two reviewers were resolved by consensus.

TABLE 1 Search terms utilized in MEDLINE

1	"tendinopathy," "paratenonitis," "peritendinitis," "tendi* OR teno* OR tendo*"
AND	
2	"patella" OR "patella*" OR "knee cap"
AND	
3	"eccentric" OR "isometric" OR "heavy slow resistance"

2.5 | Data collection process and data items

Key information were extracted by two independent reviewers from the articles, including study design, participant characteristics, loading intervention protocols, pain and function outcome measures, and length of follow-up. The extracted data were tabulated according to each heading.

Outcome measures for pain and function included but are not limited to Visual Analogue Scale (VAS), Numerical Rating Scale (NRS), and the Victorian Institute of Sport Assessment (VISA) score.

2.6 | Risk of bias

The McMaster Critical Review Form-Quantitative Studies was utilized to assess for risk of bias in each study. A "Yes," "No," "NA," or "Not addressed" was scored accordingly depending on criterion fulfilment.

The National Health and Medical Research Council (NHMRC) Body of Evidence Framework and Evidence Hierarchy was used to assess level of evidence and evaluate risk of bias across studies. An overall summary of recommendations was subsequently formulated on the basis of the five components (evidence base, consistency, clinical impact, generalizability, and applicability).

2.7 | Summary measures

Any continuous data reported were presented as mean difference, 95% confidence interval, and *p* values. Categorical data such as the VAS or VISA score were reported with percentage changes (where available), 95% confidence interval, *p* values, and chi-squared values.

2.8 | Data synthesis

An attempt was made to pool data for meta-analysis; however, given that the data were heterogeneous, a meta-analysis was not possible. A narrative synthesis was thus more suitable for this review, with no additional analysis required.

3 | RESULTS

3.1 | Study selection

Five hundred thirteen studies were identified for screening in the initial search. After removal of duplicates and reviewing of title and abstract, 493 studies were excluded. Full text of the remaining 20 studies was screened for eligibility, and 15 studies were selected on the basis of the inclusion and exclusion criteria (Figure 1). Out of the 15 studies, 3 studies examined the effects of isometric exercise programmes, 2 studies explored the effects of HSR exercises, and 10 studies investigated the effects of eccentric exercise programmes in individuals with PT. Two of these studies included had the same clinical trial registration (Rio et al., 2016; van Ark et al., 2016); however, both were included as they presented different information and length of follow-up.

3.2 | Study characteristics

Data were extracted from each study by two independent reviewers (Table 2). There were 55 participants in isometric exercise programmes, 27 subjects in HSR exercise programmes, and 228 participants in eccentric exercise programmes. Most participants took

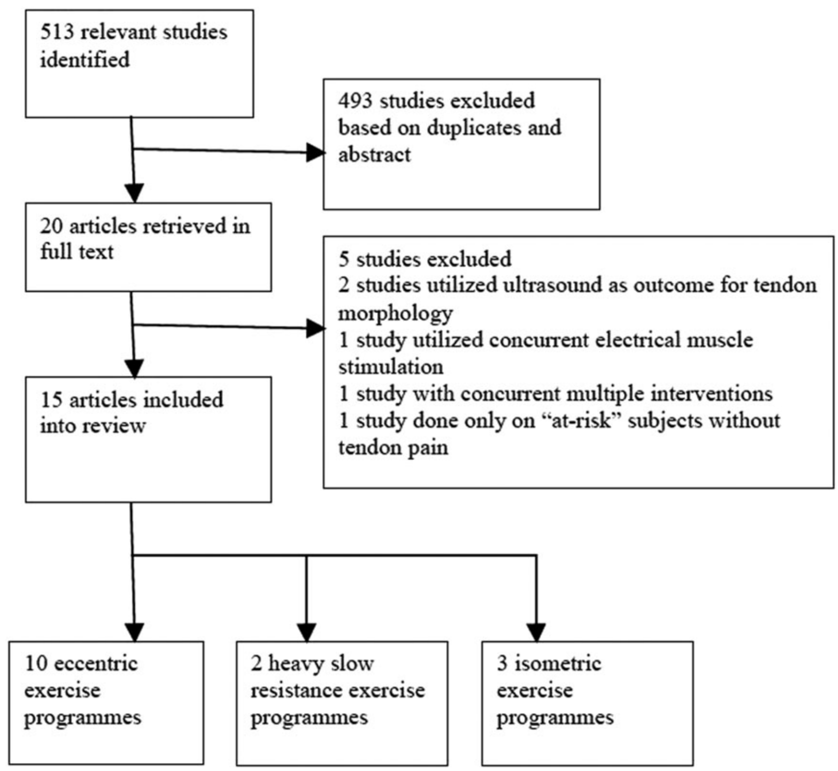

FIGURE 1 Flow chart of article search and selection according to Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines

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TABLE 2 Characteristics, interventions, and outcomes for each study

Author (year)	Study design	Participant characteristics	Intervention	Comparison	Pain	Function
Isometric						
Rio et al. (2015)	Level III-2, crossover trial	*n* = 6 (6 M, 0 F) Age (median/years): 26.9 Sports: volleyball DOS: not specified Withdrawn from activity: no	Isometric group Duration: 1 session Biodex Pro: 5 sets × 45-s hold at 60° flexion at 70% MVC	Isotonic group Duration: 1 session Leg extension machine: 4 sets × 8 repetitions, with 4-s ECC and 3-s CON phase at 100% 8RM	Follow-up at immediately postintervention and at 45 min postintervention *NRS* At immediately postintervention, significant pain reduction in both groups, isometric group 87% ($p = 0.004$) and isotonic group 42% ($p = 0.04$) At 45 min postintervention, pain reduction still significant in isometric group ($p < 0.001$) but not in isotonic group ($p > 0.05$)	*VISA*: only baseline measurements reported, postintervention measurements not done
Rio et al. (2016)	Level II, RCT	*n* = 20 (18 M, 2 F) Age (years): more than 16 Sports: elite and subelite volleyball and basketball DOS: not specified Withdrawn from activity: no	Isometric group Duration: 4 sessions per week for 4 weeks Leg extension machine: 5 sets × 45-s hold at 60° flexion at 80% MVC	Isotonic group Duration: 4 sessions per week for 4 weeks Leg extension machine: 4 sets × 8 repetitions, with 4-s ECC and 3-s CON phase per repetition at 80% 8RM	Follow-up after every intervention session over 4 weeks *NRS* Both had reduction in pain, greater change for isometric group (mean change = 1.8 ± 0.39) than isotonic group (mean change = 0.9 ± 0.25)	Follow-up at 4 weeks *VISA* Both groups improved, no statistically significant differences between groups at 4 weeks ($p = 0.99$) Median VISA score >80/100, isometric group 84/100; isotonic group 80/100
van Ark et al. (2016)	Level II, RCT	*n* = 29 (27 M, 2 F) Age (mean/years): 23 ± 4.7 Sports: volleyball and basketball DOS (mean/months): 35.8 ± 33.8 Withdrawn from activity: no	Isometric group Duration: 4 sessions per week for 4 weeks Leg extension machine: 5 sets × 45-s hold at 60° flexion at 80% MVC	Isotonic group Duration: 4 sessions per week for 4 weeks Leg extension machine: 4 sets × 8 repetitions, with 4-s ECC and 3-s CON phase per repetition at 80% 8RM	Follow-up at 4 weeks *NRS* Significant improvement in pain over 4 weeks for isometric group ($p = 0.012$) and isotonic group ($p = 0.003$) No significant difference between groups	Follow-up at 4 weeks *VISA* Significant improvement in median VISA score over 4 weeks for isometric group ($p = 0.028$) and isotonic group ($p = 0.003$) No significant difference between groups
HSR						
Kongsgaard et al. (2010)	Level III-2, cohort study	*n* = 17 (17 M, 0 F) Age (mean/years): intervention group 32.9 ± 3.5; control group 31.5 ± 3.3 Sports: not specified DOS (mean/months): 15 ± 3 Withdrawn from activity: no	HSR training group Duration: 3 sessions per week for 12 weeks Bilateral knee squats, leg press, and hack squat performed from complete extension to 90° knee flexion and back 4 sets of repetitions (6-15RM), with 3-s ECC and 3-s CON phase per repetition	Control group Healthy matched controls No intervention; no VAS/VISA measurements	Follow-up at 12 weeks (only for PT group) *VAS* (0–100) Pain reduction by 36% ± 5 ($p = 0.008$) after 12 weeks	Follow-up at 12 weeks (only for PT group) *VISA* Improvement of 27% ± 7 ($p = 0.02$) after 12 weeks
Romero-Rodriguez et al. (2011)	Level IV, case series	*n* = 10 (10 M, 0 F) No. of tendons: 15 Age (mean/years): 25 ± 6 Sports: 7 soccer, 2 basketball, and 1 distance runner, all competing at national level DOS (weeks): 31.7 (range 6–96) Withdrawn from activity: no	HSR training group Duration: 2 sessions per week for 6 weeks with at least 2 days of rest between sessions YoYo™ leg press of 4 sets of 10 repetitions (repetitions 3–10 maximal effort) of	NA	Follow-up at 6 and 12 weeks *VAS* (0–10) Significant pain reduction 60% ($p < 0.01$) at 6 weeks No further changes in pain at 12 weeks	Follow-up at 6 and 12 weeks *VISA* Significant improvement 86% ($p < 0.01$) at 6 weeks No further changes in pain at 12 weeks *Vertical CMJ*

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TABLE 2 (Continued)

Author (year)	Study design	Participant characteristics	Intervention	Comparison	Pain	Function
			maximal bilateral coupled CON and ECC actions with 2-min rest between sets			7 out of 10 subjects showed increased CMJ height
Eccentric						
Biernat et al. (2014)	Level II, RCT	*n* = 28 (28 M, 0 F) Age (mean/years): ECC squat group 17.7 ± 0.7; control group 16.5 ± 0.8 Sports: volleyball DOS (months): not specified Withdrawn from activity: no	ECC squat group Duration: daily (except on days of intense training or matches) for 24 weeks 25° SLDS up to 60° knee flexion 3 sets × 15 repetitions Perform at VAS < 5 Weeks 4–24 of training: addition of unstable surface to decline squat	Control group No intervention—usual volleyball training	No pain outcome measures monitored	Follow-up at 12 and 24 weeks *VISA* Significant difference between groups only at 24 weeks ($p < 0.05$). ECC squat group 90.3 ± 12.2, whereas control group 94.3 ± 7.2. Experimental group had improvement in scores from baseline, whereas control group scores stayed similar *CMJ test* No significant difference within or between groups ($p > 0.05$)
Cannell et al. (2001)	Level II, RCT	*n* = 19 (13 M, 6 F) Age (mean/years): drop squat group 26 ± 3; leg extension/curl group 26 ± 7 Sports: 6 basketball, 3 soccer, 3 running, 2 volleyball, 1 tennis, 1 squash, 1 rowing, 1 American football, and 1 gymnastics DOS (mean/months): drop squat group 3.1 ± 1.5; leg extension/curl group 4.2 ± 1.9 Withdrawn from activity: yes	Drop squat group Duration: 5 days/week for 12 weeks Unlock knees rapidly in standing position, dropping thighs just short of parallel to ground 3 sets × 20 repetitions, body weight	Leg extension/curl group Duration: 5 days/week over 12 weeks Leg extension: began with 5 kg weight and lift it to full extension and hold for 2 s Leg curl: performed using half the weight for leg extension in prone and flex knee to 90° and hold for 2 s 3 sets × 10 repetitions of each	Follow-up at 6 and 12 weeks *VAS* (0–10) Statistically significant within-group pain reduction for both groups ($p < 0.01$), no significant difference between groups *Drop squat group*: 4 subjects became pain free, 5 improved their pain scores (mean 2.8 points), and 1 had an increase in pain score (3 points) *Leg extension/curl group*: 2 subjects became pain free, 4 improved their pain scores (mean 2.2 points), 1 remained unchanged, and 2 had an increase in pain score (mean 1.5 points)	Follow-up at 12 weeks *RTS* No significant difference between groups in RTS *Drop squat group*: 9 of 10 subjects RTS *Leg extension/curl group*: 6 of 9 subjects RTS
Croisier et al. (2001)	Level IV, case series	*n* = 10 (6 M, 4 F) Age (mean/years): 30 ± 7 Sports: jogging, running, and soccer DOS (mean/months): 8 ± 4 Withdrawn from activity: not specified	Isokinetic ECC training group Duration: 3 sessions per week, total 20–30 sessions Pain-free through-range ECC strengthening exercises on isokinetic dynamometer Sessions 1–10: 1–3 sets × 30 repetitions, 30% MVC, 30–180°/s Sessions 11–30: 3–5 sets × 20 repetitions, 60–80% MVC, 30–180°/s Had icing, analgesic TENS, US, massage, and stretching complementary to exercises	No control group	Follow-up at Sessions 10, 20, and 30 *VAS* (0–10) After 10 sessions, statistically significant reduction in pain scores (average VAS = 5) ($p < 0.05$) After 20 sessions, pain reduced further (average VAS ≤ 2.5) ($p < 0.001$) After 30 sessions, pain improved further (average VAS < 1.8)	Follow-up at 3 months *Return to activity* 44% complete relief of pain 44% marked or moderately reduced symptoms 12% no change
	Level II—RCT	*n* = 20 (16 M, 4 F)	Bromsman ECC overload group	One-legged ECC training group	Follow-up at 12 weeks	Follow-up at 12 weeks

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TABLE 2 (Continued)

Author (year)	Study design	Participant characteristics	Intervention	Comparison	Pain	Function
Frohm et al. (2007)		Age (mean/years): Bromsman ECC group 26 ± 8; one-legged ECC group 28 ± 8 Sports: not specified, but are all athletes DOS (months): continuous symptoms >3 or recurrent symptoms >6 Withdrawn from activity: yes, for first 6 weeks	Duration: 2 × 70-min session for 12 weeks Hydraulic squat machine to 110° knee flexion, speed 0.11 m/s 4 sets × 4 repetitions (initial set for warm-up, then maximal effort for next 3 sets)	Duration: 2 × 70-min session for 12 weeks 25° SLDS Perform at VAS < 5 3 sets × 15 repetitions	*VAS* (0–10) Significantly reduced within-group VAS scores after 12 weeks' intervention *Bromsman group*: median 4 (interquartile range 4–6) decreased to 0 (interquartile range 0–1) ($p = 0.003$) *One-legged training group*: median 5 (interquartile range 4–5) to 1 (interquartile range 1–2) ($p = 0.008$)	*VISA* Significantly improved within-group for both groups, but no significant difference between groups *Bromsman ECC group*: median 49 (95% CI [38–61]) to 86 (95% CI [71–92]) ($p < 0.001$) *One-legged ECC group*: median 36 (95% CI [23–61]) to 75 (95% CI [46–83]) ($p < 0.001$) *Functional tests (5-repetition CMJ test and single-leg triple hop)* No statistically significant difference for within/between groups in CMJ test ($p > 0.05$) Significant within-group improvement for single-leg triple hop test ($p < 0.001$) for both groups, but no difference between groups was found *Bromsman group*: mean 555 (95% CI [502–607]) to 585 (95% CI [531–638]) *One-legged training group*: mean 496 (95% CI [438–554]) to 531 (95% CI [471–590])
Jonsson and Alfredson (2005)	Level II, RCT	$n = 15$ (13 M, 2 F) Age (mean/years): CON training group 24.1 ± 6.4; ECC training group 25.7 ± 9.9 Sports: 7 running, 5 soccer, 3 basketball, 3 floorball, and 1 handball DOS (mean/months): CON training group 19.6 ± 20.3; ECC training group 15.4 ± 6 Withdrawn from activity: yes, for first 6 weeks	ECC training group Duration: twice daily for 12 weeks 25° SLDS to 70° knee flexion 3 sets × 15 repetitions Squats must be painful	CON training group Duration: twice daily for 12 weeks Concentric knee extension from 70° knee flexion while standing on 25° incline board 3 sets × 15 repetitions Squats must be painful	Follow-up at 12 weeks *VAS* (0–100) *ECC training group*: significantly lower (68 decreased to 22) pain scores than baseline ($p < 0.01$) *Concentric training group*: no significant difference in pain scores from baseline ($p < 0.34$) 3 dropouts from concentric training group after 6 weeks due to severe tendon pain during and after exercises	Follow-up at 12 weeks *VISA* *ECC training group*: significantly higher VISA scores (37 improved to 83) than baseline ($p < 0.01$) *Concentric training group*: no significant difference in VISA scores from baseline ($p < 0.34$) 3 dropouts from concentric training group due to severe tendon pain during and after exercises
Purdam et al. (2004)	Level III-2, nonrandomized experimental trial with 2 intervention arms	$n = 17$ (13 M, 4 F) Age (mean/years): standard squat 22; decline squat 28 Sports: 4 floorball, 3 soccer, 2 ice hockey, 2 running, 2 high jump, 3 volleyball, and 1 skiing DOS (mean/months): standard squat 14.1 ± 6.6; decline squat 19.1 ± 17.9	Decline squat group Duration: twice daily for 12 weeks 25° SLDS to 90° knee flexion Performed with some pain and discomfort 3 sets × 15 repetitions	Standard squat group Duration: twice daily for 12 weeks On flat ground, eccentrically squat to 90° knee flexion Performed with some pain and discomfort 3 sets × 15 repetitions	Follow-up at 12 weeks and 15 months *VAS* (0–100) *Decline squat group*: significant pain reduction 74.2 ± 11.6 to 28.5 ± 29.4 ($p = 0.004$) at 12 weeks *Standard squat group*: no significant pain reduction 79.0 ± 7.0 to 72.3 ± 19.14 ($p = 0.144$) at 12 weeks	Follow-up at 12 weeks and 15 months *RTS* Week 12: *decline squat group*, 6 subjects (9 tendons) RTS; 2 subjects (3 tendons) referred for surgical treatment *Standard squat group*, 1 subject (1 tendon) RTS; 8 subjects (9 tendons) referred for surgical treatment

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TABLE 2 (Continued)

Author (year)	Study design	Participant characteristics	Intervention	Comparison	Pain	Function
		Withdrawn from activity: yes for first 4 weeks			At 15 months: performed for 6 subjects (9 tendons) in decline squat group only 4 subjects (5 tendons): mean score 26.2 ± 25.4 1 subject (2 tendons): mean score 68 1 subject (2 tendons): not specified	At 15 months: performed for 6 subjects (9 tendons) in decline squat group only 4 subjects (5 tendons) active at preinjury levels, 1 subject (2 tendons) stopped activity, but due to development of PFPS, 1 subject (2 tendons) had relapse of PT
Stasinopoulos et al. (2012)	Level III-1, CCT	*n* = 43 (31 M, 12 F) Age (mean/years): ECC 26.38 ± 4.32; ECC + stretching group 27.04 ± 5.11 Sports: not specified Training load (per week): not specified DOS (mean/months): ECC + stretching group 5.985; ECC group 6.126 Withdrawn from activity: no	ECC group Duration: 5 times per week over 4 weeks 25° SLDS at slow speed Perform with mild pain 3 sets × 15 repetitions	ECC + stretching group Duration: 5 times per week for 4 weeks 25° SLDS at slow speed Perform with mild pain 3 sets × 15 repetitions Individualized stretching exercises before and after ECC exercises 30-s hold, 1-min rest between each stretch, once daily	No pain outcome measures monitored	Follow-up at 4 and 24 weeks *VISA* Statistically significant within-group difference was found at 4 and 24 weeks Week 4: *ECC + stretching group*—+42 units (CI [33.3–48.6]) ($p < 0.0005$); *ECC group*—+28 units (CI [24.4–33.5]) Week 24: *ECC + stretching group*—+50 units (CI [38.9–54.5]) ($p < 0.005$); *ECC group*—+31 units (CI [26.8–36.1]) ($p < 0.0005$) ECC + stretching group had statistically significant greater improvements (14–19 units) than ECC group at Weeks 4 and 24 ($p < 0.05$)
Stasinopoulos and Stasinopoulos (2004)	Level II RCT with 3 intervention arms	*n* = 30 (18 M, 12 F) Age (mean/years): exercise group 28.12 ± 2.03; US group 29.17 ± 3.76; and transverse friction group 26.24 ± 4.17 Sports: 12 basketball, 6 soccer, 5 running, 5 volleyball, and 2 tennis DOS: not specified Withdrawn from activity: not specified	Exercise group Duration: 3 times per week for 4 weeks Unilateral ECC squat performed at slow speed with mild pain 3 sets × 15 repetitions Performed static stretching exercises for 30 s, with 1-min rest between each stretch, before and after exercises	US group Duration: 3 times per week for 4 weeks Applied locally for 10 min Transverse friction group Duration: 3 times per week for 4 weeks Applied continuously to patellar tendon for 10 min	Follow-up at 4, 8, and 16 weeks *Subjective pain response* Exercise group was statistically significantly better than the other 2 groups at 4 weeks ($\chi^2 = 12.21$, $p < 0.01$), 8 weeks ($\chi^2 = 23.2$, $p < 0.001$), and 16 weeks ($\chi^2 = 23.2$, $p < 0.001$) *Exercise group*: 80% much better/no pain at 4 weeks; 100% much better/no pain at 8 and 16 weeks *US group*: 10% much better/no pain at 4 weeks; 0% much better/no pain at 8 and 16 weeks *Transverse friction group*: 20% much better/no pain at 4, 8, and 16 weeks	No functional outcomes measured
Visnes et al. (2005)	Level II, RCT	*n* = 29 (19 M, 10 F) Age (mean/years): ECC training group 26.8 ± 4.6; control group 26.4 ± 3.4 (mean 26.6 years old ± 3.9) Sports: elite volleyball players	ECC training group Duration: twice daily for 12 weeks 25° SLDS to 90° knee flexion of affected leg, 2 s for ECC phase VAS = 5 during exercises 3 sets × 15 repetitions	Control group No intervention—usual volleyball training	Self-recorded for each exercise session, only done for ECC training group *VAS* (0–10) Average VAS 5.1 ± 1.8 during 12 weeks eccentric exercises in ECC training group	Follow-up immediately postintervention, 6 weeks and 6 months after intervention *VISA score* No statistically significant difference between groups immediately postintervention ($p = 0.98$), at 6

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TABLE 2 (Continued)

Author (year)	Study design	Participant characteristics	Intervention	Comparison	Pain	Function
		DOS (mean/months): ECC training group 67 ± 44; control group 79 ± 75 Withdrawn from activity: no				weeks (p = 0.71) and 6 months (p = 0.99) of follow-up Follow-up immediately postintervention (12 weeks) *Jumping performance (double leg then single leg)* *CMJ (double leg)*: significant improvement of 1.2 ± 2.9 cm in ECC training group postintervention (p = 0.046) *CMJ (single leg)/standing jump (all types)*: no statistically significant difference between groups (p = 0.17–0.67)
Young et al. (2005)	Level II, RCT	n = 17 (13 M, 4 F) Age (mean/years): 27.3 ± 1.8 Sports: elite volleyball players DOS: not specified Withdrawn from activity: not specified	Decline squat group Duration: twice daily for 12 weeks 25° SLDS to 60° knee flexion Exercise into moderate tendon pain 3 sets × 15 repetitions	Step squat group Duration: twice daily for 12 weeks Perform single-leg squats using a 10 cm step Exercise into minimal tendon pain 3 sets × 15 repetitions	Follow-up at Weeks 4, 8, and 12 and 12 months *VAS* (0–100) Statistically significant within-group improvement for both decline squat and step squat groups at 12 weeks and 12 months (p < 0.05), but no difference between groups was found Likelihood of improvement greater in step squat group at 12 weeks, with no difference between groups at 12 months	Follow-up at Weeks 4, 8, and 12 and 12 months *VISA* Statistically significant within-group improvement for both decline squat and step squat groups at 12 weeks and 12 months (p < 0.05), but no difference between groups was found Likelihood of improvement significantly higher in decline squat group at 12 months at 94% chance as compared with 41% chance in the step squat group

Note. CI: confidence interval; CON: concentric; CMJ: countermovement jump; DOS: duration of symptoms; ECC: eccentric; F: female; M: male; MVC: maximal voluntary contraction; NRS: Numeric Rating Scale; PFPS: patellofemoral pain syndrome; PT: patellar tendinopathy; RCT: randomized controlled trial; RM: repetition maximum; RTS: return to sport; SLDS: single-leg decline squat; TENS: transcutaneous electrical nerve stimulation; US: ultrasound; VAS: Visual Analogue Scale; VISA: Victorian Institute of Sport Assessment.

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part in sports regularly, with volleyball and basketball being the most common sporting group investigated.

Follow-up period ranged from immediately postintervention (Rio et al., 2015) to 12 months (Young, Cook, Purdam, Kiss, & Alfredson, 2005). Chronicity of PT ranged from 3 months (Frohm, Saartok, Halvorsen, & Renström, 2007; Visnes et al., 2005) to 79 months (Cannell, Taunton, Clement, Smith, & Khan, 2001).

3.3 | Risk of bias

Risk of bias within individual studies was assessed using the McMaster Critical Review Form for Quantitative Studies (Table 3). Mean quality score across all studies was 81.6%, with the scores ranging from 70% to 93%. Nine studies were of high quality (at least 85%), whereas six studies were of moderate quality (70–84%). Therefore, general rigour of studies included was of moderate- to high-quality evidence.

One key issue was that a large proportion of studies (13 out of 15) did not justify the selection of sample size, and some of the studies (five out of 15) did not address if contamination within control groups was avoided. These are possible areas to refine on in future research.

An analysis of level of evidence was also carried out in accordance with the NHMRC Evidence Hierarchy to assess risk of bias across studies (Table 2). Of the 15 studies, nine were randomized controlled trials, which provided good Level II evidence (two isometric and seven eccentric), on the basis of their methodological quality. Four studies were of satisfactory Level III evidence (one isometric, one HSR, and two eccentric) due to lack of randomization or crossover study design, but these studies were still appropriate in evaluating the effects of the intervention. Only two studies were case series (Level IV evidence) without a control group (Croisier, Forthomme, Foidart-Dessalle, Godon, & Crielaard, 2001; Romero-Rodriguez et al., 2011). However, given that the authors measured a battery of assessment tests or investigated effects of eccentric exercises in a variety of tendinopathies, a case-series design would be the most suitable.

On the basis of the NHMRC Body of Evidence Framework, there is strong evidence to recommend the use of isometric exercises (Grade A) in clinical practice. Moderate evidence exists to recommend the use of eccentric exercises (Grade B) in most clinical situations, whereas it is recommended that HSR exercises (Grade C) should be applied carefully to individual clinical circumstances and interpreted with care (Table 4).

4 | RESULTS OF INDIVIDUAL STUDIES

Results of all studies are summarized in Table 5 with corresponding comparators and overall effect on pain and function.

4.1 | Isometric

All studies compared the effectiveness of isometric and isotonic exercises in individuals with PT during in-season volleyball and/or basketball competitions. The isometric exercises were performed at 70–80% maximal voluntary contraction at 60° knee flexion for five sets of 45-s hold using either a Biodex or leg extension machine, whereas the isotonic exercises consisted of four sets of eight repetitions at 80–100% of 8 repetition maximum using a leg extension machine. In one study, the follow-up period was 45 min as the outcome measures were taken immediately postintervention and 45 min postintervention (Rio et al., 2015). For the other two studies, baseline and follow-up measures were taken at baseline and after 4 weeks of isometric training. No long-term follow-up (>6 weeks) was included in these three studies.

4.1.1 | Pain

Rio et al. (2015) found significant pain reduction in both isometric group (87%; $p = 0.004$) and isotonic group (42%; $p = 0.4$) immediately after a single bout of exercises, but at 45 min postintervention, only the isometric group demonstrated significant pain reduction ($p < 0.001$). Although the other two studies also reported significant improvement in pain, Rio et al. (2016) found isometric exercises (1.8 ± 0.39) elicited greater changes in the NRS pain score than isotonic exercises (0.9 ± 0.25) without any modification in training load and competition load over 4 weeks. However, van Ark et al. (2016) reported no statistically significant differences between the isometric and isotonic groups after 4 weeks of training.

4.1.2 | Function

Only two studies attempted to measure functional changes from baseline (Rio et al., 2016; van Ark et al., 2016). Both studies reported significant improvement in the VISA scores after 4 weeks of intervention, with no significant differences between the isometric and isotonic groups.

4.2 | Heavy slow resistance

Both included studies reported significant improvement in pain and function up to 12 weeks' follow-up. The HSR exercises utilized both concentric and eccentric contractions performed between 90° knee flexion and full knee extension for four sets of 6–15 repetitions. In order to achieve high inertial resistance, the HSR trainings involve using a leg press machine. These exercises were carried out two to three sessions per week, over a 6- to 12-week intervention as described in the studies.

4.2.1 | Pain

Kongsgaard et al. (2010) reported a pain reduction of 36% ($p = 0.008$) after 12 weeks of HSR training, whereas Romero-Rodriguez et al. (2011) reported a 60% pain reduction ($p < 0.01$) after a 6-week intervention, with effects persisting till 12 weeks' follow-up. Kongsgaard et al. (2010) also reported improvement in both pain and function outcomes in individuals with PT after HSR training. The authors further concluded that these clinical improvements were associated with normalization of fibril morphology due to HSR training when compared with the tendon morphology of the control group.

4.2.2 | Function

Similarly, both studies demonstrated statistically significant improvement in function using the VISA score ($p < 0.01$) up to 12 weeks postintervention. Romero-Rodriguez et al. (2011) also reported an increase in countermovement jump height in seven of 10 subjects after 6 weeks

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TABLE 3 Risk of bias in individual studies

Author (year)	Study purpose	Background literature	Design (according to options in McMaster Tool)	Sample characteristics	Sample size	Reliable outcome measures	Valid outcome measures	Intervention detailed
Isometric								
Rio et al. (2015)	Yes	Yes	Before and after Stated as single-blinded, randomized crossover trials with 2 intervention arms	Yes	No justification of sample size	Yes	Yes	Yes
Rio et al. (2016)	Yes	Yes	Stated as RCT; however, information on recruitment process was not reported	Yes	No justification of sample size	Yes	Yes	Yes
van Ark et al. (2016)	Yes	Yes	RCT	Yes	No justification of sample size	Yes	Yes	Yes
HSR								
Kongsgaard et al. (2010)	Yes	Yes	Cohort study with matched controls	Yes	No justification of sample size	Yes	Yes	Yes
Romero-Rodriguez et al. (2011)	Yes	Yes	Before and after	Yes	No justification of sample size	Not addressed	Not addressed	Yes, but not easy to replicate in practice
Eccentric								
Biernat et al. (2014)	Yes	Yes	Cohort study No specific study design stated in the article	Yes	No justification of sample size	Yes	Yes	Yes
Cannell et al. (2001)	Yes	Yes	Cohort study (with randomization and 2 intervention arms) Stated as RCT	Yes	No justification of sample size	Yes	Yes	Yes
Croisier et al. (2001)	Yes	Yes	Before and after Stated as longitudinal study	Yes	No justification of sample size	No (functional outcome measure reliability unknown)	No (functional outcome measure validity unknown)	Yes
Frohm et al. (2007)	Yes	Yes	RCT Stated as RCT but performed as clinical controlled trial	Yes	No justification of sample size	Yes	Yes	Yes
Jonsson and Alfredson (2005)	Yes	Yes	RCT Stated as prospective randomized study	Yes	Yes	Yes	Yes	Yes
Purdam et al. (2004)	Yes	Yes	Cohort study with 2 intervention arms. Consecutive subjects recruited Stated as nonrandomized pilot study	Yes	No justification of sample size	Yes	Yes	Yes
Stasinopoulos and Stasinopoulos (2004)	Yes	Yes	Cohort study with 3 intervention arms Stated as RCT	Yes	No justification of sample size	No	No	Yes
Stasinopoulos et al. (2012)	Yes	Yes	Cohort study Stated as clinical controlled trial	Yes	No justification of sample size	Yes	Yes	Yes
Visnes et al. (2005)	Yes	Yes	RCT	Yes	Yes	Yes	Yes	Yes
Young et al. (2005)	Yes	Yes	RCT	Yes	No justification of sample size	Yes	Yes	Yes

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TABLE 3 Continued

Author (year)	Contamination avoided	Cointervention avoided	Statistical significance	Appropriate analysis method	Clinical importance	Dropouts	Appropriate conclusion	Total score	Total score (%)
Isometric									
Rio et al. (2015)	NA	No, not withdrawnfrom activity	Yes	Yes	Yes	Yes	Yes	11/13	84.60
Rio et al. (2016)	Yes	No, not withdrawn from activity	Yes	Yes	Yes	Yes	Yes	43,083	0.857
van Ark et al. (2016)	Yes	No, not withdrawn from activity	Yes	Yes	Yes	Yes	Yes	43,083	0.857
								Average isometric	**85.33**
HSR									
Kongsgaard et al. (2010)	Yes	No, not withdrawn from activity	Yes	Yes	Yes	Yes	Yes	12/14	85.70
Romero-Rodriguez et al. (2011)	NA	No, not withdrawn from activity but recommended to stop activity if symptoms increased	Yes	Yes	Yes	Yes	Yes	9/13	69.23
								Average HSR	**77.50**
Eccentric									
Biernat et al. (2014)	Not addressed	No, not withdrawn from sporting activity	Yes	Yes	Yes	Yes	Yes	11/14	78.60
Cannell et al. (2001)	Not addressed	No, not withdrawn from sporting activity	Yes	Yes	Yes	Yes	Yes	11/14	78.60
Croisier et al. (2001)	NA	Not addressed	Yes	Yes	Yes	Yes	Yes	9/13	69.23
Frohm et al. (2007)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	13/14	92.90
Jonsson and Alfredson (2005)	Not addressed	Not addressed	Yes	Yes	Yes	Yes	Yes	12/14	85.70
Purdam et al. (2004)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	13/14	92.90
Stasinopoulos and Stasinopoulos (2004)	Yes	Yes	Yes	No, could have selected better outcome measures	Yes	Yes	Yes	10/14	71.40
Stasinopoulos et al. (2012)	Yes	No, not withdrawn from activity	Yes	Yes	Yes	Yes	Yes	12/14	85.70
Visnes et al. (2005)	Not addressed	No, not withdrawn from sporting activity	Yes	Yes	Yes	Yes	Yes	12/14	85.70
Young et al. (2005)	Not addressed	No, not withdrawn from sporting activity	Yes	Yes	Yes	Yes	Yes	11/14	78.60
								Average eccentric	**81.90**
								Total average	**81.58**

Note. RCT: randomized controlled trial.

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TABLE 4 Level of recommendation according to National Health and Medical Research Council

	Isometric	HSR	Eccentric
Evidence base	A	C	B
Consistency	A	B	B
Clinical impact	A	B	B
Generalizability	B	B	B
Applicability	A	C	B
Overall recommendation	A	C	B

Note. Grade of recommendation: A: body of evidence can be trusted to guide practice; B: body of evidence can be trusted to guide practice in most situations; C: body of evidence provides some support for recommendation(s), but care should be taken in its application. HSR: heavy slow resistance.

of HSR training; however, no comparator was available as this was a case-series study.

4.3 | Eccentric

All but one (Visnes et al., 2005) of the 10 included studies showed positive results after an eccentric exercise intervention in improving pain and/or function for individuals with PT. Most studies utilized a 25° decline squat as the main intervention strategy for eccentric exercises, with the concentric phase of the squat performed with the nonaffected leg or with the arms, whereas eccentric phase performed on the affected leg. There was variable prescription of eccentric exercise programmes, but most studies utilized three sets of 15 repetitions into mild–moderate pain (VAS $\leq$ 5). Some studies prescribed the exercises twice weekly (Frohm et al., 2007), whereas others prescribed twice daily (Jonsson & Alfredson, 2005; Purdam et al., 2004; Visnes et al., 2005; Young et al., 2005). Length of intervention also varied from 4 weeks (Stasinopoulos, Manias, & Stasinopoulou, 2012; Stasinopoulos & Stasinopoulos, 2004) to 24 weeks (Biernat, Trzaskoma, Trzaskoma, & Czaprowski, 2014).

4.3.1 | Pain

Pain was measured in eight of the 10 studies investigating the effects of eccentric exercises for individuals with PT using outcome measures such as the VAS, NRS, and subjective pain response. Croisier et al. (2001) showed a significant reduction in pain (p < 0.001) after 20 sessions of eccentric exercises using isokinetic machines, with average pain scores reduced from 7 to 2. However, as no control group was utilized in this study, the results should be interpreted with caution.

Studies that included a comparator with other intervention strategies showed that eccentric exercises had greater improvements; however, its effects on pain when compared with those of a control group are unknown. The study of Visnes et al. (2005) was the only study that investigated the effects of eccentric exercises on pain reduction while comparing with those of a control group. The study found no reduction in baseline and postintervention pain scores after an in-season eccentric exercise programme; however, no statistical comparison was made with the control group; therefore, the actual effects of eccentric exercises on pain are still unknown. When comparing passive treatment strategies such as ultrasound or transverse friction, Stasinopoulos and Stasinopoulos (2004) showed that a 4-week eccentric exercise programme was superior in reducing pain than passive interventions, with 100% of the exercise group in the significantly better or no pain categories, whereas only ≤20% of the

TABLE 5 Summary of results—between groups

Author (year)	Level of study (NHMRC)	Comparator	Pain	Function
Isometric				
Rio et al. (2015)	III-2	Isotonic exercises	+	Not reported
Rio et al. (2016)	II	Isotonic exercises	+	=
van Ark et al. (2016)	II	Isotonic exercises	=	=
HSR				
Kongsgaard et al. (2010)	III-2	Healthy matched controls—no intervention	+	+
Romero-Rodriguez et al. (2011)	IV	Nil	+	+
Eccentric				
Biernat et al. (2014)	II	Control—continue with usual training	Not reported	+
Cannell et al. (2001)	II	Leg extension/curl group	=	=
Croisier et al. (2001)	IV	No comparator	+	+
Frohm et al. (2007)	II	One-legged eccentric training	+	=
Jonsson and Alfredson (2005)	II	Concentric exercises	+	+
Purdam et al. (2004)	III-2	Standard squat	+	+
Stasinopoulos et al. (2012)	III-1	Eccentric exercises with stretching	Not reported	-
Stasinopoulos and Stasinopoulos (2004)	II	Ultrasound and transverse friction	+	Not reported
Visnes et al. (2005)	II	Control—continue with usual training	Not reported for between group	=
Young et al. (2005)	II	Step squat exercises	=	=

Note. +: significant improvement; =: no difference between groups; −: lesser improvement than comparator; NMHRC: National Health and Medical Research Council.

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passive intervention groups were in the same categories at 16 weeks' follow-up ($p < 0.001$).

Other studies compared the effects of eccentric exercises with other exercise types, namely, concentric or calisthenics exercises. Jonsson and Alfredson (2005) and Cannell et al. (2001) investigated effects of a 12-week eccentric exercise programme versus concentric programme. Both studies showed that eccentric exercises were effective in reducing pain; however, Cannell et al. (2001) showed that both eccentric and concentric exercises were equally effective, whereas Jonsson and Alfredson (2005) had to stop subject recruitment due to nearly 50% dropout rate from excessive pain in the concentric exercise group, with subsequent results showing significant pain reduction only in eccentric exercises ($p < 0.005$). The 25° decline squat was also more effective than standard squats (Purdam et al., 2004) and equally effective as step squats (Young et al., 2005) in reducing pain in individuals with PT.

4.3.2 | Function

Nine of the 10 studies evaluated function using various outcome measures such as the VISA score, jump tests, or return to sport (RTS).

VISA scores improved from baseline for all eccentric exercise groups to a similar (Frohm et al., 2007; Young et al., 2005) or greater (Frohm et al., 2007; Jonsson & Alfredson, 2005) extent compared with those of other active intervention types. When VISA scores were compared with those of control groups, conflicting results were present. Biernat et al. (2014) found significant improvement in VISA scoring after 24 weeks' eccentric exercise group as compared with control group, but Visnes et al. (2005) showed no significant difference in postintervention VISA scoring between both eccentric exercise and control groups. Addition of stretching exercises to eccentric exercises, however, showed statistically significant improvement in VISA scores ($p < 0.0005$) than purely eccentric exercises (Stasinopoulos et al., 2012).

Although jump tests showed significant improvement posteccentric exercises, no statistically significant differences were found between control groups (Biernat et al., 2014; Visnes et al., 2005), or varied eccentric exercise types (Frohm et al., 2007). RTS rates were superior in the eccentric exercises when compared with standard squat exercises (Purdam et al., 2004), with six out of eight subjects in the eccentric group RTS at 12 weeks' follow-up whereas only one out of nine subjects in the standard squat group was able to RTS. When leg extension or leg curl exercises were compared (Cannell et al., 2001), there was no significant difference between groups on ability to RTS.

5 | DISCUSSION

This systematic review was undertaken to evaluate the current evidence on the effects of isometric, eccentric, or HSR exercises on pain and function in PT. To our knowledge, this is the first review to include studies involving isometric exercises. All three exercise types have reported favourable outcomes in pain and function in the management of PT.

On the basis of the NHMRC Body of Evidence Framework, this review recommends that the findings from isometric exercises (Grade A) can be trusted to guide clinical practice, whereas eccentric exercises (Grade B) can be trusted to guide clinical practice in most clinical situations. It is recommended that HSR exercises (Grade C) should be applied carefully to individual clinical circumstances and interpreted with care.

Studies investigating isometric exercise programmes were of high quality, with an average score of 85% on the McMaster Tool, whereas eccentric exercise studies had an average score of 81.9%. Studies that investigated HSR had the least rigour, with an average score of 77.5%, but this was due to one moderate quality study by Romero-Rodriguez et al. (2011). Therefore, future research on HSR exercise programme should seek to ensure valid and reliable outcome measures are utilized, and potential contamination or cointervention through physical activity is clearly specified to reduce risk of bias.

As PT is a common condition affecting performance in sporting individuals, treatment strategies need to incorporate pain management and function improvement, especially during competitive seasons. Of the studies reviewed, isometric exercises appeared to be more suitable for short-term pain relief than HSR or eccentric exercises. In the current literature, all three studies investigating effects of isometric exercises reported significant improvement in pain during competitive season. In particular, Rio et al. (2015) reported immediate analgesia in PT after a single bout of isometric exercises, which was sustained at 45 min after intervention. Despite the extensive research in eccentric exercise programmes, only two studies investigated pain outcomes in the short term (≤4 weeks). Thus, it would seem that isometric exercises are more effective during competitive seasons, in which pain can greatly reduce athletic performance and rapid pain relief treatments are favoured. Future studies should include comparing short-term outcomes in pain for the three different exercise types.

Although isometric exercises may provide favourable short-term outcomes, no strong conclusion can be made regarding its effectiveness in the long run due to the lack of long-term studies (>6 weeks). Eccentric and HSR exercises have reported good long-term outcomes in pain and function, with one study displaying sustained effects up to 1 year (Young et al., 2005). Thus, it is probable that HSR or eccentric exercises can be implemented for improvement in long-term pain relief and knee function. Hence, appropriate selection of treatment strategies is required with consideration of the individual's sporting needs, pain levels, and goals.

Clinically, eccentric and isometric exercise programmes may be more practical approaches as minimal equipment is required (backpack, dumbbells, and decline board) and can be commonly found at home or in the clinics. However, the HSR exercise protocols investigated in these studies entailed usage of at least one strengthening machine (leg press machine) and would thus be difficult to replicate as a home programme. Therefore, compliance and ease of prescription of eccentric and isometric exercise programmes may be better than HSR exercise programmes.

Even though these different exercise interventions showed varying applicability in the treatment of PT, tendinopathies present in a continuum with different stages (Cook & Purdam, 2009) require different intervention approaches due to variable injury to the tendon

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(Cook, Rio, Purdam, & Docking, 2016). However, most studies did not indicate participants' stage of PT, which could potentially influence response to intervention. Future studies are therefore encouraged to specify the particular stage of PT to improve homogeneity of the study population. Although clinicians can thus evaluate the stages of PT during rehabilitation, the individual's pain, sporting needs, and goals must also be equally valued.

A limitation of this review is the inability to directly compare the effects of isometric, eccentric, and HSR exercises; thus, it is not clear which intervention may be more superior in the management of PT. This is due to the lack of available studies comparing the effects of these interventions. To address this, future research should aim to compare these interventions in order for better evaluation.

The present review included studies of different study designs and level of evidence based on the NHMRC hierarchy. Majority of the studies also did not justify sample size calculations, which may affect the clinical impact. However, these limitations do not appear to affect the present review despite the heterogeneity of the studies as rigorous critical assessment of each study is done to provide a sound evaluation.

6 | IMPLICATIONS FOR PHYSIOTHERAPY PRACTICE

This review identified the evidence surrounding various exercise strategies for management of individuals with PT. It is recommended that the findings from isometric exercises (Grade A) can be trusted to guide clinical practice, whereas eccentric exercises (Grade B) can be trusted to guide clinical practice in most clinical situations. It is recommended that HSR exercises (Grade C) should be applied carefully to individual clinical circumstances and interpreted with care.

Isometric exercises appear to be more effective during competitive seasons to yield short-term pain relief, whereas HSR or eccentric exercises are more suitable for long-term pain relief and improvement in knee function. As tendon pathology exists in a continuum with varying severity and irritability, appropriate selection of management technique should involve considering the individual's pain levels, sporting needs, and goals. Future research should aim to specify training approaches to different stages of PT as well as compare the effects of isometric, eccentric, and HSR exercises to determine which exercise strategy provides the best clinical outcomes in individuals with PT.

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CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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