

Causative factors and rehabilitation of patellar tendinopathy: A systematic review

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Background: Patellar tendinopathy (PT) is a common chronic pathology of the knee, with a high prevalence in athletes and the general population.

Objectives: The objectives of this article were to systematically investigate all the evidence applicable to the intrinsic and extrinsic causative factors and rehabilitation of PT, and then integrate and link rehabilitation with the main causative factors identified.

Method: The Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines were followed. Various tools were used to evaluate the methodological quality of the eligible articles. Data were interpreted descriptively, and the causative factors and rehabilitation of PT were analysed.

Results: Twenty studies were included in the review. The distinctive factor responsible for PT is the mechanical theory. Seven intrinsic and four extrinsic risk factors were identified, with the main intrinsic risk factors being muscle flexibility and strength, and extrinsic risk factors being acquisition and level of skills. PT can be treated with numerous different therapeutic modalities, although eccentric muscle training showed exceptional results. The intrinsic and extrinsic risk factors can only be transformed and reduced by rehabilitation, which is inevitable to improve PT pain and function.

Conclusion: The essence of an integrated management protocol for PT is to identify the dominant contributing factors, whether intrinsic or extrinsic, and to reduce the load on the patellar tendon by modifying these factors by either rehabilitation intervention or direct modification of the equipment or environment to obtain a positive outcome towards pain management and function.

Introduction

Patellar tendinopathy (PT) is a common chronic pathology of the knee, with a high prevalence in both athletes (Frizziero *et al.* 2014) and the general population (Toppi *et al.* 2015). It is characterised by microscopic tears and tissue degeneration because of excessive and repetitive mechanical loading of the patellar tendon. Epidemiological studies indicate that tendon injuries account for possibly up to 50% of injuries sustained during sporting activities, with tendon overuse because of running-associated sports accounting for nearly 30%. Athletes with PT can experience uncomfortable symptoms and decreased function for up to 3 years (Saggini *et al.* 2012), which have a negative effect on quality of life (Toppi *et al.* 2015). The risk factors for and treatment of PT can be challenging and unsatisfying (Silva *et al.* 2015). A number of risk factors for the development of PT have been identified, such as age, gender, heavy physical work, type of training surface, high training volume and level of participation (De Vries *et al.* 2015a). A better understanding of the aetiology of PT will facilitate the identification of modifiable risk factors and make a valuable contribution to planning of preventative measures and interventions (Van der Worp *et al.* 2012). It is unclear how these risk factors specifically relate to the available rehabilitation options for PT.

Only one published systematic review article (Van der Worp *et al.* 2011b) indicated the risk factors for PT, whereas three others described different rehabilitation options for PT (Frizziero *et al.* 2014; Malliaras *et al.* 2013; Mani-Babu *et al.* 2015). However, none of these reviews integrated the risk factors and rehabilitation. One of the objectives of this review was therefore to integrate the risk factors and rehabilitation of PT in a systematic review. This followed a methodical investigation of all evidence applicable to the intrinsic and extrinsic causative factors as well as rehabilitation of PT, as another objective of this review. Addressing the intrinsic and extrinsic factors with rehabilitation is considered to be a good measure in the successful rehabilitation of PT, and therefore, this systematic review provides a unique

and valuable perspective for healthcare professionals involved in the management of PT, by integrating the causative factors and rehabilitation of PT.

Research design

Research method

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used for the systematic review (Moher *et al.* 2009). Published articles were considered based on the inclusion and exclusion criteria listed in Box 1.

Search strategy

Electronic databases available on EBSCOhost were searched and included Academic Search Complete, Africa-Wide Information, MEDLINE with Full Text, AHFS Consumer Medication Information, CINAHL with Full Text, ERIC, Health Source – Consumer Edition, Health Source: Nursing/Academic Edition, Humanities Source, PsycARTICLES, PsycEXTRA, PsycINFO, PsycTESTS, SocINDEX with Full Text, SPORTDiscus with Full Text. The search was conducted by the authors and one independent researcher ('research team' hereafter), for articles published between January 2010 and October 2015. This specific time period was selected, as this review aimed to follow up on a previous systematic review conducted by Van der Worp *et al.* (2011b) on PT that included articles up to August 2010.

The search strategy included the following keywords in order to identify all the relevant articles for inclusion in this review:

("patella* tendinopath*" or (patella* and tendinit*))

AND

("intrinsic factor*" or age or gender or "body composition*" or "fat mass" or "body weight" or "body mass index" or injur* or "joint instability*" or "musc* strength" or "musc* power" or "range of motion" or "range of movement" or "anatomic* alignment*" or "postural stability*" or "sport* specific technique*" or "level of skill*" or "skill* level*" or "extrinsic factor*" or strapping or bracing or "foot wear" or footwear* or shoe* or "training surface*" or "eccentric decline squat*" or "skill* acquisition" or proprioception* or flexib* or "muscle activat*" or etiolog* or aetiolog*)

BOX 1: Inclusion and exclusion criteria.

Inclusion criteria

Publication period: Articles published between January 2010 and October 2015

Research design: Systematic reviews, randomised clinical trials, non-randomised clinical trials, quantitative research studies, qualitative research studies

Age of participants: Between 18 and 60 years

Research focus: Causative factors (intrinsic and extrinsic) and/or rehabilitation of patellar tendinopathy (PT)

Exclusion criteria

Population: Participants with other knee pathologies, previous knee surgery or injection therapy in the knee

Research focus: Patellar tendinopathy (PT), but excluding causative factors and/or rehabilitation

Language of article: Articles published in any other language than English

Availability of article: Articles of which only the abstract was available

AND

(rehab* or "return to sport" or "return to play" or "motor re-educat*") and (exercise* or train* or sport*)

This search was conducted twice during the study period (approximately 3 months apart), in order to cross-reference the results and ensure that all possible articles eligible for inclusion were identified. The combination of results from the two searches yielded 120 possible articles for inclusion before the elimination of duplicate studies (Figure 1).

Study selection

The study selection process from the eligible 120 articles was independently conducted by all members of the research team, against the inclusion and exclusion criteria (Box 1). When there was vagueness concerning the eligibility, a conversation was held between all the members of the research team to resolve any disagreement. Figure 1 shows the process of the search strategy to determine the final sampling of the articles for the review.

Methodology quality appraisal

Different methodology quality appraisal tools were selected to evaluate the eligible articles because of the different research designs of these articles. Twenty-five articles were assessed for methodology quality scoring after which 20 articles were included in this systematic review (see Figure 1). Table 1 lists more details of the methodological quality appraisal for the final 20 articles included in this systematic review. The independent researcher was responsible for verifying the data obtained from the scoring done by the authors. The average total methodological quality score for all the articles included ($n = 20$) was 72%.

Data extraction

A custom-made Excel spreadsheet was developed to extract applicable information from each article and a summary is displayed in Tables 2, 3 and 4. Information was documented with regard to the age, gender, body composition, muscle strength and flexibility, anatomical alignment, medical history, strapping or orthosis, training surfaces, and acquisition and level of skill of the participants described in each article. The researcher conducted the data extraction autonomously. The information recorded was confirmed by the rest of the research team who checked it jointly for mistakes after completion of the process.

Data analysis

Pooling of the data for the purpose of framing a meta-analysis was not an aim of the systematic review because of dissimilarities in the outcomes. Data were summarised descriptively by means of gathering information about the characteristics of the causative factors and rehabilitation of PT to form a data analysis.

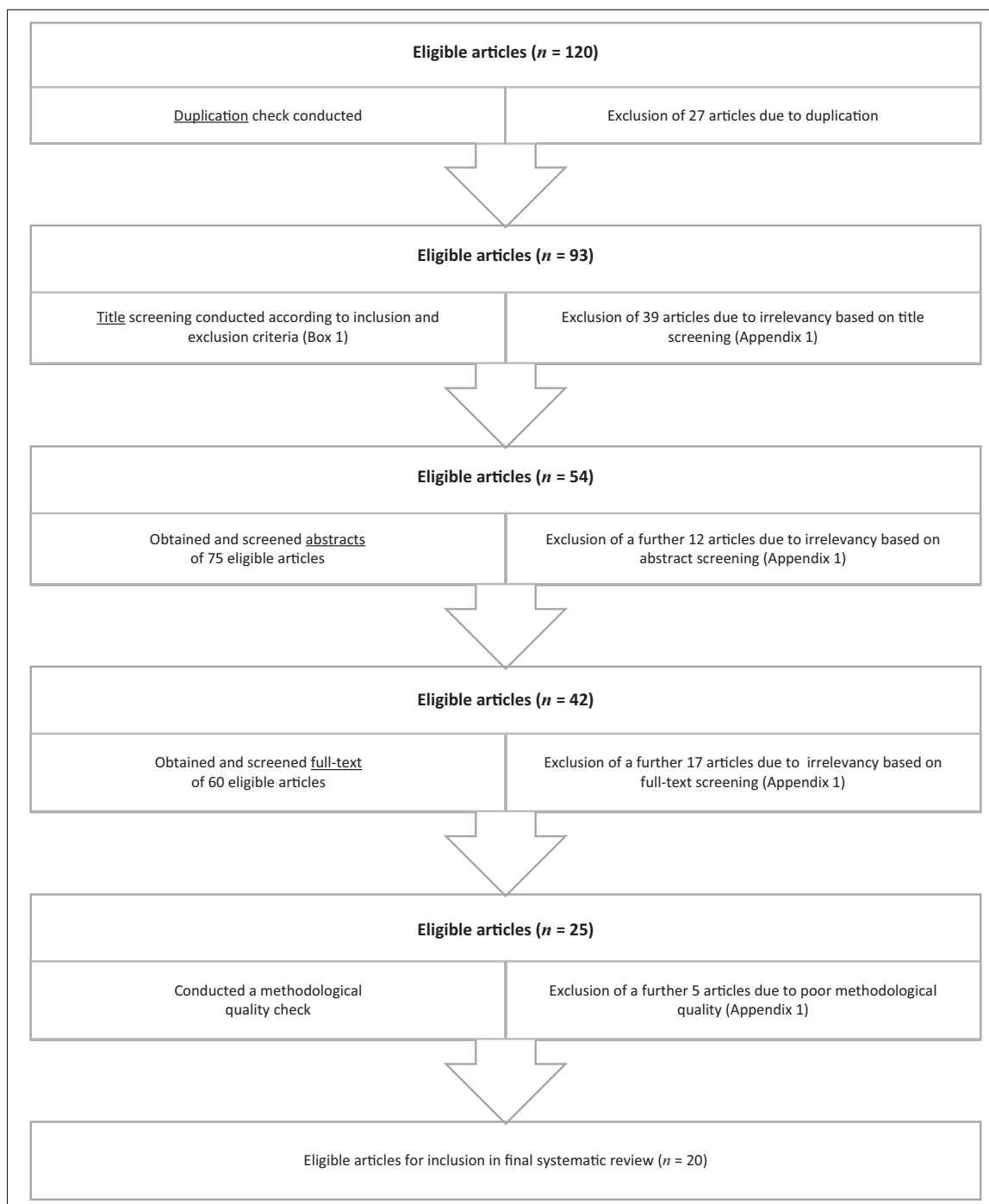


FIGURE 1: Flow diagram of search strategy to determine the final sample of the articles for the review.

Results

The search strategy yielded 20 articles that met the described inclusion criteria shown in Box 1. Results from these 20 articles are included and discussed in the next section.

Demographic information

The age of the study participants varied for each of the 15 studies in this review that revealed the age of the participants (see Tables 2, 3 and 4). All the study participants were older than 18 years, with Toppi *et al.* (2015) having the oldest study participants (with a mean age of 67 years). The

majority of the study participants were aged between 18 and 35 years. According to Van der Worp *et al.* (2012), the probability of sustaining PT decreased with age, but they argued that the risk for PT increased for individuals older than 30 years of age because of changes in the tendon structure and its mechanical properties. However, the correlation between PT and age is still uncertain (Van der Worp *et al.* 2012).

Fourteen of the studies included in this review (Tables 2, 3 and 4) described gender with 13 indicating that the majority of participants were men. Three of these studies determined gender to be a risk factor, with men more likely to develop

TABLE 1: Methodology assessment tools.

Study design	Assessment tools	Quality scoring range	Average quality scoring	Reasons for exclusion
Systematic reviews	AMSTAR Checklist	6/11–10/11 (<i>n</i> = 4)	71% (<i>n</i> = 4)	<ul style="list-style-type: none"> No <i>priori</i> design No duplicate study selection and data extraction At least two electronic sources searched No status of publication used as an inclusion checklist No list of studies provided, no characteristics of included studies No scientific quality of articles Scientific quality not used in formulating conclusions No appropriate methods to combine findings No publication bias assessed No conflict of interest stated
Randomised clinical trials	PEDro Scale	8/11–9/11 (<i>n</i> = 3)	76% (<i>n</i> = 3)	<ul style="list-style-type: none"> Less than 50% on methodology quality scoring
Non-randomised clinical trials	Downs & Black Checklist	16/27–20/27 (<i>n</i> = 3)	68% (<i>n</i> = 3)	<ul style="list-style-type: none"> Less than 50% on methodology quality scoring
Qualitative research	Methodology Checklist – Qualitative	10/14–13/14 (<i>n</i> = 5)	82% (<i>n</i> = 5)	<ul style="list-style-type: none"> Less than 50% on methodology quality scoring
Quantitative research	National Institute for Health and Excellence Checklist	15/27–21/27 (<i>n</i> = 5)	63% (<i>n</i> = 5)	<ul style="list-style-type: none"> Less than 50% on methodology quality scoring

TABLE 2: The intrinsic and extrinsic causative factors for PT in the articles included in the review.

Authors (date)	Study design	Study participants	Causative intrinsic factors	Causative extrinsic factors
De Vries <i>et al.</i> (2015a)	Survey-based prospective cohort study	Age: 18–35 years Gender: Male and female Level of skills: Non-elite and elite volleyball and basketball players	Gender: Male > female	Acquisition of skills: Heavy physical work
De Vries <i>et al.</i> (2015b)	Randomised clinical trial	Age: 18–50 years Gender: Male > female	Not included	Strapping or orthosis: ↓ PT pain, ↑ proprioception, female > male ↑ outcome
Toppi <i>et al.</i> (2015)	Prospective cohort study	Age: 40–67 years Gender: Female	Muscle strength: Larger vastus medialis muscle	Level of skills: Higher levels of physical activity
Van der Worp <i>et al.</i> (2012)	Cross-sectional study	Age: 18–35 years. Gender: Male and female	Age: 18–35 years; decreased risk for PT with increasing age Gender: Male > female for PT	Level of skills: Higher level of participation is a risk factor for PT Acquisition of skills: Some volleyball positions are more likely to develop PT Type of sport: Volleyball > basketball
Van der Worp <i>et al.</i> (2011b)	Systematic review	Not included	Body composition: Weight, body mass index, waist-to-hip ratio Anatomical alignment: Leg-length discrepancies, arch height of the foot Muscle flexibility: Decreased quadriceps, hamstring flexibility Muscle strength: Decreased quadriceps strength and vertical jump performance	Not included
Van der Worp <i>et al.</i> (2011a)	Online survey: descriptive	Age: 18–35 years Gender: Male and female	Gender: Twice as high in males than in females	Acquisition of skills: Heavy physical work
Souza <i>et al.</i> (2010)	Experimental study	Age: Experimental group mean 28.9 years; control group mean 24.9 years Gender: Male	Anatomical alignment: ↑ hip extensor contribution and ↓ knee extensor contribution in total support moment	Not included

PT than women (De Vries *et al.* 2015a; Van der Worp *et al.* 2011a, 2012). This hypothesis could be justified in that the quadriceps muscle generates more force during contraction in male than in female athletes, as well as the fact that women's oestrogen plays a role in influencing the tendon structures positively (Van der Worp *et al.* 2012). Nevertheless, PT is a multifactorial pathology and it is challenging to obtain direct evidence with regard to gender differences and the part played by oestrogen (Van der Worp *et al.* 2011a).

Intrinsic causative factors

Muscle flexibility

According to the three systematic reviews, impaired lower limb muscle flexibility was noted as being a risk factor for PT. The muscles described in these reviews are the iliotibial band (ITB) (Samukawa 2011), quadriceps and hamstring muscles (Silva *et al.* 2015; Van der Worp *et al.* 2011b). Stiffness in the ITB can cause lateral patella movement because of its anatomical attachments and can also contribute to decreased lower limb flexibility involving the quadriceps and hamstring muscles (Samukawa 2011). Impaired quadriceps

and hamstring muscle flexibility intensify tendon strain during joint movement, leading to tendon overload and the development of PT (Van der Worp *et al.* 2011b).

Muscle strength

Three of the studies raised the argument that muscle strength could be associated with PT. Both greater vastus medialis muscle strength (Toppi *et al.* 2015) and quadriceps muscle atrophy have been identified as risk factors for PT (Silva *et al.* 2015; Van der Worp *et al.* 2011b).

Anatomical alignment

Four studies referred to anatomical alignment in athletes with PT. Saggini *et al.* (2012) reported a definite correlation between an inferior patellar pole alignment and the probability to develop PT. Secondly, leg-length discrepancy, where the longer leg is the preferred take-off leg in jumping, can also be associated with PT. However, there is limited evidence to confirm this (Van der Worp *et al.* 2011b). Another hypothesis is that lower foot arch heights might cause knee and soft tissue injuries (Silva *et al.* 2015).

TABLE 3: Rehabilitation of patellar tendinopathy.

Authors (year)	Study design	Study participants	Rehabilitation
Mani-Babu <i>et al.</i> (2015)	Systematic review and meta-analysis	Not included	Extracorporeal shock wave therapy
Frizziero <i>et al.</i> (2014)	Review and meta-analysis	Not included	Eccentric training
McCreech, Riley and Crotty (2013)	Case report	Age: 34 years Gender: Male	Eight-week programme of eccentric training, twice/day, 10 repetitions
Malliaras <i>et al.</i> (2013)	Systematic review	Not included	Eccentric training; eccentric-concentric loading alongside
Dimitrios, Pantelis and Kalliopi (2012)	Controlled clinical trial	Age: 18–30 years Gender: 16 male, 6 female	Eccentric training as well as eccentric training and static stretching in combination
Da Cunha <i>et al.</i> (2012)	Randomised controlled study	Age: 18 years Gender: 14 male, 3 female	Eccentric training: 12 weeks with or without pain
Van der Worp <i>et al.</i> (2011c)	Randomised controlled trial	Age: 18–50 years	Focus and radial shockwave therapy, three times per week with eccentric training, 2 x 15, twice daily, 5 days a week
Romero-Rodriguez, Gual and Tesch (2011)	Case series	Age: 18–35 years Gender: Male	Eccentric training: 6 weeks, 12 sessions for 24 minutes
Zwerver <i>et al.</i> (2010)	Pilot study	Age: 18–58 Gender: Male	Three extracorporeal shock wave therapy treatments
Goldman and Lentz (2010)	Case report	Age: 18 years Gender: Male	Eccentric training: 6 weeks, once daily, three times per week, stretching and strengthening

TABLE 4: Causative factors and rehabilitation.

Authors (year)	Study design	Participants	Causative intrinsic factors	Causative extrinsic factors	Rehabilitation
Silva <i>et al.</i> (2015)	Case report	Age: 21 years Gender: Male	Muscle flexibility: Decreased flexibility quadriceps, hamstrings Muscle strength: Decreased muscle strength of quadriceps Range of motion: Decreased dorsiflexion Anatomical alignment: Longitudinal arch height of the foot	Not included	Eight weeks, 3 times per week, 30 minutes. Gluteus maximus strengthening bilateral 3 x 15. Drop jumps 3 x 10. Resume sport participation < 3/10 on the Visual Analogue Scale
Saggini <i>et al.</i> (2012)	Prospective, single-centre study	Age: 18–34 years Gender: Male	Anatomical alignment: Lower patella pole	Level of skills: > 12 hours per week of training/playing, weight training > 5 hours per week Training surfaces: Hard surfaces	Three weeks, one session of extracorporeal shock wave therapy and three physiotherapy sessions of eccentric training per week
Samukawa (2011)	Case review	Age: 29 years Gender: Female	Anatomical alignment: Frog's eye patellae bilaterally, patella baja right patella-femoral joint, hips external alignment, 1 cm left > right leg, Q angle of 10° both legs Muscle flexibility: Ober test + bilateral, Thomas test +, J-sign bilateral Range of motion: Decreased internal hip rotation and dorsiflexion bilateral	Not included	Eight weeks, 15-minute jog, static stretching lower limb, eccentric training, closed-chain strengthening of quadriceps, cryotherapy and proprioception

It is anticipated that greater quadriceps muscle contraction is desired to avoid further knee flexion (Van der Worp *et al.* 2011b).

Body composition

Three studies mentioned body mass index (BMI), with two of them not finding any relationship between BMI and PT (De Vries *et al.* 2015a; Toppi *et al.* 2015). The third study indicated that a higher BMI can contribute to PT because of a theoretically greater loading of the patellar tendon (Van der Worp *et al.* 2011b).

Joint range of movement

Samukawa (2011) and Silva *et al.* (2015) mentioned in both their case reports that decreased dorsiflexion was a risk factor for PT. This must, however, be interpreted with caution because of the methodology used (i.e. only one study participant per case report).

Extrinsic causative factors

Acquisition and level of skills

In sporting activities where the level and acquisition of skills are important, the development of PT is a possibility, as noticed in five studies included in this review (Saggini *et al.* 2012;

Samukawa 2011; Souza *et al.* 2010; Toppi *et al.* 2015; Van der Worp *et al.* 2012). Research also indicated a direct link between higher levels of participation in sport (Van der Worp *et al.* 2012) and physical activity (Toppi *et al.* 2015) as risk factors for PT. Additionally, some possible supplementary extrinsic risk factors that could influence the development of PT are player position, an increased demand in training hours per week, number of games per month, increased training from year to year, the amount of hours participating in additional sports (Van der Worp *et al.* 2012) and weight training for at least 5 hours per week (Saggini *et al.* 2012). Heavy physical work has a considerable effect on the development of PT in sports-related and non-sports-related basketball and volleyball players, which affects their work performance (De Vries *et al.* 2015a; Van der Worp *et al.* 2011a).

Type of sport

Only one article referred to the type of sport as an extrinsic causative risk factor for PT. Volleyball players are more likely to develop PT than basketball players, possibly because of the difference in the number of jumps performed and the players' jumping technique (Van der Worp *et al.* 2012).

Training surface

Saggini *et al.* (2010) were the only authors who reported that training on hard surfaces is a risk for PT because of the load

on the tendon. It has been suggested that softer training surfaces may reduce the risk (Van der Worp *et al.* 2012).

Strapping or orthosis

According to De Vries *et al.* (2015b), a patella strap or sports tape decreases pain in an experimental group compared with a control group in the short term, although none of them is more effective than placebo taping. The long-term effect remains unclear, with an amplified effectiveness of taping in female participants (De Vries *et al.* 2015b).

Rehabilitation

Thirteen of the 20 studies included in the systematic review had one or more component that described parts of the rehabilitation intervention for PT. The literature reported on rehabilitation intervention comprising cryotherapy (Samukawa 2011), lower limb strengthening (Frizziero *et al.* 2014; Goldman & Lentz 2010; Malliaras *et al.* 2013), lower limb stretching (Goldman & Lentz 2010) and proprioception retraining (Samukawa 2011). Table 3 summarises the rehabilitation for PT.

Eccentric exercise

Eccentric exercise (EE) is extremely popular in the conventional treatment of chronic lower limb tendinopathies (Saggini *et al.* 2012), and literature on EE dates back to 1938. It is therefore not surprising that 10 of the studies included for review described EE as a rehabilitation modality for PT. McCreesh *et al.* (2013) clarified that the mechanism of action of EE is to resolve the neovascularity in the patellar tendon.

Positive rehabilitation intervention results can also be accomplished by combining EE with other treatment modalities, such as extracorporeal shock wave therapy (ESWT) (Saggini *et al.* 2012) and static stretches of the lower limb (Dimitrios *et al.* 2012). Four studies reported that ESWT (Mani-Babu *et al.* 2015) is a promising adjunctive (Zwerwer *et al.* 2010) modality for PT in both short- and long-term programmes (Frizziero *et al.* 2014; Mani-Babu *et al.* 2015). Malliaras *et al.* (2013) suggested that an eccentric-concentric loading programme for individuals with PT is more beneficial than EE on its own, particularly in athletes with noticeable concentric muscle weakness that may not recover with isolated EE because of the muscle type contraction.

PT and other treatment modalities

Non-specified drug therapy (Dimitrios *et al.* 2012) and deep transverse friction massage also improve the symptoms of PT (Samukawa 2011).

Hip and core strengthening

The gluteus maximus muscle is considered to be an important hip extensor muscle to strengthen during PT rehabilitation (Silva *et al.* 2015).

Stretches

Improved flexibility of the muscles of the lower limb, especially muscles surrounding the hip and knee, forms an essential component of rehabilitation and the resolution of chronic symptoms of PT (Samukawa 2011).

Return to sport

There are contradicting views regarding return to sport during the rehabilitation intervention. Silva *et al.* (2015) advised that sport participation can be continued, but the pain experienced during the activity may not exceed 3/10 on the Visual Analogue Scale. On the contrary, it is recommended that activity participation must only resume after tendon healing is complete (Dimitrios *et al.* 2012), which is suggested to take approximately 12 weeks (Frizziero *et al.* 2014). Sport-specific activities that cause pain in the tendon must be avoided until the tendon has healed completely (Dimitrios *et al.* 2012).

Sport-specific technique

Jumping with appropriate kinematics is an important factor to consider in PT. The jumps in PT athletes must be evaluated and modified accordingly to produce a 'soft landing' to reduce the load on the tendon (Silva *et al.* 2015).

Discussion

PT is a diverse and complex pathology with numerous challenges regarding risk factors for developing PT and its rehabilitation, and it can be more complicated than assumed to identify these aspects. A limited number of articles ($n = 20$) were included in the systematic review because of the inclusion and exclusion criteria for this review, as well as poor methodological quality of a number of studies initially identified. This, in addition to the heterogeneity of the studies when considering specific aspects related to the causative factors and rehabilitation, prevented a meta-analysis to be performed.

Intrinsic and extrinsic causative risk factors for patellar tendinopathy

The initial aim of this systematic review was to review the literature concerning the intrinsic and extrinsic causative risk factors for PT. The distinctive factor responsible for the development of PT is the mechanical theory. It can be defined as a failed healing process with micro-injuries to the patellar tendon because of overloading, which is responsible for matrix and cell changes and altered mechanical properties of the tendon (Van der Worp *et al.* 2011b). The data varied and seven intrinsic and four extrinsic risk factors were identified. The main intrinsic risk factors identified were muscle flexibility and strength. Regarding the extrinsic risk factors, acquisition and level of skills were the prominent factors. Evidence for all the other risk factors was indecisive. Although several risk factors for PT were recognised, the systematic review did not demonstrate robust evidence for numerous intrinsic or extrinsic causative risk factors, which

has possibly been limited by the inclusion and exclusion criteria for this review.

If the mechanical pathophysiological theory discussed previously (Van der Worp *et al.* 2011b) is taken in consideration, it clearly indicates that all intrinsic and extrinsic causative risk factors for PT mentioned in the results are responsible for loading the patellar tendon in altered ways (see intrinsic causative risk factors and Table 2). If the intrinsic and extrinsic causative factors could be addressed in rehabilitation and the load on the tendon could be minimised, improvement in pain and function will be noticeable.

Rehabilitation for patellar tendinopathy

Regarding the rehabilitation, mainly descriptive articles with a widespread range of research designs were included. PT can be treated with numerous different therapeutic modalities; EE training showed exceptional results, with 10 of the 13 articles on rehabilitation for PT reporting positive results. The perception is still that EE is the gold standard conservative treatment modality and superior to other treatment options based on its excellent and sturdy outcomes over the years. This happens when EE lengthens the tendon, which is responsible for 'squeezing out' the flow of neovessels (McCreesh *et al.* 2013). Doppler ultrasound imaging after a period of EE indicated a minimal improvement in tendon echogenicity and a substantial decline in tendon neovascularity, with a dramatic improvement in the symptoms and pain in the tendon (Da Cunha *et al.* 2012; Samukawa 2011). This explains why EE is so successful and beneficial in the treatment of PT. EE not only assists with diminishing of neovascularity, but also facilitates improvements in neuromuscular activation, improved muscle strength (Samukawa 2011) and muscle endurance (Saggini *et al.* 2012).

EE is performed as a single leg squat on a decline board with an angle of 25° at a slow speed to assist with tissue healing (Dimitrios *et al.* 2012) and has superior results over a squat that is performed on a flat-step (Frizziero *et al.* 2010; Goldman & Lentz 2010). EE can be performed in an aggressive manner causing pain (Da Cunha *et al.* 2012) or without pain, because evidence reveals that both establish improvements in pain and function (Da Cunha *et al.* 2012). The frequency and repetitions of performing EE differed in the reviewed articles, but generally included three sets of 15, one or twice daily and 5–7 days a week (Goldman & Lentz 2010; McCreesh *et al.* 2013; Van der Worp *et al.* 2011c).

EE can be performed at home without full-time supervision, although the athlete's compliance may influence the outcomes (Dimitrios *et al.* 2012). The high intensity of performance of EE seems to be decisive for favourable therapeutic results (Da Cunha *et al.* 2012). More than one of the articles included in this review combined EE with an additional treatment modality. Although this systematic review did not specifically aim to address the possible different treatment methods in combination with EE, it has

been noticed that EE has positive outcomes when used in combination with other treatment modalities.

Multiple treatment options are available for PT, and the collective aim is to improve pain and function in PT. One of these additional modalities is ESWT, of which the therapeutic outcome is based on its bio-stimulating effects (Saggini *et al.* 2012). The authors suggested different dosage prescriptions which vary from one (Saggini *et al.* 2012) to three treatment sessions per week for 3 weeks (Van der Worp *et al.* 2011c). Secondly, static stretches contribute to the reversal of PT (Dimitrios *et al.* 2012), and deep transverse friction massage contributes to reduce the adhesions and enable realignment of collagen fibres (Samukawa 2011).

An important factor in managing symptoms of tendinopathy during the rehabilitation intervention is regulating or reducing the tendon load for good execution of the exercise programme.

Romero-Rodriguez *et al.* (2011) described a rehabilitation programme with training twice a week for 24 minutes per session, whereas Silva *et al.* (2015) suggested the frequency to be three times a week with a duration of 30 minutes per session. The length of the rehabilitation period varied from 6 to 12 weeks, as proposed by different authors (Da Cunha *et al.* 2012; Goldman & Lentz 2010). Romero-Rodriguez *et al.* (2011) proposed a rehabilitation period of 6 weeks to have positive results in highly trained athletes, although a prolonged rehabilitation period may be applicable because of the sluggish recovery of the patellar tendon (Saggini *et al.* 2012). The benefits of a conservative rehabilitation programme can include an improvement in knee range of movement, quadriceps muscle strength, reduction in PT pain symptoms and general improvement in knee function (Goldman & Lentz 2010).

The association between intrinsic and extrinsic causative risk factors with rehabilitation

Intrinsic and extrinsic causative risk factors can only be addressed by rehabilitation which is essential to the improvement of PT pain and function. Therefore, it is essential to address each intrinsic and extrinsic causative risk factor individually during the rehabilitation period and make adaptations to the environment if necessary. Research studies describing the rehabilitation of intrinsic and extrinsic causative factors were found in the results of this systematic review (see Tables 2, 3 and 4).

A positive observation from this systematic review is that inadequate lower limb flexibility and muscle strength, especially around the hip and knee, has an adverse effect on knee kinematics (Samukawa 2011) and can be addressed by a stretching and strengthening programme. It is advised to start with non-weight bearing strengthening exercises and then progress to more advanced exercises that will contribute to improve lower limb biomechanics during landing kinematics (Silva *et al.* 2015). This indicates a direct link

between addressing intrinsic and extrinsic causative factors in rehabilitation and the difference in the pain and function associated with PT.

Acquisition and level of skills are extrinsic risk factors for PT that can be modified during rehabilitation to correct the execution technique of activities and lower the demand on the tendon. For example, in a task requiring lower limb effort, such as hopping, it has been found that athletes with PT perform the task differently to 'off-load' the knee and decrease the effort on the affected joint (Souza *et al.* 2010). This requires evaluation of the athlete's technique and the necessary adjustments must be made. De-loading of the tendon can also be achieved by means of decreasing the load by reducing the frequency, intensity and duration of activities (Van der Worp *et al.* 2012). Furthermore, working activities must be considered when modifying the load on the tendon (Van der Worp *et al.* 2011a), and load progression must always be done gradually (Goldman & Lentz 2010). Prevention of PT can be promoted by taking note of complaints and monitoring athletes individually to identify any symptoms of PT (Van der Worp *et al.* 2012).

Some recommendations regarding the causative factors and rehabilitation are relatively broad rather than explicit guidelines. Therefore, there is a need for continuous high-quality research studies in order to identify better evidence regarding the intrinsic and extrinsic risk factors associated with PT and to investigate the diverse rehabilitation interventions for tailoring a rehabilitation programme to manage this challenging pathology.

A limitation of this systematic review was the inclusion of a limited number of articles because of the specific research focus, inclusion and exclusion criteria set for this review, and the poor methodological quality of a number of studies initially identified. In an attempt to address this limitation, the researchers applied the search strategy twice during the study period and also examined the reference lists of all the included studies in an effort to identify possible additional studies. This additional measure, however, yielded no further articles for inclusion.

Strengths of this systematic review include the perspectives presented, which give insight into the causative factors and rehabilitation for PT. This will enhance the knowledge of health care professionals involved in the management of PT. Another strength is the inclusion of articles with a good methodological quality (i.e. with an average of 72%) following the rigorous methodology quality assessment. The results, however, indicate a high incidence of similar authors included in the systematic review, which may direct publication bias. PT is a troublesome pathology which requires intensive research and rehabilitation and the high methodological quality of articles included in this review contribute to reliable outcomes in the reporting of the findings.

Conclusion

This systematic review presents a unique perspective on the integration of intrinsic and eccentric causative factors with the rehabilitation of PT. This insight into the latest evidence highlights the essence of an integrated management protocol for PT to obtain a positive outcome with regard to pain management and function in athletes with PT.

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Competing interests

The authors declare what there were no financial or personal relations that may have inappropriately influenced them in writing the article.

Author contributions

S.M., E.C.J.v.V. and F.F.C. compiled the systematic review, discussed the construction of the article, screened the literature according to the eligibility criteria, performed the methodology quality appraisal and analysed the data in order to formulate the article. S.M. wrote the article with the advice and supervision of the co-authors.

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Appendix starts on the next page →

References excluded articles

Appendix 1

Exclusion of articles because of irrelevancy based on title screening ($n = 39$)

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