Chapter 9

General discussion
Introduction

Patellar tendinopathy still remains a difficult-to-treat overuse injury of the patellar tendon with a very negative impact on the careers of many athletes (Chapter 2), therefore prevention programs and interventions aimed at a fast return to play are important. These can only be developed if the extent and severity of the problem and its aetiology and injury mechanism are known.

This thesis focused on patellar tendinopathy in non-elite athletes and the evaluation of the effectiveness of ESWT in managing this condition. Prevalence of patellar tendinopathy (Chapter 3) appears to be high among non-elite athletes as well (2.5-14.4%). Male athletes are affected twice as much as female athletes. Sport-specific loading characteristics, age, height and weight seem to be risk factors associated with patellar tendinopathy.

In order to evaluate the outcome of different treatment interventions, feasible cross-cultural and validated outcome measures and specific functional test for patellar tendinopathy are necessary. The translated Dutch version of the VISA-P questionnaire turned out to be equivalent to its original version, has satisfactory test-retest reliability, and is a valid score to evaluate symptoms, knee function and ability to perform in sports of Dutch athletes with patellar tendinopathy (Chapter 4). Biomechanical analysis of the single-leg decline squat revealed that this exercise can increase patellar tendon force and therefore seems suitable for use as a functional loading test for the patellar tendon in athletes with patellar tendinopathy (Chapter 5).

From what is known in the literature so far, ESWT seems to be a safe and promising treatment for chronic patellar tendinopathy with a positive effect on pain and function. However, based on current knowledge it is impossible to recommend a specific treatment protocol (Chapter 6). No studies into the effectiveness of ESWT in athletes with patellar tendinopathy for less than 12 months who are still actively competing have been conducted before. We therefore designed the TOPGAME study, the first randomised controlled trial into the effectiveness of ESWT on pain, symptoms and function of athletes with early symptomatic patellar tendinopathy who are still in training and competition (Chapter 7). Based on this multicentre study we concluded that ESWT as monotherapy during the competitive season has no benefit over placebo treatment in the management of actively competing jumping athletes with patellar tendinopathy who have symptoms for less than 12 months (Chapter 8).

In this general discussion the results of the research described in the previous chapters are examined in a broader perspective. The first part of this chapter describes the epidemiology of patellar tendinopathy in athletes and its implications for prevention. The second part focuses on the different assessment tools that might be used as outcome measures for patellar tendinopathy. In the third part the role of ESWT, amongst other treatment options, in the management of patellar tendinopathy is discussed. If applicable, clinical implications and further research suggestions are presented.
Epidemiology and prevention of patellar tendinopathy

The first step in the sequence of sports injury prevention research (Figure 9.1), as outlined by Van Mechelen et al. in 1992, is to describe the magnitude of the problem in terms of the frequency and severity of injuries.

Overuse injuries might represent as much of a problem as do acute injuries in many sports. However, the frequency and severity of overuse injuries is often underestimated because only the incidence of these injuries is reported and a ‘time-loss injury’ definition is being used. Many athletes continue their sporting activities despite their chronic overuse injury. This means that in many epidemiological studies, despite their prevalence overuse injuries are not included in the incidence rate as new injuries that cause time loss from sports. When this ‘traditional’ study approach is used for the overuse injury of patellar tendinopathy, an underestimation of the problem can be expected. For this reason, Bahr made the following recommendations on how overuse injuries can be quantified in a more appropriate standardised method.

(a) studies should be prospective, with continuous or serial measurements of symptoms;
(b) valid and sensitive scoring instruments need to be developed to measure pain and other relevant symptoms;
(c) prevalence and not incidence should be used to report injury risk;
(d) severity should be measured based on functional level and not time loss from sports.

Although the study described in Chapter 3 was not prospective, it did show that patellar tendinopathy is a common and often chronic problem not only in elite but also in non-elite athletes. In non-elite jumping sports the prevalence was over 10% and mean duration of
symptoms was more than one and a half years. The Dutch VISA-P score was used as a scoring instrument; it has been demonstrated to be valid and sensitive to measure pain, other symptoms and functional level of sports in these athletes. The non-elite athletes in the study still continued to play despite their symptoms, but the mean VISA-P score of 71 (out of 100) points to their inability to compete at their full potential. This thesis has thus shown that patellar tendinopathy is common and impeding among non-elite athletes too, therefore preventive strategies seem warranted for this treatment-challenged injury.

The next step in the sequence of prevention of sports injuries is to map out the causes of injuries in order to identify their risk factors and mechanisms. Since overuse injuries, including tendinopathies, seem to have a multifactorial aetiology, this is not an easy step. Both intrinsic and extrinsic factors have been described in the literature (Table 9.1), but there is little robust and often even conflicting evidence for these factors. Among all potential risk factors, the loading characteristics of the sport – especially landing – are increasingly considered important factors in the aetiology of patellar tendinopathy. Bisseling et al. demonstrated that athletes with a ‘stiffer’ landing pattern are more at risk for developing jumper’s knee. More recently, Edwards showed that asymptomatic athletes with and without a patellar tendon abnormality (PTA) had different landing strategies. Athletes with PTA landed with significantly greater knee flexion and extended their hips while the controls flexed their hips as they landed. These findings provide both trainers and clinicians with important landing assessment criteria against which to identify athletes at risk of developing patellar tendinopathy. Moreover, landing strategy is a factor that can be modified and might therefore be important towards preventing patellar tendinopathy in jumping athletes.

Although in the last decades some progress has been made in elucidating the underlying pathological process of (patellar) tendinopathy, little is known about the link between mechanical loading and the pathophysiological response in the tendon. Clarification of

### Table 9.1. Predisposing factors for patellar tendinopathy (modified from Brukner & Khan, Clinical Sports Medicine, 3rd ed., 2006 McGraw-Hill, Australia).

<table>
<thead>
<tr>
<th>Intrinsic factors</th>
<th>Extrinsic factors</th>
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<tbody>
<tr>
<td>Gender</td>
<td>Training (volume, intensity, type, increase)</td>
</tr>
<tr>
<td>Genetic factors</td>
<td>Technique (jumping, landing)</td>
</tr>
<tr>
<td>Age</td>
<td>Playing surface (hard, soft)</td>
</tr>
<tr>
<td>Size and body composition</td>
<td>Shoes and equipment</td>
</tr>
<tr>
<td>Malalignment</td>
<td>Environmental conditions</td>
</tr>
<tr>
<td>Leg length discrepancy</td>
<td>Psychological conditions</td>
</tr>
<tr>
<td>Muscle imbalance and weakness</td>
<td>Nutrition</td>
</tr>
<tr>
<td>Lack of flexibility/restricted range of motion</td>
<td>Medication</td>
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</table>
this complex underlying working mechanism together with other prospective studies investigating the various risk factors and their influence on the tendon would certainly aid in establishing more appropriate and effective preventive measures. A lot of research has to be done before these intriguing and important questions can be answered. Steps 3 and 4 of the sequence of injury prevention need to be investigated in future studies. Developing and introducing a training program that teaches athletes how to land in the most appropriate way could be one important preventive measure to reduce the risk of developing patellar tendinopathy. One should realise though that only programs that can and will be adopted by athletes, coaches and sporting associations will be successful in preventing injuries. Hence implementation strategies and effect research are also necessary to evaluate if preventive methods really are being adopted by the athletes. Finally, the costs and effectiveness of the introduced preventive measures should be evaluated by repeating step 1, or preferably by conducting a randomised controlled trial.

Diagnostic and outcome assessment tools

Next to the fact that the pathophysiological mechanism of patellar tendinopathy has not been elucidated, research and clinical management are also hampered by a lack of firm diagnostic tools and criteria as well as a limited number of reliable evaluation tools. Novel tools are needed to diagnose patellar tendinopathy, monitor progress during a rehabilitation program and evaluate the effectiveness of interventions. So far, clinical examination still represents the gold standard in the diagnosis of patellar tendinopathy. It is based primarily on a history of activity-related anterior knee pain associated with well-localised, palpable patellar tendon tenderness. Differentiating between patellar tendinopathy and other pathologic entities causing anterior knee pain can sometimes be difficult. Pain on palpation thus plays an important role in the diagnosis and follow-up evaluations of patellar tendinopathy. Palpation pressure and the evoked pain can also be measured in a standardised way using an algometer. Determining the pressure pain threshold with an algometer seems to be a feasible and reliable method that might be useful to objectify the longitudinal effects of interventions in patients suffering from patellar tendinopathy.

Another frequently used assessment tool is the VISA-P questionnaire, which was specifically designed for rating the severity of patellar tendinopathy. This brief questionnaire is not a diagnostic tool but assesses symptoms, simple tests of function and the ability to undertake physical activity. It therefore fits into the aforementioned recommendations of Bahr. In Chapter 4 a Dutch version of this questionnaire was developed and validated, so this evaluation tool is now also available for research among Dutch-speaking athletes. Deployment of this easy-to-use, reliable and valid scoring instrument is therefore recommended in future studies on patellar tendinopathy. Since this questionnaire has also been translated into other languages, comparison of studies from different countries is possible.

Next to a questionnaire that determines patient-based outcome, functional tests are con-
considered useful. The single-leg decline squat as an additional evaluation tool is therefore recommended for use in patients with patellar tendinopathy. This simple function test can increase patellar tendon load up to 40%. Purdam et al. also recommend this test because it has the best discriminative ability in the physical assessment of patellar tendinopathy and can be easily performed in a standardised way. The research described in this thesis also uses the maximal vertical jump test and triple hop test as evaluation tools. These evaluation tools combine specific tests of function, pain scores and objective performance outcomes (jumping height or distance); they are easily performed functional tests that give a good impression of how painful loading of the patellar tendon is, and appear suitable for monitoring athletes with patellar tendinopathy. However, validation studies and research into the link between these functional tests and, for example, the VISA-P score and imaging abnormalities are necessary and should be object of future studies.

The role of imaging in diagnosis and outcome assessment

The usefulness of imaging techniques in the diagnosis and follow-up of patellar tendinopathy remains controversial. Magnetic resonance imaging (MRI) and grey-scale ultrasonography (GS-US) are often used in the diagnostic work-up, and both provide excellent anatomic representation of the patellar tendon. In recent years Colour-Doppler (CD-US) and Power-Doppler Ultrasound (PD-US) have also been used to show neovascularisation in tendinopathies. Nerves accompanying these vessels might play a role in the pain observed in tendinopathies. Histopathological studies have demonstrated the characteristic tendinopathy appearances observed with both MRI and GS-US to be caused by the underlying pathological tendon changes. Warden et al. studied the comparative accuracy of US and MRI, and concluded that US was more accurate than MRI in confirming clinically diagnosed patellar tendinopathy. GS-US and CD-US may represent the best combination for confirming clinically diagnosed patellar tendinopathy because GS-US had the greatest sensitivity, while a positive CD-US test result indicates a strong likelihood of an individual being symptomatic.

One should realise however that it is not uncommon for symptomatic tendons to have the MRI or GS-US appearance of normal asymptomatic tendons; imaging abnormalities characteristic of patellar tendinopathy can be found in asymptomatic tendons. The role of MRI and US in the follow-up and evaluation of treatment of athletes with patellar tendinopathy is also debated. A number of studies has shown that both before and after a treatment intervention the correlation between clinical findings and US and MRI imaging is low. It has also been demonstrated that symptoms, tendon changes on GS-US and MRI and degree of neovascularisation on CD-US can vary independently, even during the course of a season. Recently Malliaras et al. suggested that these transitions in GS-US may represent different phases of tendon pathology. This interesting concept which certainly merits further investigation is discussed in more detail in the next section. Another promising development is ultrasonographic tissue characterisation (UTC), a novel non-invasive technique that visualises the structure of tendon tissue and quantifies its structural integrity with an excellent reproducibility. Different stages of pathology and regeneration within the tendon are visualised in a standardised and operator-independent way. As such, UTC might be a very useful quantitative method to monitor and evaluate treatment protocols of athletes with a tendinopathy. Future studies
should address the value of US-GS, US-CD, MRI and UTC in the diagnosis, staging and follow-up of athletes with patellar tendinopathy.

**Management of patellar tendinopathy**

Although some progress has been made in recent decades, the clinical management of patellar tendinopathy remains problematic. Athletes of different ages with tendons exposed to various loads present acute or chronic symptoms and varying degrees of pain and functional limitation. Numerous management options have been tried, including rest, (eccentric) exercise, training modification, splinting, taping, cryotherapy, electrotherapy, pharmaceutical agents such as nonsteroidal anti-inflammatory drugs (NSAIDs), various (peri)tendinous injections and different surgical procedures. However, the success rate of these interventions is quite divergent.

Another management option, ESWT, was under study in this thesis (Chapters 6, 7 and 8). Based on a review it was concluded that, notwithstanding the limited evidence, ESWT seems to be a safe and promising treatment for athletes with patellar tendinopathy. However, no significant treatment effect was found in the TOPGAME study, in which patient-guided focused piezoelectric ESWT was compared to sham ESWT treatment in actively playing athletes with symptoms for less than 12 months. It has to be concluded that ESWT is not the optimal treatment option either. Some patients did benefit from the ESWT treatment though. Further analyses should determine whether predicting factors can be found.

Overall it has to be concluded that the search for the optimal treatment strategy for patellar tendinopathy has not yet ended; why some tendons recover with simple interventions while others remain resistant to all kinds of treatments remains to be answered. This is frustrating for the athlete as well as the treating physician. Moreover, it is unclear why a certain treatment is successful for one athlete and has no effect on another. A potential explanation might be found in the ‘continuum of tendon pathology’ model.

**Continuum of tendon pathology**

The underlying pathology of tendinopathy has previously been described as degenerative or failed healing. However, this rather simplified description of a complex pathophysiological process does not fully explain the heterogeneity in presentation and variability in recovery. Cook and Purdam recently proposed a new model of tendinopathy, based on available evidence from pathological, clinical and imaging studies. This ‘continuum of tendon pathology’ (Figure 9.2) describes three distinct stages: (1) reactive tendinopathy, (2) tendon dysrepair (failed healing) and (3) degenerative tendinopathy.

Clinical and imaging features allow a tendon to be classified as one of these stages (Table 2). One should however keep in mind that there is continuity between these stages and that combined stages can exist within a tendon. As mentioned before the role of ultrasound imaging remains equivocal. This hypothetical yet interesting model requires further scientific and clinical evaluation.
Table 9.2. Clinical and imaging features of different stages of tendon pathology

<table>
<thead>
<tr>
<th></th>
<th>Clinical manifestation</th>
<th>Ultrasound Imaging</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactive tendinopathy</td>
<td>Acute overload in athlete</td>
<td>Fusiform swollen tendon, collagen fascicles intact with hypoechogenic zones in-between</td>
</tr>
<tr>
<td>Tendon dysrepair</td>
<td>Chronic overload in young athlete</td>
<td>Discontinuity of collagen fascicle and small focal areas of hypoechogenicity, vascularisation</td>
</tr>
<tr>
<td>Degenerative tendinopathy</td>
<td>Chronic overload in older or elite athlete</td>
<td>Extensive hypoechogenicity and vascularisation, few reflections from collagen fascicles</td>
</tr>
</tbody>
</table>

Figure 9.2. Pathology continuum; this model embraces the transition from normal through to degenerative tendinopathy and highlights the potential for reversibility early in the continuum.
Table 9.3. Clinical and pharmacological treatments placed in the model

<table>
<thead>
<tr>
<th>Stage</th>
<th>Pharmacological management</th>
<th>Physical management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reactive tendinopathy/early tendon dysrepair</td>
<td>Tenocyte inhibitors (ibuprofen, celecoxib, corticosteroids), aggrecan inhibitors (ibuprofen, naproxen sodium, indomethacin)</td>
<td>Load management. Reduction in frequency ± intensity of tendon load</td>
</tr>
<tr>
<td>Late tendon dysrepair/ degeneration</td>
<td>Prolotherapy, blood, platelets, platelet-rich plasma, aprotinin, sclerosing therapy, glyceryl trinitrate</td>
<td>Exercise with eccentric component, ESWT, frictions, ultrasound</td>
</tr>
</tbody>
</table>

This conceptual model might also facilitate the rational placement of treatments along the continuum. Common interventions and their proposed place in the ‘continuum model’ are summarised in Table 3. It must be stipulated that this is only a simplified and hypothetical framework, designed for further investigation and clinical evaluation. Currently there tends to be no difference in the treatment approach between for example a young active athlete with a (sub)acute tendon problem and a more sedentary older person with a chronic tendinopathy. If both started an intensive eccentric exercise program, different outcomes can be expected. This might also explain the variable and sometimes conflicting results from intervention studies in (patellar) tendinopathies. If the included study population differed in its stage of tendon pathology, some athletes received the appropriate treatment while others received a ‘wrong’ treatment which is inappropriate for their underlying stage of pathology. This would have had a negative influence on the outcome of the studies. The situation gets even more complicated if one realises that it is highly probable that some tendons have discrete regions that are in different stages at one time. For example, tendons with degenerative changes can acutely be overloaded, leading to heterogeneous pathology in a single tendon. Treatment of these complex tendon situations requires an even more differentiated approach.

For these reasons, both researchers and clinicians should be aware of this continuum of tendon pathology (as well as the limitations of this simplified concept) when designing a study or treating an athlete with patellar tendinopathy. In the early stages, reduction of load is important to reduce pain and to give the tendon time to recover. The frequently used daily eccentric exercise program is less appropriate in this phase of the disease and can even aggravate symptoms. Although it has been reported that NSAIDs and corticosteroids have a negative effect on tendon repair in the long term, they might be useful in reactive tendinopathy, as they reduce the pain and inhibit the tenocytes from producing excess ground substance proteins responsible for the swelling of the tendon. In reactive tendinopathy, NSAIDs and corticosteroids ‘calm down’ the tendon.
Treatments that stimulate collagen synthesis and restructuring of the matrix need to be used in the late dysrepair and degenerative stages. Exercise – particularly slightly painful eccentric exercises – appear to be a positive stimulus for these processes. Further, eccentric exercise has been demonstrated to be beneficial for pain relief as well as return to function and activity. Frictions and ultrasound can also increase production of collagen but are less effective than exercise. Extracorporeal shockwave therapy might also give pain relief. In animal studies it was demonstrated that it can increase collagen synthesis and improve the structure of the tendon.

Several other treatments that are considered to influence the healing and remodelling process of the tendon have been proposed, among them injection treatments. An injection itself (prolotherapy) can already have a beneficial effect on tendon structure. Blood or platelet-rich plasma injections (PRP) can stimulate cell proliferation and the healing process in the tendon. Injections with aprotinin, a collagenase inhibitor, are supposed to diminish collagen breakdown in the remodelling matrix. Ultrasound-guided sclerosis of neovessels appears to be effective in treating pain and improving tendon structure. Application of glyceryl trinitrate combined with eccentric training might also improve collagen synthesis. All seem to be promising treatments, but their role in the clinical management of patellar tendinopathy needs further investigation.

**Treatment protocol**

Next to the need for more research to determine the optimal treatment at each stage of patellar tendinopathy, another problem is that for most treatment options there is no consensus about the most effective treatment protocols. For ESWT, for example, different shockwave devices are used. Electromagnetic, electrohydraulic and piezoelectric devices generate focused shockwaves, but there are differences between the shockwave characteristics of these devices. On the other hand, ballistic devices generate radial pressure waves with completely different characteristics, yet treatment provided with these devices is often called radial shockwave therapy (RSWT) too. Positive results have been reported for both focused shockwave and radial pressure therapy, but it is difficult to compare these studies because of the different underlying technical principles. Not only the device used but also number of ESWT treatments, treatment interval, energy density and number of impulses can be varied; these are all important parameters that might influence the effectiveness of this treatment method.

**Recommendations for future research in ESWT and patellar tendinopathy**

The results of this thesis are not in line with previously published studies on the effectiveness of ESWT on patellar tendinopathy. This raises new questions on this topic that should be studied in future research. The following recommendations for future studies are made:

- Research that elucidates pathophysiological mechanisms of patellar tendinopathy.
- Clinical, imaging and pathology studies that further substantiate the continuum of tendon pathology model.
- Studies on the working mechanism of ESWT and RSWT at different stages of tendinopathy.
- Randomised controlled trials to investigate the effectiveness of ESWT and RSWT at different stages of the disease.
• Randomised controlled trials to compare different devices and treatment protocols.
• Studies that investigate the synergistic role of different treatment combinations, e.g. eccentric training in combination with ESWT, platelet-rich plasma in combination with ESWT.

Conclusions

This thesis focussed on patellar tendinopathy among non-elite athletes and the evaluation of the effectiveness of ESWT in managing this condition. Based on the research described in this thesis it can be concluded that patellar tendinopathy is also a common overuse injury with a multifactorial aetiology among non-elite athletes. Developing and introducing preventive programs that change elements such as the landing strategy of jumping athletes seem warranted to reduce the risk of getting this difficult-to-treat knee injury.

The Dutch VISA-P questionnaire is a valid and reliable tool to assess symptoms, function and ability to play sports among Dutch athletes with patellar tendinopathy. The single-leg decline squat can be used as a functional test that specifically loads the patellar tendon.

ESWT seems to be a promising treatment for patellar tendinopathy. However, no benefit of ESWT treatment was found in a multicentre randomised controlled trial (the TOPGAME study) investigating the effectiveness of ESWT in athletes with patellar tendinopathy with symptoms for less than 12 months. Further research is needed to determine the optimal treatment strategy for patellar tendinopathy. Treatment options, including different ESWT protocols, should be placed in a rational manner along the continuum of tendon pathology. The effectiveness of interventions must be monitored using feasible, valid and sensitive scoring instruments.
References


