Høgskulen på Vestlandet

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Høgskulen på Vestlandet

MASTER'S THESIS

The effect of resistance training versus other type of exercise for pain and function for patellar tendinopathy: a systematic review

Effekten av styrketrening sammenlignet med annen type trening med tanke på smerte og funksjon for patellar tendinopati: en systematisk oversikt

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Declarations

This master's thesis have followed the submission guidelines to BMC Sports Science, Medicine and Rehabilitation, see appendix 4.

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

Data sharing is not applicable to this article as no datasets were generated or analysed during the current study.

Competing interests

The authors declare no competing interests.

Founding

Not applicable

Footnotes

Not applicable.

Author's contributions

EAB and TB together produced the idea to perform a systematic review and did a pre search for current reviews before deciding on the current research of effect of resistance training in patellar tendinopathy. The two authors performed the literature search together, including search through references and grey literature. Data extractions were performed individually by both EAB and TB before together implementing them in a table. The first draft was written by EAB and TB, and revised by BEB. The narrative analysis was performed by EAB and TB. Continuous improvements were made by EAB and TB, and revised periodically by BEB. The final linguistic revision of the study was performed by all authors, and all read and commented on the manuscript before submission.

Acknowledgements

The final piece of the puzzle finally fell in place, and this master's thesis has come to an end. We have learned a lot about the process of conducting a research article, and it has challenged our ability to cooperate with one another and organise and execute a plan together in an already hectic life. We have gained valuable experience as scientists and feel we have increased our knowledge about the physiotherapy profession.

This master's thesis would not be possible without the support from our families. We would like to thank Kristine Ødegård Bjerke and Sindre Tverå Brevik for continuous encouragement throughout the process, and for giving us the time to finalise this master's degree.

Further on we would like to give a thank you to our supervisor Bård Erik Bogen for being our guide and helping hand from start to finish in this project. His experience from the field of research have been of major help and support during the project.

Finally, we would like to thank Kristine Røren Nordén and Kristine Ødegård Bjerke for revising our study

Abstract

Background: Patients diagnosed with patellar tendinopathy (PT) are commonly treated with resistance training, although the most appropriate mode of resistance training is not clear. The purpose of this study is to evaluate the newest evidence and provide an updated review of what mode of resistance training provides the best effect regarding pain and function for treating PT.

Methods: Systematic review with a narrative analysis using pain and function as primary outcome measurements. Scientific databases were searched in December 2021 and included Medline, CINAHL, Embase, PEDro, Epistemonikos and The Cochrane library. Studies investigating resistance training as an intervention compared to other types of exercise therapy or different modes of resistance training where included. The Cochrane risk of bias tool for randomised trials were used to assess the risk of bias. The National Health and Medicine Research Council Body of Evidence Framework was used to construct recommendations for clinical practice.

Results: 11 randomised controlled trials were identified for this review. Two studies received a low risk of bias, six received some concerns regarding risk of bias, while three had a high risk of bias. Eccentric, concentric, isotonic, isometric, heavy slow resistance training, moderate slow resistance training and progressive tendon loading exercise were the different modes of resistance training included.

Conclusion: The findings of this systematic review support the use of eccentric and heavy slow resistance training in treating patellar tendinopathy (grade B), while concentric exercises should not be the treatment of choice (grade D). Isotonic and isometric exercises is a satisfactory option (grade C). Moderate slow resistance and progressive tendon-loading exercises appears effective, but further research is needed (grade C).

Keywords: Patellar tendinopathy, Resistance training, Rehabilitation, Eccentric, Heavy slow resistance training

Abstrakt

Bakgrunn: Pasienter diagnostisert med patellar tendinopati behandles vanligvis med styrketrening, selv om den mest effektive modaliteten ikke er funnet. Hensikten med denne studien er å evaluere den nyeste forskningen og gi en oppdatert oversikt over hvilken type styrketrening som gir best effekt med tanke på smerte og funksjon ved behandling av patellar tendinopati.

Metode: En systematisk oversikt ved bruk av narrativ analyse med smerte og funksjons som utfallsmål. Et litteratursøk ble gjort i desember 2021, i databasene CINAHL, Embase, PEDro, Epistemonikos og Cochrane library. Studier som sammenlignet styrketrening med annen type treningsterapi eller forskjellige typer styrketrening ble inkludert. Cochrane risk of bias verktøy ble brukt for å vurdere faren for skjevhet. National Health of Medicine Research Council Body of Evidence Framework ble brukt for å gi anbefalinger for implementering i klinisk praksis.

Resultat: 11 randomiserte kontrollerte studier ble inkludert i denne systematiske oversikten. To studier hadde en lav risiko for skjevhet, seks hadde noen bekymringer med tanke på skjevhet, og tre hadde stor risiko for skjevhet. De involverte styrketrenings metodene var eksentrisk, konsetrisk, isotonisk, isometrisk, heavy slow resistance, moderate slow resistance og progressive tendon-load.

Konklusjon: Denne systematiske oversikten støtter bruken av eksentriske og heavy slow resistance øvelser ved behandling av patellar tendinopati (karakter B), mens konsentriske øvelser ikke burde være en foretrukket behandlingsmetode (karakter D). Isotoniske og isometriske øvelser er en tilfredsstillende behandlingsmetode (karakter C). Moderate slow resistance og progressive tendon-loading øvelser viser gode resultater, men videre forskning er nødvendig (karakter C).

Nøkkelord: Patellar tendinopati, styrketrening, rehabilitering, eksentrisk, heavy slow resistance

Abbreviations

BASE	Bielefeld Academic Search Engine
BMJ	British Medicine Journal
CERT	The Consensus for Exercise Reporting Template
EBP	Evidence based practice
ECCT	Eccentric training
ESWT	Extracorporeal shockwave therapy
HSR	Heavy slow resistance
MCID	Minimal clinically important change
MeSH	Medical subject heading
MRI	Magnetic resonance imaging
MSR	Moderate slow resistance
NHMRC	The National Health and Medical Research Council
NPR	Numeric pain rating
NRS	Numeric Rating Scale
PICO	Population, intervention, control group, outcome
PRISMA-MNA	Preferred reporting items for systematic reviews and meta-analyses
PROSPERO	International prospective register of systematic reviews
PT	Patellar Tendinopathy
PTLE	Progressive tendon-loading exercise

RCT	Randomised controlled trial
RM	Repetition maximum
RoB 2	Cochrane Risk of bias tool for randomised controlled trials version 2
SLDS	Single leg decline squat
US	Ultrasound
VAS	Visual Analogue Scale
VISA-P	Victorian Institute of Sports Assessment questionnaire for patellar tendon

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Introduction

In our clinical practice as physiotherapists, we often meet patients with knee pain, and patellar tendinopathy (PT) is one of the most prevalent knee conditions we encounter in active adults. As health providers, our focus and aim are to aid the patient through an effective and efficient rehabilitation, guided by evidence-based practice. Over time, research and recommendations for rehabilitation of patellar tendinopathy have evolved and been updated, paralleling other recommendations in the field of physical therapy. In order to uphold an evidence-based practice, one of the key elements is to be updated on research. International guidelines such as “UpToDate” (1) and “BMJ Best Practice” (2) are of great help. However, some guidelines are infrequently updated or are too generic to provide us with confidence when meeting individual patients in hectic workdays – where time constraints can be a barrier to seek and evaluate new research. We experience uncertainty regarding what mode of resistance training we should recommend when meeting patients with PT. Thus, we want to take a closer look at the newest research in the field of resistance training in rehabilitation of patellar tendinopathy. Following the evidence hierarchy used in evidence-based practice (EBP) (3), we seek to perform a systematic review of randomized controlled trials that investigate the effect of resistance training or strength training compared with other types of resistance training or exercise interventions. The aim of a systematic review is to summarize the available evidence in the field through a specified plan and process. This project is done within a biomedical framework, where information about participants is quantified and then analyzed using statistical methods. However, the researcher still interprets their data and their findings from their perspective and based on their experiences and beliefs. As researchers, we must strive to be aware of how our preconceptions influence how we approach this study. Also, using quantitative methodology, vital information from the participants, such as beliefs, experiences and expectations may not be captured. This is in accordance to the post-positivism (3, 4).

In chapter 1 we will present a theoretical background about patellar tendinopathy and earlier research on the field of physical training in rehabilitation of PT. The method chapter will provide an understanding of the procedures used for collecting, screening, and

evaluating the data material. In the results chapter, we will present the included studies in a table and give a narrative description of the results. We will proceed to discuss the methodology and findings in further detail in chapter 3.

1. Background

1.1 Patellar tendinopathy

PT, also known as jumper's knee, is a common overload injury frequently seen in sports that involve repetitive explosive movements such as jumping, running and turning (5, 6). The pain is often located to the inferior pole of the patella, and in the patellar tendon as increasing loads infers increasing demands on the knee extensors. In addition, tenderness, swelling and change in tendon structure may be found upon palpation of the patellar tendon (7). PT is usually a clinical diagnosis, but ultrasound (US) or magnetic resonance imaging (MRI) may be used to investigate structural changes in the tendon (8, 9). There is variance in the reported prevalence of PT depending on activity level, sport and sex. The reported prevalence in recreational athletes is 2.5% to 14%, and as high as 45% of all elite men volleyball players (10, 11). The pain associated with the condition may reduce the physical function and impair athlete sports participation. Cook et al. (5) report that of all athletes seeking help in sports medicine clinics due to PT, 33% are unable to participate in sports for at least six months. Individuals with PT also report impaired ability to perform physically demanding work (12). Pain and function have been validated and operationalized through the Victorian Institute of Sports Assessment questionnaire for patellar tendon (VISA-P) and are widely used as outcome measure in clinical practice for patients with PT as it is known as a favourable tool for assessing the severity of the condition (13).

1.2 Physiology

A tendon is a group of musculoskeletal tissue that transfers force from the muscle to bone and consists of different types of collagen fibres bundled together (14). A tendon is stronger per unit than a muscle, has a durability equal to bone, is flexible and has the ability to expand (14). Human tendons respond to increased loading by becoming stiffer; mechanics that support this adaptation include tendon hypertrophy (increased tendon cross-sectional area) and improvement in tendon material (Young's modulus) (15-17). Young's modulus is

the elastic modulus of the tendon tissue; the ratio of tensile stress to tensile strain (17). This process is often called mechanotransduction, where cells sense and respond to mechanical loads (18). During loading and stress the tendon elongates, and the fibres become more parallel. If this stress continues micro failures will occur, which is a normal response, but if the loading of the tendon continues, the healing process may cease, and pain can occur (19). Regarding PT, there are several causes for the development of the clinical impairments: excessive loading and poor technique, muscle strength and flexibility. This will again cause an inflammatory response, including T and B lymphocytes, macrophages and increased levels of interleukin-6, that can be seen in both early overload stages and in established tendinopathy (20). In microscopic assays, the tendon is characterized by abnormal collagen, tenocytes and vasculature, in addition to disordered fibres and bundles of collagen that are replaced by necrotic and degenerative tissue with signs of micro tearing (8, 19). These abnormalities can be found in different areas of the tendon, such as the main body of the tendon, its insertion, and other structures surrounding the tendon (19). This leads to the stiffness and Young's modulus is reduced (16). Restoration of normal function of the tendon requires resettlement of tendon fibres, gliding mechanism and the surrounding structures (14). Studies have shown that by implementing therapeutic exerices for these conditions, remodelling and tissue repair will occur (18), and that similar loading on different tendons gives similar flexible responses (21).

1.3 Resistance training

Resistance training, or strength training, is an exercise program that provides progressive overload to the skeletal muscles with the intent of increasing muscle strength (22). The overload principle results in different adaptations in the muscular system depending on the type, frequency, intensity, and duration of exercise (22). The muscular action in resistance training may be eccentric, concentric, isometric or isotonic. Resistance training principles of overload, specificity and progression secures subsequent adaptations after the initial phase of training, as the tissue only adapts to the specific stimulus created (23, 24). In other words, the adaptations rely on the design of the resistance training program. Several methods may be used to achieve progressive muscle overload. One of the most known methods is to consistently use repetition maximum (RM) where the load will increase automatically in ratio to increased muscle strength (23). The instruction can be in percentage of 1 RM, or it

may be submaximal where the instruction states the number of RM to be completed. Alfredson et al. (25) had great success with their heavy-load eccentric program in treatment of Achilles tendinopathy. This program allows for soreness and some pain during and after exercise. Consequently, pain has, to some degree, been acceptable and used as index to assess load and progression during rehabilitation of tendinopathy (26).

1.4 Historical process and aim of this systematic review

The guidelines for treatment of PT are not conclusive. However, resistance training has been recommended as the first-line treatment for several decades. The training protocol of Alfredson et al. from 1998 (25) for Achilles tendinopathy led to increased research in the field of tendinopathy. In 2007 Visnes and Bahr (27) published "The revolution of eccentric training as treatment for patellar tendinopathy (jumper´s knee): a critical review of exercise programmes" where they concluded that eccentric training was the most effective non-surgical treatment option for patellar tendinopathy. However, Visnes et al. (26) showed that eccentric training has reduced effect on athletes with PT during the competitive season. Since then, there has been an ongoing discussion about which mode of resistance training has the best efficacy on PT, especially in regards to different patient characteristics such as activity level.

The first known systematic review addressing treatments for patellar tendinopathy was published by Larsson et al. (6) in 2012. Their conclusion recommends physical training or resistance training as the primary treatment of patellar tendinopathy. However, they suggest future studies to analyse type of exercise, dosage, frequency and load.

As mentioned, physical rehabilitation has been recommended as the fundamental treatment of tendinopathy for several decades. Nevertheless, there is uncertainty regarding what type of training has the best effect in the treatment of PT. Multiple studies have explored different types of resistance training in the rehabilitation of PT. Eccentric training (ECCT) and heavy slow resistance (HSR) training have been the most explored measures (28, 29). To our knowledge Lim and Wong (30) from 2018 is the first and latest systematic review addressing the previously mentioned different types of resistance training in treatment of PT, without

evaluating other types of treatment, as for example extracorporeal shockwave therapy (ESWT).

Accumulating evidence over the last years suggest that exercise may be beneficial for PT. However, many of the studies compare exercise to no treatment or non-exercise interventions. Given that exercise is recommended as the primary treatment for PT, comparing exercise with other modes of exercise seems prudent. Therefore, this study seeks to find and assess evidence from randomized controlled trials where different exercise modes are compared, with the use of pain and/or function as an outcome measure. Our findings may be helpful for determining the best approach for treatment of PT. As far as we know, a knowledge synthesis on this topic has not yet been undertaken.

2. Methods

A population, intervention, control group and outcome form (PICO) was used to formulate the research question, see table 1. By using this, the eligibility criteria were set, and main search words were formed.

Table 1: PICO

Population	Intervention	Control group	Outcome
Individuals diagnosed with patellar tendinopathy	Resistance training or strength training	Exercise therapy or resistance training	Function and pain

The research question for this study is "What mode of resistance training is more effective on pain and function for individuals with patellar tendinopathy?".

This study was conducted as a systematic review and aligns with the "Preferred Reporting Items for Systematic Reviews and Meta-Analyses-MNA's" (PRISMA-MNA) guidelines (31) and was registered in the International Prospective Register of Systematic Reviews (PROSPERO #CRD420221287389 on December 15, 2021) (32).

2.1 Eligibility

Studies reporting pain and function as outcomes in a PT population were included. Pain could be reported during activity, and function is normally reported through VISA-P in individuals with PT. The age criteria were > 18 years. However, we chose to include studies with mean age over 18 years since older adolescents also are affected by PT. PT was diagnosed clinically and/or by use of diagnostic imaging such as MRI or ultrasound. Treatment criteria were all types of resistance training in the intervention group, and resistance training or other types of exercise therapy in the comparison group. Studies with other types of interventions, such as manual therapy, ESWT, injections or no treatment at all in the intervention or comparison group were excluded. Previous treatment or duration of symptoms of the condition was not a criterion. Neither was the type of population, such as athletes/non-athletes, specific age range or sex. Only Randomized Control Trial (RCT) studies were included, and inclusion criteria were set to studies published in English or Scandinavian language due to limited time to translate.

2.2 Search strategy

A literature search was performed by the two authors on December 3, 2021, via Medline, EMBASE, CINAHL, Epistemonikos, PEDro and The Cochrane library. The main search words were “patellar tendinopathy” and “jumpers’ knee” in combination with different kinds of medical subject headings (MeSH) terms, and variations for muscle contraction, resistance training and load using boolean operators AND and OR. We also searched for synonyms of tendinopathy, such as tendinitis, tendonitis and tendinosis. The searches were performed using the search methods specified for the different databases with help from a librarian (Appendix 1).

The articles identified from the initial search were screened by the two authors individually using Rayyan (33), a research tool for screening and selecting studies with blinding between the reviewers. In the first step, duplicates were removed, then eligibility was judged by scanning titles and abstracts of identified studies. In the last step, the articles were read in full-text and assessed for eligibility. Between each step, any discrepancies between the authors were discussed and resolved by consensus. Previous systematic reviews that were identified through the screening process, were screened for appropriate

RCTs. Additionally, the reviewers performed citation tracking via Google scholar and reference screening of the included studies. Grey literature was search through Google Scholar, Clinicaltrials.gov and Bielefeld Academic Search Engine (BASE), and screened for possible missed unpublished studies.

2.3 Risk of bias – Strength of evidence assessment

The recently updated version of Cochrane "Risk of bias in randomized trials" (RoB 2) (34) tool was used to assess the risk of bias for each of the included studies. This was performed separately by the reviewers with the assessment form where each study was given a score of low, some concerns or high risk of bias in the domains of the randomization process; deviations from intended interventions; missing outcome data; measurement of the outcome; selection of the reported result. An overall risk of bias score was determined through a predefined algorithm summarizing the domains. Any disagreement between the reviewers was resolved by mutual agreement.

The National Health and Medical Research Council's (NHMRC) Body of Evidence Framework and Evidence Hierarchy (35) was used to assess the level of evidence. The authors individually used this guide to screen the included studies regarding level of evidence. In addition to sum up the supported evidence in a statement using the five components of the body of evidence framework: evidence base; consistency; clinical impact; generalizability; applicability. If the authors did not agree on the grade of recommendation, it was resolved by consensus discussion.

2.4 Data extraction

Key information from the included studies was extracted independently by the reviewers and organized in table 2. This includes authors and year published, population characteristics such as mean age, sex, duration of symptoms, activity level and if other types of training were allowed during the study. Type of intervention and comparison is included, along with a detailed description of loading and progression. The VISA-P ranges from 0-100 with a higher score indicating less pain and better function. The score is described as mean and between group difference, when possible, with p-value in the table. If not, the median is included. The pain outcome is described as Visual Analogue Scale (VAS) from 0-10 or 0-100

when possible or with Numeric Rating Scale (NRS) from 0-10. Outcome data were extracted at baseline, short term (4-6 weeks), medium term (12 weeks) and long term (24-52 weeks) follow-up.

2.5 Data synthesis

We initially sought to conduct a meta-analysis as 10 out of 11 studies used VISA-P as outcome measure. However, this was not possible due to lack of precise VISA-P scores in several of the included studies. Due to time constraints, no researchers were contacted for additional information about study characteristics or missing data. We concluded that a meta-analysis of the available data would not give a representative result of the effect of each exercise modality, and a narrative analysis was considered more appropriate. The narrative synthesis was grouped by exercise modalities to give a better presentation of the summarized generalizability and effect.

2.6 Ethical aspects

We found that there was a current need for this systematic review, and we have tried our best to carry out the results from the primary studies in a correct and ethically sound manner. The included studies are all approved by local ethics committees. No adverse advents are reported in the studies, but one study stopped recruiting at half time control due to ethical reasons as participants experienced increased pain (36).

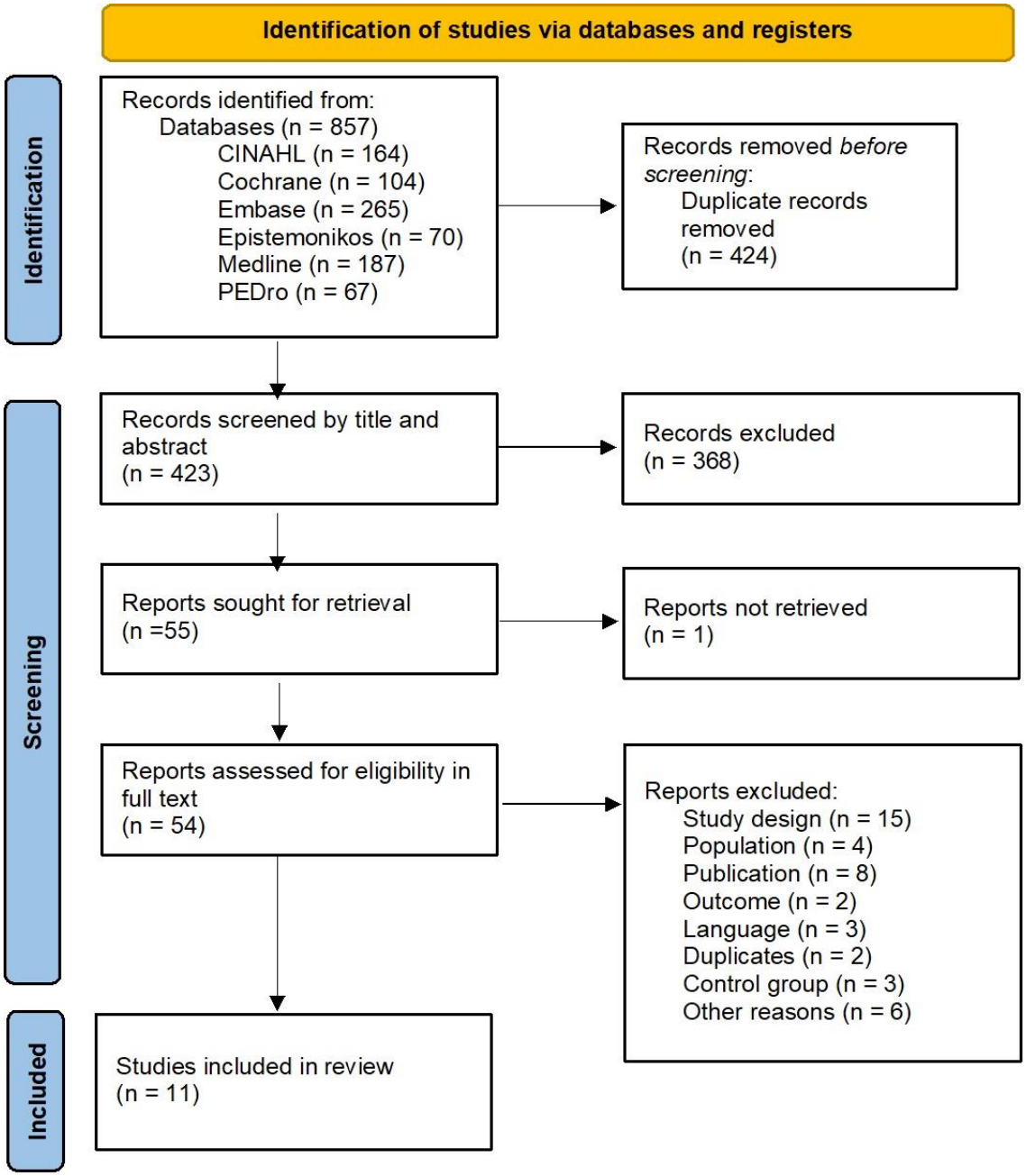
3. Results

3.1 Search result

A total of 857 records were identified through our search strategy. After removing duplicates, 423 records were screened by title and abstract. 55 reports were sought for retrieval, and after help from an expert, 54 reports were retrieved and read in full text. A total of 846 records were excluded from the initial search result, yielding 11 studies (36-46) that were included in this systematic review (Figure 1). In the full-text assessment, most of the excluded studies were due to publication type such as protocol articles. Dimitrios et al. (47) was excluded due to its controlled trial design. Well-known studies that investigate

physical treatment of PT, like Visnes et al. (26) and Kongsgaard et al. (29) were excluded as their comparison or control group did not meet the eligibility criteria of organized physical exercise.

Figure 1: PRISMA flow diagram



3.2 Study characteristics

The 11 studies (36-46) have a total of 327 participants (87% male) assigned to a total of 22 exercise protocols, as shown in table 2. There is some heterogeneity in the study populations with regards to activity level and age, but all studies include participants that are physically active, and the mean age range from 22,5 to 30,5 years. All the included RCT studies compare two resistance training modes. Four studies hypothesized that one exercise mode is superior to the comparator: Agergaard et al. (37) – HSR, Rio et al. and van Ark et al. (43, 45) – isometric, and McDonald (41) – eccentric with concentric exercise. Two studies (43, 45) have the same clinical trial registration but are included as they present different information regarding outcome measurement and follow-up time. Out of the 11 studies, eccentric training is the most included modality – six studies; isotonic – five studies; isometric – three studies; HSR – two studies; concentric – one study; eccentric + concentric – one study; moderate slow resistance (MSR) – one study; progressive tendon-loading exercise (PTLE) – one study. Follow-up measurements range from directly post intervention to 52 weeks post baseline predominates. VISA-P was used in 10 out of 11 studies included. VAS or NRS was used in 10 studies for reporting pain during activity.

Table 2: Study characteristics, interventions and outcomes in the individual studies

Study (year)	Population	Intervention	Comparison	Outcome (VISA-P, points 0-100)			Pain (VAS or NRS)
				Intervention	Comparison	Between-group difference	
Agergaard et al. (36)**(2021)**	N=42 Age (mean): 30,5y 42M Activity level: recreational athletes, mean 8 h/w. DOS (Mean): 7,1 months Activity allowed: Yes if pain NRS-score < 3 points	MSR (55% of 1RM) exercise for 12w (n=21) 3 sessions per week. Bilat leg press. Unilat knee ext. 3 sets x 15-7 reps with 3 sec CON and 3 sec ECC phase per rep. Progression: every second week 5RM submaximal test.	HSR exercise (55% - 90% of 1RM) for 12w (n=21) 3 sessions per week. Bilat leg press. Unilat knee ext. 3 sets x 15-4 reps. with 3 sec CON and 3 sec ECC phase per rep. Progression: every second week 5RM submaximal test.	Mean ± SEM (95% CI) Baseline: 59.9 ± 2.5 (54.8 to 65.0) 12 weeks: 72.5 ± 2.9 (66.5 to 78.5) 52 weeks: 82.6 ± 2.5 (77.4 to 87.8) Significant effect of time from baseline to 12 and 52 weeks ($p < 0.01$ and $p < 0.0001$ respectively).	Mean ± SEM (95%CI) Baseline: 58.8 ± 4.3 (49.8 to 67.8) 12 weeks: 70.5 ± 4.4 (61.3 to 79.7) 52 weeks: 79.7 ± 4.6 (70.0 to 89.4) Significant within-group improvement from baseline to 12 and 52 weeks ($p < 0.01$ and $p < 0.0001$ respectively).	Mean Baseline: 1.1 12 weeks: 2.0 52 weeks: 2.9 No significant difference between groups	NRS measured during different activities at baseline, 6-, 12- and 52 weeks. NRS during SLDS test decreased significantly from baseline to 12 weeks in both groups ($p < 0.0001$), but not from 12 weeks to 52 weeks (MSR: $p = 0.73$; HSR: $p = 0.37$).
Breda et al. (37) **(2021)**	N=67 Age (mean): 24y 58M, 9F Activity level: athletes, at least 3 t/w. DOS (Median IQR): 24,6 months. Activity allowed: Not in intervention group. Allowed after 4 weeks in comparison group if pain VAS-score = 3 points (scale 0-10).	PTLE for 24w (n=37) 4 stages with specific approach: <u>Stage 1:</u> daily isometric exercises. <u>Stage 2:</u> isometric exercises on every first day, and isotonic (dynamic) exercises on every second day. <u>Stage 3:</u> same as stage 2 + plyometric (energy storage) loading and running exercises on every third day. <u>Stage 4:</u> sport-specific exercises on every 2-3 day with isometric exercises from stage 1 on remaining days. Stage progression criteria: pain provocation test: VAS-score = 3 points (scale 0-10). Each stage completed for at least 1 week.	Pain-provoking EET for 24w (n=30) 2 stages with specific approach: <u>Stage 1:</u> pain provoking EET with SLDS, twice daily in 12 weeks. Pain VAS-score = 5 points (scale 0-10). <u>Stage 2:</u> sport-specific exercises + stage 1 exercises twice a week. Stage progression criteria: complete adherence to stage 1, and pain VAS-score = 3 points (scale 0-10) with additional weights during eccentric exercises.	Unadjusted mean (SD) Baseline: 55.0±13.1 12 weeks: 71.2±13.8 24 weeks: 82.8±13.1 Baseline – 12 weeks: 16,2 Significant within-group improvement from baseline to 12 and 24 weeks ($p < 0.001$).	Unadjusted mean (SD) Baseline: 55.6±13.2 12 weeks: 67.7±15.4 24 weeks: 73.7±17.3 Baseline – 12 weeks: 12,1 Significant within-group improvement from baseline to 12 and 24 weeks ($p < 0.001$).	Unadjusted mean Baseline: -0.6 12 weeks: 3.5 24 weeks: 9.1 No significant difference between groups after 12 weeks ($p = 0.69$). Significant difference between groups after 24 weeks in favour PTLE ($p = 0.023$)	N/A

Cannell et al. (39) **(2001)**	N=19 Age (mean): 26y 13M, 6F Activity level: athletes, no time info. DOS (Mean): 3,7 months Activity allowed: No	ECC exercise for 12w (n=10) One session a day, 5 days per week. Drop squat. 3 sets x 20 reps body weight + specific increasing hand weights when drops were completed easily.	Isotonic exercise for 12w (n=9) One session a day, 5 days per week. Leg ext. Leg curl. 3 sets x 10 reps. Starting with 5 kg weight on leg ext. and 2.5 kg on leg curl. Specific increasing weights when able to complete 3 sets x 10 reps.	N/A	N/A	N/A	VAS-score (1-10) No exact numbers mentioned, significant within group pain reduction ($p < 0.01$) in both groups at 12 weeks. No significant between-groups difference.
Frohm et al. (40) **(2007)**	N=20 Age (mean): 27y 16M, 4F Activity level: competitive and recreational athletes, no time info. DOS: Continuous over 3 months or recurrent over 6 months. Activity allowed: Yes, after 6 weeks	Brosman ECC overload training for 12w (n=11) 2 sessions of 70 min per week. ECC squats in hydraulic machine. 4 sets x 4 reps. Progression: First set warm up, remaining 3 sets maximum effort.	One-legged standard ECC training according to Curwin for 12w (n=9) 2 sessions of 70 min per week. ECC SLDS: 3 sets x 15 reps. Progression: 5 kg increased load if VAS-score < 3 for a set.	Median (95% CI) Baseline: 49 (38 to 61) 12 weeks: 86 (71 to 92) Significant within-group improvement from baseline to 12 weeks ($p < 0.001$).	Median (95% CI) Baseline: 36 (23 to 61) 12 weeks: 75 (46 to 83) Significant within-group improvement from baseline to 12 weeks ($p < 0.001$).	Median Baseline: 13 12 weeks: 11 No significant difference between groups	VAS-score (0-10) <u>Intervention:</u> Baseline: median 4 12 Weeks: median 0 $p = 0.003$ <u>Comparison:</u> Baseline: median 5 12 Weeks: median 1 $p = 0.008$
Jonsson and Alfredson (36) **(2005)**	N=15, 19 tendons Age (mean): 24.9y 13M, 2F Activity level: athletes, no time info. DOS (Mean): 17,5 months Activity allowed: after 6 weeks if no severe pain.	ECC quadriceps training for 12w (n=10) Sessions twice a day, 7 days per week. ECC SLDS to 70° knee flexion. 3 sets x 15 reps. Progression: Individual load adjustment based on desire of pain provoking training.	CON quadriceps training for 12w (n=9) Sessions twice a day, 7 days per week. Concentric SLDS from 70° knee flexion. 3 sets x 15 reps. Progression: Individual load adjustment based on desire of pain provoking training.	Mean (SD) Baseline: 41.1±17.9 12 weeks: 83.3±23.4 Significant within-group improvement from baseline to 12 weeks ($p < 0.005$).	Mean (SD) Baseline: 40.7±16.3 12 weeks: 37.0±4.6 $p < 0.34$ No significant within-group improvement from baseline to 12 weeks ($p < 0.34$).	Mean Baseline: 0.4 12 weeks: 46.3 Significant difference after 12 weeks in favour eccentric quadriceps training ($p < 0.001$)	VAS-score (0-100) Mean (SD) <u>Intervention:</u> Baseline: 72.7±6.2 12 weeks: 22.5±26.4 $p < 0.005$ <u>Comparison:</u> Baseline: 74.3±16.6 12 weeks: 68.0±18.5 $p < 0.34$ Significant between-group difference after 12 weeks in favour eccentric quadriceps training ($p < 0.01$).

MacDonald et al. (41) **(2019)**	N=31 Age (mean): 29y 29M, 2F Activity level: active-duty soldiers. DOS (Mean): 10,8 months Activity allowed: Yes	ECC plus CON training for 12w (n=14) ECC SLDS: sessions twice a day, 7 days per week. 3 sets x 15 reps. Concentric hip muscle strengthening exercises: Sessions three times per week. 3 sets x 10 reps, Progression: Individual load adjustment based on desire of pain provoking training.	ECC training for 12w (n=17) ECC SLDS: sessions twice a day, 7 days per week. 3 sets x 15 reps. Progression: Individual load adjustment based on desire of pain provoking training.	Mean±SD Baseline: 51.8±13.7 4 weeks: 52.7±25.2 12 weeks: 63.8±25.1 24 weeks: 72.0±28.0 No significant within-group improvement from baseline to 12 weeks (p = 0.105) but significant within-group improvement from baseline to 24 weeks (p = 0.002)	Mean±SD Baseline: 51.7±14.2 4 weeks: 60.5±11.9 12 weeks: 67.3±16.1 24 weeks: 70.4±18.8 Significant within-group improvement from baseline to 12 weeks (p = 0.002) and baseline to 24 weeks (p = 0.001)	Mean Baseline 0.1 4 weeks: 7.8 12 weeks: 3.4 24 weeks: 1.6 No significant difference between groups at any timepoint.	VAS-score (0-10) Mean (SD) <u>Intervention:</u> Baseline: 4.1 ± 2.0 4 weeks: 3.5 ± 2.3 12 weeks: 2.9 ± 2.2 24 weeks: 1.9 ± 1.9 p < 0.093 at 12 weeks <u>Comparison:</u> Baseline: 3.9 ± 1.7 4 weeks: 3.7 ± 1.9 12 weeks: 2.3 ± 1.8 24 weeks: 2.6 ± 2.0 p < 0.004 at 12 weeks No significant between-groups difference.
Pearson et al. (42) **(2018)**	N=16 Age (mean): 28y 16M Activity level: active in sports, no time info. DOS: 148,2 months Activity allowed: No	Short duration ISO for 4w (n=8) Isometric leg ext. 5 times per week 24 sets x 10sec ISO contraction, 20sec rest between sets.	Long duration ISO for 4w (n=8) Isometric leg ext. 5 times per week 6 sets x 40sec ISO contraction, 80sec rest between sets.	Median (IQR) Baseline: 53 (14.5) 4 weeks: N/A	Median (IQR) Baseline: 58 (12.8) 4 weeks: N/A	N/A	VAS-score (0-10) during SLDS. Not stated in numbers, just figure 2. Significant reduction in pain in both groups (mean difference = 1.66, 95% CI, 0.13–3.19, p < 0.01). No significant between-groups difference.
Rio et al. (43) **(2016)**	N=20 Age (mean): 22,5y 18M, 2F Activity level: subelite and elite athletes, no time info. DOS: Not specified. Activity allowed: Yes	ISO training for 4w (n=10) 4 sessions per week Single leg ext. machine: 5 sets x 45sec hold at 60 ° flexion at 80% MVIC	Isotonic training for 4w (n=10) 4 sessions per week Leg ext. machine: 4 sets x 8 reps. with 4sec ECC and 3sec CON phase per rep at 80% 8RM	Median (range) Baseline: 72.5 (13-88) 4 weeks: 84 (41-100)	Median (range) Baseline: 69.5 (46-83) 4 weeks: 80 (60-94)	Median Baseline: 3.0 4 weeks: 4.0 p = 0.99 No significant between-groups difference at 4 weeks.	NRS (0-10) during SLDS before and after every session. <u>Intervention:</u> Mean±SD change = 1.8±0.39 <u>Comparison:</u> Mean±SD change = 0.9±0.25 Significantly greater immediate analgesia with isometric training then isotonic training.

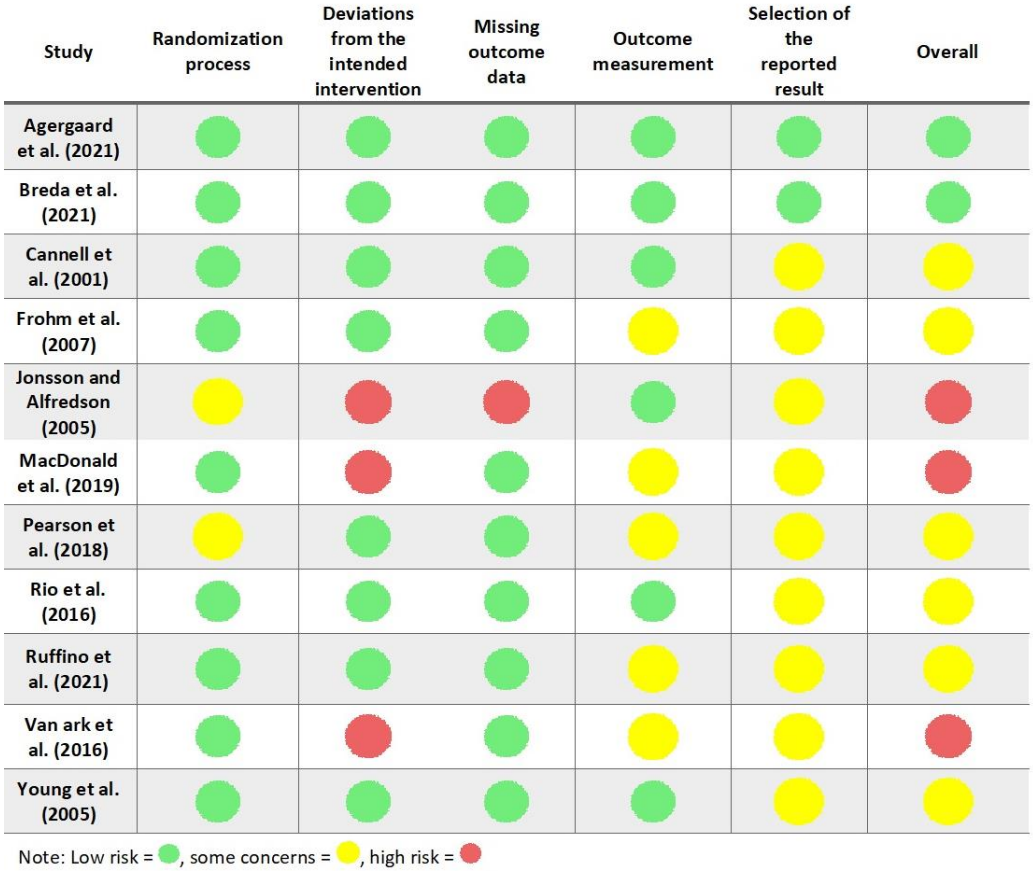
Ruffino et al. (44) **(2021)**	N=41 Age (mean): 29,6y 40M, 1F Activity level: recreational athletes, mean 5,4 h/w. DOS (Mean): 13,4 months Activity allowed: Yes	Inertial flywheel resistance training for 12w (n=20) 3 sessions per week. Three inertial flywheel machines: two-legged squat, leg press and knee ext. 4 sets x 10 reps. Progression: Week 1-6: 2.5 kg flywheel (moment inertia 0.05 kg/m^2) Week 6-12: 4 kg flywheel (moment inertia 0.10 kg/m^2)	HSR training for 12w (n=21) 3 sessions per week. Two-legged squat. Two-legged press. Two-legged hack squat. 4 sets x 15-6 RM with 3 sec CON and 3 sec ECC phase per rep. Progression: RM reduction in specified weeks.	Baseline 6w 12w Not stated in numbers, just figure 2. Significant within-group improvement from baseline to 12 weeks.	Baseline 6w 12w Not stated in numbers, just figure 2. Significant within-group improvement from baseline to 12 weeks.	N/A No statistically significant between-groups difference.	VAS-score (0-10) during SLDS. Mean (95% CI) <u>Intervention:</u> Baseline: 7.2 (6.4-8) 12 weeks: 3.7 (2.44-4.96) <u>Comparison:</u> Baseline: 6.2 (5.34-7.06) 12 weeks: 2.9 (2.04-3.76) No significant between-groups difference at 12 weeks (p = 0.286)
Van ark et al. (45) **(2016)**	N=20 Age (mean): 23y 27M, 2F Activity level: subelite and elite athletes, at least 3 times/w DOS (mean): 35.8 Activity allowed: Yes	ISO exercise for 4w (n=10) 4 sessions per week Single leg ext. machine: 5 sets x 45sec hold at 60 ° flexion with 80% MVC Progression: increasing weight by 2.5% every week if possible.	Isotonic exercise for 4w (n=10) 4 sessions per week Single leg ext. machine: 4 sets x 8 reps. with 4sec ECC and 3sec CON phase per rep at 80% 8RM Progression: increasing weight by 2.5% every week if possible.	Median (IQR) Baseline (n=8): 66.5 (59.5-75.8) 4 weeks: 75.0 (72.5-87.0) Significant within-group improvement (p = 0.028)	Median (IQR) Baseline (n=10) 69.5 (55.0-75.8) 4 weeks: 79.0 (67.0-86.0) Significant within-group improvement (p = 0.003)	Median (IQR) Baseline: 12.5 4 weeks: 4.0 No significant between-groups difference.	NRS (0-10) during SLDS Median (IQR) <u>Intervention</u> Baseline: 6.3 (5.3-7.0) 4 weeks: 4.0 (2.0-5.0) <u>Comparison</u> Baseline: 5.5 (4.0-6.0) 4 weeks: 2.0 (1.0-3.0) No significant between-groups difference at 4 weeks (p = 0.208)
Young et al. (46) **(2005)**	N=17 Age (mean): 27,3y 13M, 4F Activity level: elite athletes. DOS: Not specified Activity allowed: Not specified, preseason intervention.	ECC decline squat for 12w (n=9) Twice a day ECC SLDS to 60 ° knee flexion 3 sets x 15 reps. Progression: adding 5 kg increased load to a backpack in increments.	Isotonic step squat for 12w (n=8) Twice a day Single leg ECC and CON squat on 10 cm step 3 sets x 15 reps. Progression: adding 5 kg increased load to a backpack in increments.	Mean (SD) Baseline, 12 and 52 weeks: not stated in numbers, just figure 3A. Significant within-group improvement at 12 and 52 weeks (p < 0.05).	Mean (SD) Baseline, 12and 52 weeks: not stated in numbers, just figure 3A. Significant within-group improvement at 12 and 52 weeks (p < 0.05).	Not stated in numbers No significant between-groups difference at any time.	VAS-score (0-10) during weekly activity Mean (SD) Baseline, 12 and 52 weeks: not stated in numbers, just figure 3B. Significant within-group improvement at 12 and 52 weeks (p < 0.05). No significant between-groups difference

Note. CI: Confidence interval; CON: Concentric; DOS: Duration of symptoms; ECC: Eccentric; EET: Eccentric exercise therapy; Ext: Extension; F: Female; HSR: Heavy slow resistance; ISO: Isometric; IQR: Interquartile range; M: Male; MSR: Moderat slow resistance; MVC: Maximal voluntary contraction; MVIC: Maximal voluntary isometric contraction; N/A: Not available; NRS: Numeric Rating Scale; PTLE: Progressive tendon-loading exercises; Reps: repetition; RM: Repetition maximum; SLDS: Single leg decline squat; VAS: Visual analogue scale; VISA-P: Victorian Institute of Sport Assessment questionnaire, patellar tendon; y: y

3.3 Risk of bias – Strength of evidence assessment

The RoB 2 was used to assess the risk of bias (34). Breda et al. (38) and Agergaard et al. (37) had a score of low risk in all the components and received a total score of low risk. Six studies earned a total score of some concerns regarding the risk of bias (39, 40, 42-44, 46). This was due to of lack of outcome measurement (three out of six) and due to no information regarding if the pre-specified analysis plan was finalized priori to complete data collection (six out of six). The randomization process in Pearson et al. (42) was deemed to be of some concern. Three included studies received a high risk of bias score (36, 41, 45). Jonsson and Alfredson (36) had missing outcome data and deviations from the intended intervention and the latter also pertains to Van ark et al. (45) and Macdonald et al. (41). The score and summary of all studies are shown in figure 2. See appendix 2 for further information about each study.

Figure 2: Risk of Bias for randomized controlled trials – individual studies



Regarding the level of evidence using the NHMRC (35), all studies in this review were randomized controlled trials and therefore earned a Level II score of evidence. Considering the Body of Evidence Framework, we opted to categorise the studies based on type of muscle action used in the intervention or the comparison group. They were divided into either isometric, concentric, eccentric, isotonic, eccentric combined with concentric, MSR, HSR or PTLE. There is good evidence for eccentric exercise and HSR training in treating PT (grade B). Grade C was given to isometric, isotonic, MSR and PTLE, and provides some support for recommendations for use in clinical practice. MSR and PTLE were included in only one study each and could therefore not receive a higher grade than C. Concentric and eccentric combined with concentric, earned a score of grade D which means that the grade of recommendation is weak and this mode of resistance training should be applied with caution in the treatment of PT. The grade of recommendation is summarized in table 3. See appendix 3 for the body of framework of each intervention.

Table 3: Grade of recommendations, NHMRC

Grade of recommendation	Description
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 but care should be taken in its application
D	Body of evidence is weak, and recommendation must be applied with caution

Overall	Isometric	Concentric	Eccentric	Isotonic	Eccentric + Concentric	MSR	HSR	PTLE
Evidence base	C	D	B	C	D	B	B	B
Concistency	B	NA	B	B	NA	NA	B	NA
Clinical impact	C	D	B	B	D	B	B	B
Generalizability	B	B	B	B	C	B	B	B
Applicability	B	B	B	B	B	B	B	B
Overal recommendation	C	D	B	C	D	C	B	C

3.4 Exercise modalities

3.4.1 Eccentric

Six studies (36, 38-41, 46) with a total of 94 participants, 85% men, with different description of activity level (sub- and elite athletes, active-duty military, athletes, competitive- and recreational athletes) were randomized to seven protocols. Five protocols (36, 38, 40, 41, 46) utilized 25-degree single leg decline squat (SLDS) where the eccentric phase is done on the affected leg, while the unaffected leg is used as support back to starting position to avoid concentric phase. Cannell et al. (39) applied two-legged drop squats where the knees unlock rapidly and drops from standing position until the thighs are short of parallel to the ground. Frohm et al. (40) compares two different eccentric exercises where one is SLDS and the second is Brosman overload squat in a hydraulic machine. Three programs are described as pain-provoking (VAS-pain $\geq$ 5 point) and four completes exercise with acceptable pain (VAS-pain < 5 points). All protocols have load progression based on VAS-pain scores.

Studies utilising eccentric SLDS showed significantly increased VISA-P score from baseline to 12 weeks. Breda et al. (38) and Young et al. (46) also showed significant improvement from baseline to long-term at 24 and 52 weeks. Both eccentric protocols of Frohm et al. (40) showed significant improvement from baseline to 12 weeks. All except Breda et al. (38) used VAS-pain during activity as outcome measurement and showed significant reduction in pain 12 weeks after baseline.

3.4.2 Heavy Slow Resistance

HSR training was investigated in two studies (37, 44). A total of 42 participants, 41 men, with mean age of 30 and 31 years and activity level set to recreational athletes were allocated to this modality. Both training protocols lasted for 12 weeks with 3 sessions per week, and had a specific plan for load progression for each training week. There were some differences regarding exercises and total volume (sets and repetitions) between the two protocols. Each study performed the exercises with a total of 6 seconds per repetition; 3 seconds in concentric phase and 3 seconds in eccentric phase.

Both studies (37, 44) used VISA-P as primary outcome and showed significant improvement from baseline to 12 weeks. Agergaard et al. (37) also showed significantly improved VISA-P

score from 12 weeks to 52 weeks follow-up. Both studies reported reduced pain score during SLDS from baseline to 12 weeks.

3.4.3 Isotonic

Five studies (39, 43-46) investigated some form of isotonic exercise where both concentric and eccentric phase are a part of the exercise. Two studies (43, 45) operate with the same exercise protocol and participants, but with different measurement time. The total of unique participants is 48, with a blend of all levels of active athletes. The mean age ranges from 23 and 30 years, with few women included. All except two had training protocols that lasted for 12 weeks, but with different training design. van Ark et al. (45) and Rio et al. (43) protocol lasted for 4 weeks aiming to investigate short-term pain relief with same design only different measurement time. Ruffino et al. (44) used inertial flywheel, a strength training modality using a rotating disc instead of traditional weights.

All except one study (39) used VISA-P as outcome measurement. Ruffino et al. (44) and Young et al. (46) showed significant improvement in VISA-P score from baseline to 12 weeks. Cannell et al. (39), Young et al. (46) and Ruffino et al. (44) showed reduction in VAS-pain from baseline to 12 weeks. Rio et al. (43) and van Ark et al. (45) investigated short-term pain relief and the measurements were assessed at baseline and after 4 weeks with increase of VISA-P score. Rio et al. (43) measured pain during SLDS before and after every session and showed a mean reduction change at 0.9 points immediately after exercise.

3.4.4 Isometric

Three studies (42, 43, 45) investigate the short-term effect of isometric exercise on pain relief and function in pre- and in-season patients. Two studies (43, 45) operate with the same exercise protocol and participants, but with different measurement time. The assigned participants were in-season sub and elite basketball and volleyball players with a mean age of 23 years (43, 45), and preseason sports athletes with a mean age of 28 years (42). The three studies lasted for 4 weeks, and they all used leg extension exercise. Pearson et al. (42) investigated the difference in effect between short- and long isometric contraction in the two groups. Rio et al. (43) and Pearson et al. (42) measured pain during SLDS immediately pre- and post-exercise sessions, and both showed immediate mean pain reduction of 1.8 and

1.66 respectively after exercise – with no between group difference in short- and long contraction. van Ark et al. (45) showed a reduction of 2.3 points in NRS-pain during SLDS from baseline to 4 weeks. van Ark et al. (45) and Rio et al. (43) found a positive change in VISA-P after 4 weeks while Pearson et al. (42) did not include VISA-P in the follow-up.

3.4.5 Progressive Tendon-Loading Exercise

Only one study (38) utilised PTLE with 37 participants assigned, 31 men, with a mean age of 24 years and activity level described as athletes involved in sports activities at least three times per week. The exercise protocol contained four stages with a specific approach. The first stage included daily isometric single-leg leg-press or leg-extension of 5 repetitions of 45 seconds mid-range hold at 70% of maximal muscle contraction. Second stage included the isometric exercise performed every first day, with isotonic single-leg leg-press with 4 sets of 15 repetitions with progression to 4 sets of 6 repetitions with increased knee flexion, every other day. Stage three included the same as stage one and two with plyometric exercises such as jump squats performed every third day starting with 3x10 using both legs and progression to 6x10 with one leg. Finally, the fourth stage consisted of sport-specific exercises every 2-3 days with the exercises from stage one during the rest days. Progression to next stage was determined by pain during one single-leg-squat.

VISA-P outcome measurement were collected at baseline, 12 and 24 week and showed significant improvement at both follow-up time. Pain alone was not reported.

3.4.6 Moderate Slow Resistance

Agergaard et al. (37) compared MSR with HSR in a 12-week training program with the purpose of investigating if the load magnitude affects the efficacy of treating PT. The MSR group consisted of 21 male recreational athletes with a mean age of 31 years. MSR training consisted of one bilateral leg press exercise and one unilateral knee extension exercise where the concentric phase and eccentric phase lasted for 3 seconds each. The loading program was performed 3 times a week, and the resistance load started at 55% of 1 RM and was maintained throughout the whole period. Outcome measurements were registered at baseline, 6, 12 and 52 weeks. There was significant change in VISA-P in time at both 12 and

52 weeks ($p < 0.01$ and $p < 0.0001$ respectively). NRS-pain during SLDS was found to decrease significantly from baseline to 12 weeks.

3.4.7 Eccentric + Concentric

Eccentric exercise combined with a concentric exercise was a part of one study (41). Fourteen active-duty soldiers, 13 men, with a mean age of 31 years was included. The exercise was performed as eccentric SLDS two times a day with 3 sets of 15 repetitions with pain up to 5 on numeric pain rating (NPR) during exercise. Adjustments of squat depth and increased external load were done if possible. The additional concentric exercise was performed with elastic bands in abduction, extension, and external rotation 3 times a week with 3 sets of 10 repetitions. Resistance was adjusted by the ability to perform 10 correctly repetitions. Macdonald et al. (41) reported an improvement in VISA-P score during all the follow-up measurements (4, 8, 12 and 24 weeks), but only the improvement at 24 weeks reached statistical significance ($p = 0.002$).

3.4.8 Concentric

Jonsson and Alfredsson (36) was the sole study that included concentric exercise as treatment for PT. Seven participants, six men, presenting with a total of nine painful patellar tendons were included. Mean age was 24 years and participants were described as athletes. The exercise was performed as a concentric SLDS, from 70 degrees knee flexion to gradually full extension. The training was done twice daily with 3 sets of 15 repetitions. The exercise was supposed to be painful, based on individual acceptable pain. If there was no pain the external load was increased. Three participants with four out of nine tendons dropped out after 6 weeks of training due to severe pain. The outcomes were measured at baseline, 6 and 12 weeks. This study showed no effect of concentric exercise as treatment for PT with a decrease in VISA-P and VAS-pain after 12 weeks.

3.4.9 Comparison of exercise modalities included in this review

Eccentric exercise was the most common intervention used in the included studies, and was compared against PTLE, isotonic, concentric and eccentric in combination with concentric. Eccentric showed better results compared to pure concentric training and protocols that used a combination of eccentric and concentric exercises. PTLE showed significantly better

result regarding pain and function compared to eccentric at long-term follow-up (24 weeks). There was no detectable between-group difference when eccentric was compared with isotonic.

HSR training displayed no superior effect when compared to MSR training at medium (12 weeks) and long-term follow-up, nor with isotonic training at medium-term follow-up.

Isometric was compared against isotonic, and had no superior effect after 4 weeks, but the immediate pain reduction was significantly better with isometric training compared to isotonic.

4. Discussion

In this systematic review, we have investigated the evidence for resistance training in the treatment of function and pain in PT. Well known exercise modalities such as eccentric, isometric, isotonic, concentric and HSR were included together with lesser-known methods such as PTLE and MSR. All treatment methods showed significant within-group improvements on function and pain, except for concentric exercise and eccentric exercise combined with concentric exercise, which only showed significant effect after 52 weeks. There was no significant between-group difference in nine out of 11 included studies that showed significant improvements. In summary, there is grade B evidence for use of eccentric and HSR training, grade C for isometric, isotonic, MSR training and PTLE, and grade D evidence for concentric exercise and eccentric exercise in combination with concentric exercise using the NHMRC Body of Framework (35).

4.1 Results

It is not surprising that there were few between group differences, as exercise modalities that are not fundamentally different were compared. Eccentric muscle contractions are assumed to be beneficial due to the capability in producing greater force than during concentric exercise, and heavy slow resistance training involve longer time under tension which again leads to an increased adaptive response (48). It is therefore possible that the benefits lie in higher loads rather than any specific exercise modality. However, Agergaard et

al. (37) study has shown that the load magnitude of both HSR and MSR generated an increase in VISA-P scores, and decrease in pain, and that a higher load of 90% of 1RM is not clinically preferable to a moderate load of 55%.

Eccentric exercise is the modality that is backed by the largest amount of evidence regarding physical treatment for PT and has been shown to be effective in previous systematic reviews (30, 49, 50). Despite satisfactory clinical outcomes with isolated eccentric training, there are concerns regarding applicability across various patient demographics. Most of the eccentric protocols instruct training twice a day with 3 sets of 15 repetitions, thus totalling 180 daily repetitions, which is time consuming and may reduce the feasibility and compliance. This high volume does not align with scientific resistance training recommendations to enable optimal physiological adaptations for improving clinical outcome (24). In addition, some clinicians may be hesitant to use this modality because it can be pain-provoking (7), and could lead to decrease in intensity and repetitions when performing the intervention, especially when treating non-athletic patients (51). There are indications of central sensitization in persistent tendinopathy (52). Central sensitizations may, with variable degree, influence psychosocial factors like stress, fear of pain, peer pressure and behavioural factors like thoughts and beliefs that may lead to overuse or inadequate adaptions (52). This is often seen in the context of other chronic musculoskeletal pain syndromes like low back pain and fibromyalgia. There are not found any superior effect of pain-free exercises versus painful exercises in managing chronic musculoskeletal pain in medium- and long-term outcomes (53). Nevertheless, the psychosocial factors indicate that clinicians should be aware of the individual differences when choosing exercise modalities for patients with persistent pain. On the other hand, when pain has accrued for shorter period, peripheral sensitization is normal response (54), and perhaps factors like fear of pain doesn't need that much of consideration. Due to concerns regarding pain, Malliaras et al. (7) suggested a progressive resistance training program following stages with different exercise modalities. Breda et al. (38) used a PTLE program and is the only study included in this review using an exercise progression protocol, and so results should be interpreted with caution. However, this study had a relatively large sample size, and the results seem promising enough to warrant further research. It is possible that the increasing popularity after Alfredson et al. (25) eccentric protocol were known, have brought an overrated effect due to the number of

studies investigating eccentric training in treatment of PT. The overall methodological quality of the studies investigating eccentric exercise is moderate, something that has been demonstrated in previous reviews as well (30, 50, 55). Despite the improved results in both eccentric exercise and PTLE training, the eccentric training is surpassed by the effect of PTLE on function and pain in PT in long term (24 weeks) as measured by VISA-P.

Rio et al. (43) and Pearson et al. (42) found immediate pain relief after isometric exercise, and van Ark et al. (45) and Pearson et al. (42) found increased VISA-P score 4 weeks after isometric training. Pearson et al. (42) reported that short and long muscle contractions had similar effects. However, we have not identified any studies that investigate the long-term effects and there is a current need for further studies. A new crossover study by Holden et al. (56) used the same protocol as Rio et al. (43) but were unable to replicate the results in a larger population where both sexes and all types of sports were included. The cause of the altered result is not identified, but there are reasons to question the generalizability of primary results to a more heterogenic population.

Concentric exercise was included as the comparator in Jonsson and Alfredsson (36), and there were no significant within-group changes in pain. However, several participants in the concentric group withdrew due to severe pain, and study enrolment was ceased because of the poor results in the group performing concentric exercise. Conversely, most participants in the eccentric group were satisfied with their results. The exercise dose was similar for both groups, and the authors state that it is difficult to explain why there should be such pronounced differences. In a study of Achilles tendons, Rees et al. (57) found that similar forces were produced during eccentric and concentric exercises, but that there were high frequency tissue oscillations during eccentric exercises and suggest that this may be the reason for the differences in outcome. This may be supported by two of the included studies where no between-group difference were detected when comparing pure eccentric to isotonic exercise, which includes an eccentric and concentric phase (39, 46). Four of the included studies (37, 38, 40, 41) showed improvements of 13 points or higher, or an improvement of 15,4-27% of inverted baseline scores, which is the minimal clinically important change (MCID) for VISA-P (58). In these studies, HSR, MSR, PTLE, eccentric and

eccentric with concentric were the intervention or comparator, emphasizing that it is difficult to identify one exercise modality as superior to others.

We did not select studies based on participant characteristics, but most of the studies included athletes, and men were predominant in the study populations. Former studies suggest that PT is more common for men than for women (8), but recent studies have shown that there is no clear gender difference, and that PT is more related to multiple biological and physiological factors (59). Lian et al. (10) found PT to be twice as common among male athletes compared to female athletes, and this could be explained by the lower forces generated by the quadriceps and patellar tendon in women versus men. With regards to transferability, all studies were not explicit to type of sport or at which level the participants played. The same appears in the results of HSR training where the population is homogeneous and thus transferable, but the result is valid only for male recreational athletes around 30 years of age. Even though men may be afflicted by PT to a greater extent than women, the number of assigned women in the studies included in this review is remarkably poor. Further research should include a larger population of women to see if the effect of treatment modalities are equal across gender.

In this review, there is poor to moderate risk of bias in most of the included studies, and the statistical power is limited. Caution should be taken when applying the recommendations, and more high-quality studies are required.

4.2 Strengths and limitations

Strengths include the use of several databases. Satisfactory internal validity was attempted by performing every screening and assessment step by the two reviewers separately. All included studies (36-46) are RCTs, which is necessary when investigating effect. However, only two of the studies (37, 38) have a low risk of bias. The placebo effect is reduced as both groups exercise (60). Comparing the effect of already known treatment methods is perceived as ethically virtuous as opposed to comparison to no treatment in the control group (61).

There are some important limitations to this systematic review. The authors are novices in performing a systematic review, and we acknowledge that our lack of experience may have limited how we undertook the study. Furthermore, we chose to solely include self-report outcomes in the systematic review. Measures of physical performance are relevant for many athletes, and self-report may be systematically more positive than observed function. Stevens-Lapsley et al. (62) found, in a study of persons who had undergone knee arthroplasty, that self-reports did not reflect the deficits in physical function that were revealed through physical tests. Although the patient groups are different, some of the mechanisms may be similar, for example how participants' beliefs and experiences influence how they perceive their physical functioning. In our thesis, all the studies included exercise for both the intervention and the control group, so it is difficult to explain how beliefs and experiences would be systematically different. We emphasize the importance of subjective experience of improvement as outcome measures, like VISA-P, in patients. Nonetheless, physical performance would possibly be less influenced by context and previous experience, and should be included in studies of PT.

The lack of precise VISA-P scores in several of the included studies made it difficult to perform a meta-analysis. In a meta-analysis, pooling of studies would increase statistical power. As such, intervention effects that are not seen in single studies due to low statistical power could become clearer with pooled data. Therefore, our findings may be less clear than they ideally would. Due to limited time no researchers were contacted for more information regarding study characteristics or missing data which could have made a meta-analysis possible.

In order for research to be replicable and applicable to clinical practice, researchers should report their methods extensively and transparently. The Consensus for Exercise Reporting Template (CERT) is a checklist for reporting in trials using exercise as an intervention that has gained interest in recent years (63). We have not used this checklist in our systematic review, but this would have been useful for determining how easily the findings could be adapted by clinicians and other researchers.

4.3 Clinical practice

Previous guidelines have recommended eccentric exercise and HSR training as the main modes of resistance training for rehabilitation of PT. Based on our current systematic review, these training modalities can be further recommended for use in clinical practice. Nevertheless, both Agergaard et al. (37) and Breda et al. (38) report that MSR training and PTLE can prove equally beneficial, if not better effect in the long run. Patients in clinical practice all have different characteristics, as well as subjective pain and function level experience. There are several differences between the training protocols that are presented in this review, for example simultaneous participation in sports and pain response during training. In addition to the recommendation, individual needs and preferences should be considered when choosing exercise modalities in clinical practice.

5. Conclusion

The findings of this systematic review support the use of eccentric and HSR training in treating PT (grade B). These modalities have been shown to give an increase in function and decrease in pain during both moderate and long term, while isometric could be the preferred option in-season for pain relief (grade C). Isotonic have demonstrated an effect in both short and medium term (grade C). Concentric exercise modalities should not be the treatment of choice when dealing with PT, since it has shown no advantage compared to other interventions (grade D). PTLE and MSR appears effective in both medium and long term, although its effect is based on limited evidence (grade C). Future research should emphasise PTLE, preferably compared to HSR, to determine if PTLE is a viable option to eccentric and HSR training. More high-quality research in populations with different activity levels are recommended.

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Appendix

Appendix 1. Search strategy

Search name: Patellar tendinopathy
Date run: 3/12-2021
Example from MEDLINE

#	Searches	Results	Type
1	patella* tendinopath*.tw.	579	Advanced
2	jumpers knee.tw.	194	Advanced
3	or/1-2	722	Advanced
4	Exercise/	131982	Advanced
5	Exercise Therapy/	46517	Advanced
6	Resistance Training/	11187	Advanced
7	Muscle Contraction/	98441	Advanced
8	Isometric Contraction/	16218	Advanced
9	Isotonic Contraction/	688	Advanced
10	((strength* or resist* or weight*) adj3 (training or exercise*)).tw.	35049	Advanced
11	high load.tw.	2236	Advanced
12	low load.tw.	1512	Advanced
13	isometric.tw.	35579	Advanced
14	eccentric.tw.	14597	Advanced
15	concentric.tw.	18546	Advanced
16	isotonic.tw.	14709	Advanced
17	heavy slow resistance.tw.	29	Advanced
18	or/4-17	351263	Advanced
19	3 and 18	189	Advanced

Appendix 2. Risk of bias assessment

Study (year)	**Cochrane risk-of-bias tool for randomised controlled trials, version 2**						
	Randomisation process	Deviation from intended interventions	Missing outcome data	Measurement of the outcome	Selection of the reported result	Overall risk	Explanation
Agergaard et al. (2021)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	NA
Breda et al. (2021)	Low risk	Low risk	Low risk	Low risk	Low risk	Low risk	NA
Cannel et al. (2001)	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns	No prespecified analysis plan
Frohm et al. (2007)	Low risk	Low risk	Low risk	Some concerns	Some concerns	Some concerns	Outcome assessors aware of the intervention received by study participants
Jonsson and Alfredson (2005)	Some concerns	High risk	High risk	Low risk	Some concerns	High risk	Failures in implementing the intervention that could have affected the outcome
Macdonald et al. (2019)	Low risk	High risk	Low risk	Some concerns	Some concerns	High risk	Non-adherence, and no analysis with regards to this
Pearson et al. (2018)	Some concerns	Low risk	Low risk	Some concerns	Some concerns	Some concerns	Outcome assessors aware of the intervention received by study participants
Rio et al. (2016)	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns	No prespecified analysis plan
Ruffino et al. (2018)	Low risk	Low risk	Low risk	Some concerns	Some concerns	Some concerns	Not blind to group allocation, no prespecified analysis plan
Van ark et al. (2016)	Low risk	High risk	Low risk	High risk	High risk	High risk	Non-adherence, and no analysis with regards to this. No prespecified analysis plan
Young et al. (2005)	Low risk	Low risk	Low risk	Low risk	Some concerns	Some concerns	No prespecified analysis plan

Appendix 3. National Health and Medical Research Council (NHMRC) Grades of recommendation

Eccentric	Grade	Comments
Evidence base	B- Good One or two level II studies with low risk of bias (1/6). 4 level II studies with moderate risk of bias. 1 level II study with high risk of bias.	Quantity: 6 studies with eccentric as either intervention or control Participants: 96 (total in eccentric groups) Level of studies: All six are level-II
Consistency	B- Good Most studies consistent and inconsistency may be explained	All studies reported within group improvement Similar interventions Same outcome measures taken at short to medium time (12-24w). One study missing VISA-P, and one study missing VAS.
Clinical impact	B- Good Substantial	Short time before effect (12w) Increased function and reduced pain (VISA-P) and VAS No unwanted events
Generalizability	B- Good population/s studied in the body of evidence are similar to the target population	Population is similar to target population. Age and activity level similar Few females included overall
Applicability	B- Good applicable to healthcare context with few caveats	Trained personnel and clinic time available. 1/7 interventions need hydraulic machine, which is most likely not available everywhere
Overall recommendation	B- Body of evidence can be trusted to guide practice in most situations	Moderate to good quality of studies, especially risk of bias. Within group improvements for all studies.

Concentric	Grade	Comments
Evidence base	D- Poor Level II studies with high risk of bias.	Quantity: 1 study with concentric as either intervention or control. Participants: 9 Level of study: Level II study
Consistency	Not applicable	Only one study
Clinical impact	D- Poor Slight or restricted	No potential benefit. Little effect in short term. Dropouts because of pain during intervention
Generalizability	B- Good	Age and activity level together with duration of symptoms is similar.

	Population studied in the body of evidence are like the target population.	
Applicability	B- Good Applicable to healthcare context with few caveats	Decline board and trained personnel available
Overall recommendation	D- Body of evidence is weak and recommendation must be applied with caution	Low quality of study and several dropouts. Only one study with high risk of bias

Isometric	Grade	Comments
Evidence base	C- Satisfactory Level II studies with moderate risk of bias (1/3). Level II studies with high risk of bias. (2/3).	Quantity: 3 studies with isometric as either intervention or control Participants: 36 Level: Level II studies
Consistency	B- Good Most studies consistent and inconsistency may be explained	2/3 reported within group improvement regarding VISA-P. All three reported improvement in pain after 4w.
Clinical impact	C- Satisfactory Moderate clinical impact	Pain reduced after 4w. 2 of the studies are built up on the same participants
Generalizability	B- Good Population studied in the body of evidence are similar to the target population.	Age and activity level together with duration of symptoms is similar. Few females included
Applicability	B- Good Applicable to healthcare context with few caveats	Knee extension machine and trained personnel available
Overall recommendation	C- Body of evidence provides some support for recommendation but care should be taken in its application	Low quality regarding risk of bias. 2 of the studies are built up on the same participants

Isotonic	Grade	Comments
Evidence base	C- Satisfactory Level II studies with moderate risk of bias (3/5). Level II studies with high risk of bias (2/5).	Quantity: 5 studies with isotonic as either intervention or control. Participants: 57 Level: Level II studies
Consistency	B- Good Most studies consistent and inconsistency may be explained	Reported decreased pain and improved VISA-P. Different measurements of pain (VAS or NSR during weekly activity or single leg decline squat) and time of outcome measures.

Clinical impact	B- Good Substantial clinical impact	Improved function and decreased pain. Short-, medium- and long-term effect (4-12-52w)
Generalizability	B- Good Population studied in the body of evidence are like the target population.	Population is similar to target population. Age and activity level similar
Applicability	B- Good Applicable to healthcare context with few caveats	Equipment and trained personnel available in most cases, inertial flywheel not available everywhere.
Overall recommendation	C- Body of evidence provides some support for recommendation but care should be taken in its application	Risk of bias is high or moderate. 2 of the studies are built up on the same participants

Eccentric +Concentric	Grade	Comments
Evidence base	D- Poor Level II studies with high risk of bias.	Quantity: One study Participants: 14 Level: Level II study
Consistency	Not applicable	Only one study
Clinical impact	D- Poor Slight or restricted	No favourable effect in combining eccentric with concentric compared to just eccentric.
Generalizability	C- Satisfactory population/s studied in body of evidence differ to target population for guideline, but it is clinically sensible to apply this evidence to target population	Active-duty military personnel.
Applicability	B- Good Applicable to healthcare context with few caveats	Equipment and trained personnel available
Overall recommendation	D- Body of evidence is weak and recommendation must be applied with caution	High risk of bias, only one study. Effect on VISA-P between 4-24w

Moderate slow resistance	Grade	Comments
Evidence base	B- Good One level II study with low risk of bias.	Quantity: One study Participants: 21 Level: Level II study
Consistency	Not applicable	Only one study
Clinical impact	B- Good Substantial clinical impact	Reported significant increased VISA-P after 12 and 52w, and pain after 12w No unwanted events
Generalizability	B- Good Population studied in the body of evidence are similar to the target population.	Mean age of 30,5 and athletes, but only male
Applicability	B- Good Applicable to healthcare context with few caveats	Equipment is available, personnel must be trained and instructed in the protocol.
Overall recommendation	C- Body of evidence provides some support for recommendation but care should be taken in its application	Good study with many participants with improved function and decreased pain, but only one study – which means it achieves its highest possible grade

Heavy slow resistance	Grade	Comments
Evidence base	B- Good One level II study with low risk of bias. One level II with moderate risk of bias	Quantity: 2 studies with heavy slow resistance as either intervention or control Participants: 42 Level: Level II studies
Consistency	B- Good Most studies consistent and inconsistency may be explained	Similar exercises with some adjustments regarding sets and repetitions. Outcome measurements at the same time, 12w
Clinical impact	B- Good Substantial clinical impact	Reported within group effect in both pain and VISA-P Effect after both 12w and 52w No unwanted events
Generalizability	B- Good Population studied in the body of evidence are similar to the target population.	Athletes and recreational activity level. Age similar in both studies and target population
Applicability	B- Good Applicable to healthcare context with few caveats	Equipment are available, personnel must be trained and instructed in the protocol.
Overall recommendation	B- Body of evidence can be trusted to guide practice in most situations	Both studies showed similar results, even though one of the studies have a high risk of bias

Progressive tendon load	Grade	Comments
Evidence base	B- Good One level II study with low risk of bias.	Quantity: One study Participants: 37 Level: Level II study
Consistency	Not applicable	Only one study
Clinical impact	B- Good Substantial clinical impact	Increased VISA-P and decreased pain with significant difference compared to control group.
Generalizability	B- Good Population studied in the body of evidence are similar to the target population.	Both male and female Athletes, with exercise at least three times a week
Applicability	B- Good Applicable to healthcare context with few caveats	Equipment are available, personnel must be trained and instructed in the protocol.
Overall recommendation	C- Body of evidence provides some support for recommendation but care should be taken in its application	Good study with low risk of bias, many participants and good effect after 12w and 24w - which means it achieves its highest possible grade

Appendix 4. Submission Guidelines

https://bmcsportsscimedrehabil.biomedcentral.com/submission-guidelines/preparing-your-manuscript/review

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Criteria

Reviews are summaries of recent insights in specific research areas within the scope of *BMC Sports Science, Medicine and Rehabilitation*. Key aims of Reviews are to provide systematic and substantial coverage of a research or clinical area of wide interest or to present a critical assessment of a specified area. A review must focus on recent research and on a topic that is timely and relevant to the field. All Reviews published by *BMC Sports Science, Medicine and Rehabilitation* are peer-reviewed.

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Preparing your manuscript

The information below details the section headings that you should include in your manuscript and what information should be within each section.

Please note that your manuscript must include a 'Declarations' section including all of the subheadings (please see below for more information).

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The title page should:

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  - "A versus B in the treatment of C: a randomized controlled trial", "X is a risk factor for Y: a case control study", "What is the impact of factor X on subject Y: A systematic review"
  - or for non-clinical or non-research studies: a description of what the article reports
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