An Integrated Management Model for Patellar Tendinopathy

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DECLARATION

I, Sanell Morgan declare that the thesis hereby submitted by me for the degree DOCTOR OF PHILOSOPHY in Physiotherapy at the University of the Free State is my own independent work and has not been previously submitted at another university or faculty for degree purposes. In addition, I cede copyright of this thesis in favour of the University of the Free State.

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Elizabeth C. Janse van Vuuren

July 2017

In loving dedication to my husband, Craig, whose sacrifice and support made this dream a reality.

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“You have enclosed me behind and before,
And laid Your hand upon me.
Such knowledge is too wonderful for me;
It is too high, I cannot attain to it.”
Psalm 139:5-6 (New King James Version)

“We can only be said to be alive in those moments when our hearts
are conscious of our treasures.”
Thornton Wilder

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Friedrich Nietzche

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ABSTRACT

Introduction

Patellar tendinopathy (PT) is a common chronic pathology of the knee. Elite athletes are especially affected by PT with a prevalence rate of 13%-20%. PT is related to overloading of the patellar tendon and can affect athletes in a variety of sporting codes, resulting in pain and functional impairment. Even with contemporary treatment, almost all athletes experience long lasting symptoms, which makes PT management challenging and highlights the necessity for continuous research.

Aim

The main aim of this research study was to formulate an integrated management model for PT based on existing sport management models and supplemented with results from this study.

Methodology

The study was conducted in three stages, including a systematic review, focussing on the intrinsic and extrinsic causative factors and rehabilitation of PT; an e-Delphi survey to formulate a draft rehabilitation framework for PT; and a 12-week exploratory pre-test, post-test clinical testing of the Delphi-based rehabilitation framework amongst elite rugby players of a South African rugby union.

Results and discussion

Three core elements for the management of PT are identified in this study and include risk factor identification, prevention, and rehabilitation. Sub-components are linked to each of these core elements, where risk factor identification is linked to intrinsic and extrinsic causative factors, prevention is linked to assessment and preventative strategies and rehabilitation is linked to load tolerance, functionality, individualisation, the use of relevant outcomes measures and educational strategies. The model thus enables both a systematic approach to the management of PT through the core elements, and a flexible approach through the variation in the application of these elements in the clinical context.

Conclusion

The proposed integrated management model for PT provides a singular, structured, yet flexible model as a modernistic platform for the management of PT and a basis for further PT research.

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CONCEPT CLARIFICATION

To ensure an unambiguous understanding of this study in its entirety, certain essential terms and concepts included throughout the script are clarified below:

Contracted elite rugby players	Any agreement or arrangement, either official or informal, and technically whether legally enforceable or not made between a rugby club, provincial union or any other company and a rugby player for the provision of a material benefit to the player entirely or partially in consideration for the player's participation in the game of rugby (Rugby Football Union, 2015:4).
Exercise	Defined as "a subcategory of physical activity that is planned, structured, repetitive and purposeful in the sense that the improvement or maintenance of one or more components of physical fitness is the objective" (World Confederation for Physical Therapy, 2014:23).
Rehabilitation	Includes both personal and environmental aspects; a technique with main focus being to minimise the limitations, disability and symptoms at a participation and activity level (Khan *et al.,* 2012:89).
Patellar Tendinopathy	A general overuse tendon disorder of the knee characteristically occurring in athletes or the general population who partake in sports or activities that necessitate jumping and running. The primary pathologic process in PT is degenerative rather than inflammatory and typically appears the inferior pole of the patella. PT has a direct relation with the load on the patellar tendon (Reinking 2016:855, 856).

Pathology / Disease	A condition comprising of specific signs and symptoms that negatively influences the human body (World Confederation for Physical Therapy, 2014:18).
Physiotherapy	An all-inclusive system or method approach to maintain, improve, and re-establish movement and functionality in individuals (World Confederation for Physical Therapy, 2014:38).
Rugby	A collision team sport played with a rugby ball on a field. A team consists of 15 players which include forward and back line players with each player performing a specific role. A rugby match lasts for 80 minutes with two 40 minute halves (Duthie *et al.,* 2003:975).
Treatment	The sum of all interventions provided to an athlete / patient during an episode of care (World Confederation for Physical Therapy, 2014:48).

References for Concept Clarification

Duthie, G., Pyne, D. & Hooper, S. (2003). Applied Physiology and Game Analysis of Rugby Union. *Sports Medicine,* 33(13), pp. 973-991.

Khan, F., Amatya, B. & Hoffman, K. (2012). Systematic review of multidisciplinary rehabilitation in patients with multiple trauma. *British Journal of Surgery,* 99(1), pp. 88-96.

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EXECUTIVE SUMMARY

Introduction

Patellar tendinopathy (PT) is a common chronic pathology of the knee, with a high prevalence in both elite and recreational athletes as well as the general population. PT is related to overloading of the patellar tendon and frequently associated with jumping sports, and is characterised by pain and functional impairment. Even with contemporary treatment, the symptoms do not resolve rapidly, with a number of athletes experiencing symptoms for extended periods of time. This tendency is unacceptable in today's competitive milieu, making PT treatment extremely challenging in the medical environment. A better understanding of PT through further research will therefore make a valuable contribution to the management of PT in the sport environment.

Aim and objectives of the study

The main aim of this study was to formulate an integrated management model for PT through the integration of three current models in sports medicine, namely the etiological sport injury model, the injury prevention model, and the rehabilitation model, as a novel approach to the management of PT.

In order to achieve the main aim of the study, three research objectives were formulated, namely:

- Objective one: systematically analysing current literature, with a specific focus on the causative risk factors and rehabilitation of PT.
- Objective two: formulating a rehabilitation framework for PT by means of an international e-Delphi survey.
- Objective three: implementing the proposed rehabilitation framework for PT in a clinical set-up by means of a pilot pre-test, post-test clinical intervention.

Methodology

The methodology of this study consisted of a mixed-method research approach. This approached assisted in achieving the purpose and objectives of the study by means of both quantitative and qualitative research methods for the collection and analysis of the data for each individual objective in terms of an article.

The methodology that objective one of the study followed was a descriptive approach, and data was gathered about the characteristics of the causative risk factors and rehabilitation of PT. The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines were used for the systematic review. 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. The search strategy included a variety of electronic databases for articles published between January 2010 and October 2015, with specific keywords used in order to identify all the relevant articles for inclusion in this review. The results yielded 120 possible articles for inclusion before the eligible article process commenced. Different methodology quality appraisal tools were selected to evaluate the eligible articles due to 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. The average total methodological quality score for all the articles included (n=20) was 72%.

The methodology of objective two entailed using mostly a qualitative research approach for the e-Delphi survey, supplemented with some quantitative elements. In this study, it equipped the researchers with information relevant to PT rehabilitation as a basis for the formulation of a PT rehabilitation framework. The selection of experts for this e-Delphi survey was based on a published systematic review on PT (Morgan *et al.,* 2016) that was used as a screening tool to identify members who would serve on the e-Delphi panel. The international experts (n=5) were authors of publications included in the systematic review, and the South African experts (n=3) were from different South African universities with publications in the field of sport and sport science. The e-Delphi survey consisted of three rounds. The first two rounds focused on collecting opinions from the experts on the rehabilitation of PT as a basis for the development of a rehabilitation framework, which was then evaluated by these experts in the third and final round. The data collection process consisted of a semi-structured questionnaire. Items included in the questionnaire for round one of the survey were based on the data collected in the prior systematic review (Morgan *et al*., 2016). The questionnaires for rounds one and two consisted of a three-point Likert scale (agree/partially agree/disagree) (i.e., quantitative component). This was followed by an open-ended question at the end of each section whereby additional comments or suggestions could be given (i.e., qualitative component). After completion of these two rounds of the e-Delphi survey, the results were used to compile a draft framework for the rehabilitation of PT. Round three provided the e-Delphi panel with a final opportunity to review the draft framework and to provide feedback. This feedback was qualitative in nature.

The methodology of objective three entailed a pre-test, post-test pilot research design, which was utilised to determine the outcomes of the international e-Delphi-based rehabilitation intervention on PT symptoms and functionality in elite rugby players. The research and data capturing was conducted in Pretoria, South Africa. The rugby union medical manager (team physician) was informed about the study and requested to identify injured elite rugby players with PT. The players were also informed about the contribution they could make should they be willing to participate in the research study. The study population consisted of 16 elite rugby union players who met the inclusion criteria for the study. A subjective questionnaire compiled by the researcher and given to participants (during baseline testing) was used to capture demographic information, injury pattern of PT, load tolerance, and sport participation. Secondly, knee pain and functionality of the elite rugby players were subjectively measured by means of the Visual Analogue Scale (VAS) (baseline and 12-week after rehabilitation intervention) and the Victorian Institute of Sport Assessment–Patella (VISA-P) (baseline and 12-week after rehabilitation intervention). The objective outcomes measures included height and weight measurements at the baseline testing, according to the International Standards for Anthropometric Assessment, as well as quadriceps surface electromyography (EMG) done at baseline and 12-week after rehabilitation intervention.

Results

Objective one

Twenty studies covering the last five years that met the inclusion criteria were included in the review. The results revealed that the distinctive factor responsible for 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. Seven intrinsic (age, gender, anatomical alignment, body composition, joint range of movement, muscle strength, and muscle inflexibility) and four extrinsic causative risk factors were identified (acquisition and level of skills, type of sport, training surfaces, strapping or orthosis), with the main intrinsic causative risk factors being muscle flexibility and strength, and the main extrinsic causative risk factors being acquisition and level of skills. If the mechanical pathophysiological theory is considered, 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.

PT can be treated with numerous different therapeutic modalities, and the collective aim is to improve pain and function. The therapeutic modalities include, amongst others, eccentric exercises, other treatment modalities (non-specified drug therapy and deep transverse friction massage), hip and core strengthening, extracorporeal shock wave therapy, stretches, return to sport, and sport-specific techniques. Eccentric muscle training showed the most optimistic results.

In summary, if the modifiable intrinsic and extrinsic causative factors could be addressed in the management of PT, and the load on the tendon minimised, improvement in pain and function could be noticeable.

Objective two

Eight experts contributed to the first two rounds (n=8) of the e-Delphi survey, of which six (n=6) also participated in round three of the e-Delphi survey. The response rate was 100% (n=8) for the first and second rounds, and 75% (n=6) for round three. In the third and final round, the experts who responded to the PT draft framework were mostly in support of the rehabilitation framework, with some additional suggestions.

The e-Delphi survey identified three central aspects on which consensus was reached, namely functional abilities, individualised rehabilitation, and load tolerance. This formed the foundation of the proposed rehabilitation framework. Load tolerance, as a principal conclusive result of the e-Delphi survey, can be achieved by establishing the load via loading, specific to the individual's functionality. The experts in the e-Delphi survey were of the opinion that, although acceptable, all rehabilitation activities are not necessary and may therefore be viewed as secondary (as long as the athlete can tolerate the load on the tendon); nevertheless, these activities might assist faster return to sport, reduce re-occurrence, and improve overall function. The load tolerance principle implies that pain on the provocation test must return to baseline within 24 hours after activity or rehabilitation, which indicates that the patellar tendon has tolerated the load. Explicit consensus on a variety of other components was also reached, and formed part of the rehabilitation framework. This included rest from activity in the 1st – 2nd week, lower limb flexibility/stretching, hip strengthening, core strengthening, proprioception training, return-to-sport assessment, and that progression of the rehabilitation programme must be according to the athlete's response to load. Partial consensus was reached on the supplementary components of the rehabilitation framework, which included isometric training, eccentric exercise, cardiovascular training in the 1st – 2nd week, patella strapping during rehabilitation and return-to-sport, and the influence of the expectations from the trainer and/or coach on rehabilitation. This e-Delphi survey makes a unique contribution by means of a PT rehabilitation framework compiled from the opinions of international experts in the field of sport, rehabilitation, and, more specifically, PT.

Objective three

The 16 male rugby athletes (mean age 21.8) with confirmed signs and symptoms of PT all successfully completed the 12-week rehabilitation intervention programme without any participant dropouts or rehabilitation sessions missed. The participants were homogeneous with respect to training regime, with 37% being involved in international and 63% in provincial level of sport participation.

As expected, the forward rugby players' mean BMI was significantly greater than that of the backline players. PT occurred in the dominant leg in 75% of the elite rugby players and the recurrence of this pathology was 25%, with a gradual onset of PT symptoms being another prominent finding. The duration of symptoms was prolonged in some of the elite rugby players, with 19% experiencing symptoms for between three and six months, and 25% with persisting symptoms for six months or more. Jumping, running, change of direction, and intense training regimes were contributing factors to the mechanism of injury, and increased intensity (100%), frequency (94%), and duration (100%) contributed to the amplified load on the patellar tendon.

The EMG testing on the quadriceps muscle in the participants provided noteworthy findings. Based on the values obtained from the results, the single leg 25º decline squat provided decent activation results after the 12-week rehabilitation intervention, with significantly greater muscle recruitment. These results emphasise respectable outcomes, showing that the rehabilitation intervention made a statistically significant difference ($p<0.05$) in the mean scores of the VAS and VISA-P at baseline compared to 12-weeks after the intervention. The VISA-P score improved for all 16 participants over the 12-week rehabilitation period, with a mean increase in VISA-P score of 29.6 and a significant reduction in pain ($p<0.001$) on the VAS when comparing baseline pain to the degree of pain after a 12-week rehabilitation intervention.

This research did not determine the precise rehabilitation component in isolation that was accountable for the major improvement, but rather illustrated that a variety of essential rehabilitation components were responsible for the significant improvement in the elite rugby players.

An integrated management model for Patellar Tendinopathy

The essence (and main aim) of the entire research study was to formulate the integrated management model for PT as an overarching outcome. The integrated management model for PT was planned and developed by the researcher, based on the previously mentioned models and augmented with the findings of this study through the systematic review, international e-Delphi survey, and the implementation of the e-Delphi rehabilitation framework in the clinical set-up. Within the integrated management framework for PT, three core elements, each with different subdivisions, have been included. The first core element of the integrated management model for PT is *risk factor identification*. If the intrinsic and extrinsic causative factors could be identified and addressed in rehabilitation, the load on the tendon could be minimised, and improvements in pain and function would be noticeable. The causative risk factors play a vital role in prevention, planning, and motivation of an individualised rehabilitation programme. *Prevention strategies* form another respectable concept in PT, and were considered as the second core element in the integrated management model for PT. The focus is on PT pathology, preventative screening strategies, noticing PT complains in athletes, improving lower limb flexibility, and monitoring training loads. The final core element of the integrated management model for PT focuses on *rehabilitation,* and includes aspects such as load tolerance of the patellar tendon; functionality; individualisation; rest from activity; cardiovascular training;

isometric training; eccentric exercise; lower-limb flexibility; hip strengthening; core strengthening; proprioception training; progression of the rehabilitation programme according to response to load; patella strapping or orthosis imported in return-to-sport; sport-specific technique; return to sports assessment; and education.

Conclusion

The integrated management model for PT proposed in this study is a singular management model for PT, developed from up-to-date evidence, and has an innovative impact on the knowledge base of PT in sports medicine. The proposed model also sets a modernistic platform for forthcoming research in the field of PT.

CHAPTER ONE: ORIENTATION TO THE STUDY

1.1. Introduction

The research documented in this study was planned and implemented as a single report, but is offered in the form of either articles or chapters (containing background or additional information to the research). This reporting approach serves to combine the articles and chapters in a cohesive entity. However, the articles should also be interpreted as independent entities, with some connection and consequent overlap. This orientation to the study functions as an introduction to the research on Patellar Tendinopathy (PT) and is intended to provide the reader with a holistic view of the study.

1.2 Background and problem statement

Overuse of tendons, also defined as tendinopathies, accounts for between 30% – 50% of all sports injuries and result in a large quantity of morbidity and financial expenditure in the health care system (Sànchez-Ibàñez, 2015:1). Sànchez-Ibàñez (2015:1) highlights the statistical data, which reveal that an estimated 28 million patients in the United States of America alone present with tendon damage annually. One particular tendon pathology, commonly visible in the knee (Reinking, 2012:3), is PT (Malliaras *et al.,* 2015:887). The first literature on PT, which dates back to 1973, is currently still related to a poor understanding and unsuccessful rehabilitation path (Backman & Danielson, 2011:2626).

The pathology of PT is multifactorial and predisposed by intrinsic and extrinsic causative risk factors. Intrinsic causative risk factors include height, weight, lower limb joint range of motion, leg length, body composition, lower limb alignment, inadequate length and strength of the hamstring and quadriceps, lower foot arch height, reduced ankle dorsiflexion, larger leg length difference and patella alta, particularly in men (Rudavsky & Cook, 2014:125). Extrinsic causative risk factors for PT comprise intensification in training volume and frequency, change in surface density and shock absorption, or athletic tracks with high horizontal traction (Rudavsky & Cook, 2014:124-125). These causative risk factors will possibly increase the strain on the patellar tendon with long-lasting tendon overload resulting in weakening of the tissues, which Schwartz *et al.* (2014:415) suggest is the most frequently proposed theory for PT.

The prevalence of PT is quite common in men ranging in ages from 15 to 30 years (Malliaras *et al*., 2015:887). It also has a prevalence in recreational athletes and an exceptionally high prevalence in elite athletes (Van Ark *et al.,* 2011:1068; Rudavsky & Cook, 2014:122), with an extraordinary prevalence rate in sports where the knee extensors are loaded ballistically. Contrastingly, there is a low correlation of PT in sports with lesser loads on the tendon which emphasises the link of PT with high loads on the patellar tendon (Vetrano *et al.,* 2013:796). This is a challenging injury to rehabilitate and may potentially cause early retirement from sport (Malliaras *et al*., 2015:887). Fifty-three per cent of athletes diagnosed with PT discontinue sports participation due to the serious nature of the injury (Van Ark *et al.,* 2011:1068). Determining the exact loss of time in sports due to PT is problematic, as overuse injuries are often not recorded as acute in terms of loss of time from competitions and training. Estimating the prevalence of PT accurately is therefore also problematic (Rudavsky & Cook, 2014:122).

The first stage of this pathology is characterised by an inflammatory process and, as the pathology progresses, it develops into a degenerative pathology of the patellar tendon, with a failed healing process rather than tendinitis (Van Ark *et al.,* 2011:1068). The onset of symptoms is gradual and associated with localised pain in the anterior part of the knee, and the pathology briefly entails "…increased tenocyte numbers and rounding, in ground substance expression, instigating oedema, matrix degradation and neovascular ingrowth" (Malliaras *et al*., 2015:887). Pain is observed during or directly after repeated running or jumping and fades after a short period of rest, but returns immediately after continuation of physical activity (Vetrano *et al*., 2013:795). The clinical diagnosis of PT symptoms is based on the medical history of the patient (Sànchez-Ibàñez, 2015:1), with the purpose of assessing and replicating pain in specific clinical tests and palpation of the patellar tendon (Stasinopoulos & Malliaras, 2016:15). Imaging techniques such as colour Doppler sonography (CDS) and magnetic resonance imaging (MRI) are valued tools in confirming the diagnosis of PT (Sànchez-Ibàñez, 2015:1).

Researchers agree that the ideal management of PT is still a controversial aspect among medical and rehabilitation personnel (Crisp *et al.,* 2008:1626), and evidence-based guidelines regarding the treatment of PT are vague (Schwartz *et al.*, 2014:419). Numerous PT treatment protocols are based on evidence concerning other tendinopathies in the human body with practical application to the patellar tendon, but dissimilarities in tendons at a structural and clinical level may invalidate these findings (Rudavsky & Cook, 2014:122). Some management strategies may also work exceptionally well with some athletes, but be unsuccessful with others (Crisp *et al.,* 2008:1629). As yet, no single isolated treatment modality can be associated with complete recovery of athletes (Van Ark *et al*., 2011:1068) and unfortunately, also no supportive treatment modality is as yet capable of reversing their injuries (Sànchez-Ibàñez, 2015:1). This results in PT rehabilitation being lengthy and frustrating for all involved (Rudavsky & Cook, 2014:122). This highlights a shortage of supportive and integrated evidence to justify any standard treatment (Crisp *et al.,* 2008:1629).

The limitations in literature motivated the research for this study, with the purpose of exploring PT rehabilitation from a literature and international opinion-based perspective, as well as from a pilot study trial in the clinical set-up. The researcher's focus was on two key aspects, the first being that there is a lack of evidence on effective rehabilitation for this pathology. The treatment of PT is often prolonged and unsuccessful (Rudavsky & Cook, 2014:122), which seems undoubtedly clear from the reoccurrence rate of PT, which according to Stuhlman *et al*. (2016:e1029), could unfortunately be as high as 23% in athletes who had already successfully completed an extensive and intensive rehabilitation programme. Secondly, there is a lack of integration of existing models into a management model for PT. Currently, none of the PT models regarding the pathology (Rudavsky & Cook, 2014:122), for example the tendinitis model (Reinking, 2016:855) and the eccentric exercise training model (Visnes & Bahr, 2007:217), have indicated any evidence of the linking of an injury and rehabilitation model in research yet.

1.3 Research purpose and objectives

The main purpose of this study was to compile an integrated management model for PT, which would be based on the integration of comprehensive injury and rehabilitation models. This research would have a unique approach, where three dissimilar models would be combined to achieve the main purpose of the study.

In order to realise the main purpose of the study, the following research objectives were formulated:

- Objective one: analysing current literature, with a specific focus on the causative risk factors and rehabilitation of PT.
- Objective two: formulating a rehabilitation framework for PT by means of an international e-Delphi survey.
- Objective three: implementing the proposed rehabilitation framework for PT in a clinical set-up by means of a pilot pre-test, post-test clinical intervention.

1.4 Research methodology

A mixed-method research approach was followed to achieve the purpose and objectives of the study by means of both quantitative and qualitative research methods for the collection and analysis of the data for each individual article. The purpose of the mixed-method approach was to intensify and deepen the understanding and validation of the data collected in the study, in order to enrich the findings and conclusions (Almalki, 2016:291).

The results would be presented as an integrated management model for PT. More details regarding the specific research methods, study participants, measuring instruments and data capturing applied to answer each of the research objectives would be included later in this thesis.

1.5 Ethical considerations

The protocol was presented to the Health Sciences Research and Ethical Committee (HSREC) at the University of the Free State (UFS) for approval. Ethical clearance (HSREC *181/2015*) was obtained before the commencement of the study. Any changes necessary in measuring instruments or study participants during the progress of the study were approved as amendments to the protocol by the same committee (refer to Annexure A1-A3).

1.6 Chapter exposition

This thesis consists of an introductory chapter, followed by five main chapters - comprising a literature review, three independent articles, followed by the integrated management model for PT as part of the discussion chapter. A personal reflection on the study is included as the closing chapter. Each individual chapter is concluded with its own appropriate reference list. This is done to ensure continuity throughout the thesis since three of the chapters follow the journal's guidelines for authors. The seven chapters are:

1.6.1 Chapter 1: Orientation to the study

In the first chapter, a brief background to the study is provided, serving as an introduction to the study, and highlighting the main purpose and objectives of the study. An overview of the remainder of the thesis is also presented.

1.6.2 Chapter 2: Literature review on patellar tendinopathy

In the second chapter, all the appropriate literature regarding PT are covered, including pathology, rehabilitation, and outcome measurements.

1.6.3 Chapter 3: Article 1: Causative factors and rehabilitation of patellar tendinopathy: A systematic review

In the third chapter, a systematic review article is presented. The objectives 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 to the main identified causative factors. The article was published in the South African Journal of Physiotherapy with citing reference:

Morgan, S., Janse van Vuuren, E.C. and Coetzee, F.F., 2016, 'Causative factors and rehabilitation of patellar tendinopathy: A systematic review', South African Journal of Physiotherapy 72(1), a338. http://dx.doi.org/10.4102/ sajp.v72i1.338).

1.6.4 Chapter 4: Article 2: Patellar tendinopathy: An international e-Delphi perspective

The fourth chapter comprises the e-Delphi survey, and the article was submitted to the South African Journal of Research in Sport, Physical Education and Recreation and formulated according to the journals guidelines. The main purpose of the research was to utilise an e-Delphi survey as a unique approach to formulate a rehabilitation framework for PT. This was accomplished by collecting qualitative opinions, supplemented with some quantitative elements, from eight experts representing South African and international views.

1.6.5 Chapter 5: Article 3: Patellar tendinopathy: A rehabilitation intervention in elite rugby union players

The e-Delphi survey rehabilitation framework for PT, as implemented in the clinical set-up, is presented in the fifth chapter. The article was submitted to the South African Journal of Research in Sport, Physical Education and Recreation and formulated according to the journals guidelines. The purpose of the research was to highlight the fact that there was limited research within the professional rugby environment, and that continuous poor outcomes of PT rehabilitation were evident, which necessitated further research. This article reports on the exploratory implementation of the e-Delphi-based rehabilitation intervention among elite rugby players of a South African rugby union, based on an initial compilation of a 12-week rehabilitation intervention by means of an international e-Delphi survey.

1.6.6 Chapter 6: An integrated management model for Patellar tendinopathy

The sixth chapter contains the formulation of the integrated management model for PT, based on the findings as indicated chapters two to five, as well as limitations of the study and recommendations for future research.

1.6.7 Chapter 7: Epilogue: "The silent voice of PT management: Perspectives from a sports team physiotherapist."

The seventh and final chapter, comprises a physiotherapist's self-reflection on the encompassing study.

1.7 Conclusion

In this orientation to the study chapter, a holistic view of the research project as a single entity was provided, also indicating the research articles contained therein as separate entities addressing the research objectives. The subsequent chapter clarifies the current literature regarding PT, with a focus on the pathology and treatment of PT, as well as the outcomes measures, as utilised in PT rehabilitation.

1.8 References

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CHAPTER TWO: LITERATURE REVIEW ON PATELLAR TENDINOPATHY

2.1 Introduction

The inclusive synopsis of existing literature on the subject of Patellar Tendinopathy (PT) over the last decade is defined in this chapter of the research study. It is comprised of three sections in which the different features of PT pathology, treatment and outcome measures are outlined, and is followed by a conclusion. The literature under review formed the basis in establishing prior and contemporary tendencies in PT and was utilised to define the three phases of this research study. In this chapter the reader will gain a broader understanding of PT, and the research study's planning, formulation and execution are demonstrated.

Section one and two of the literature review forms the encompassing basis of the research study and articles one and two was formulated thereof. Article three is based on part two and article two are interconnected to part three of the literature review. Figure 2.1 provides a schematic overview of the study, indicating the literature relevance.

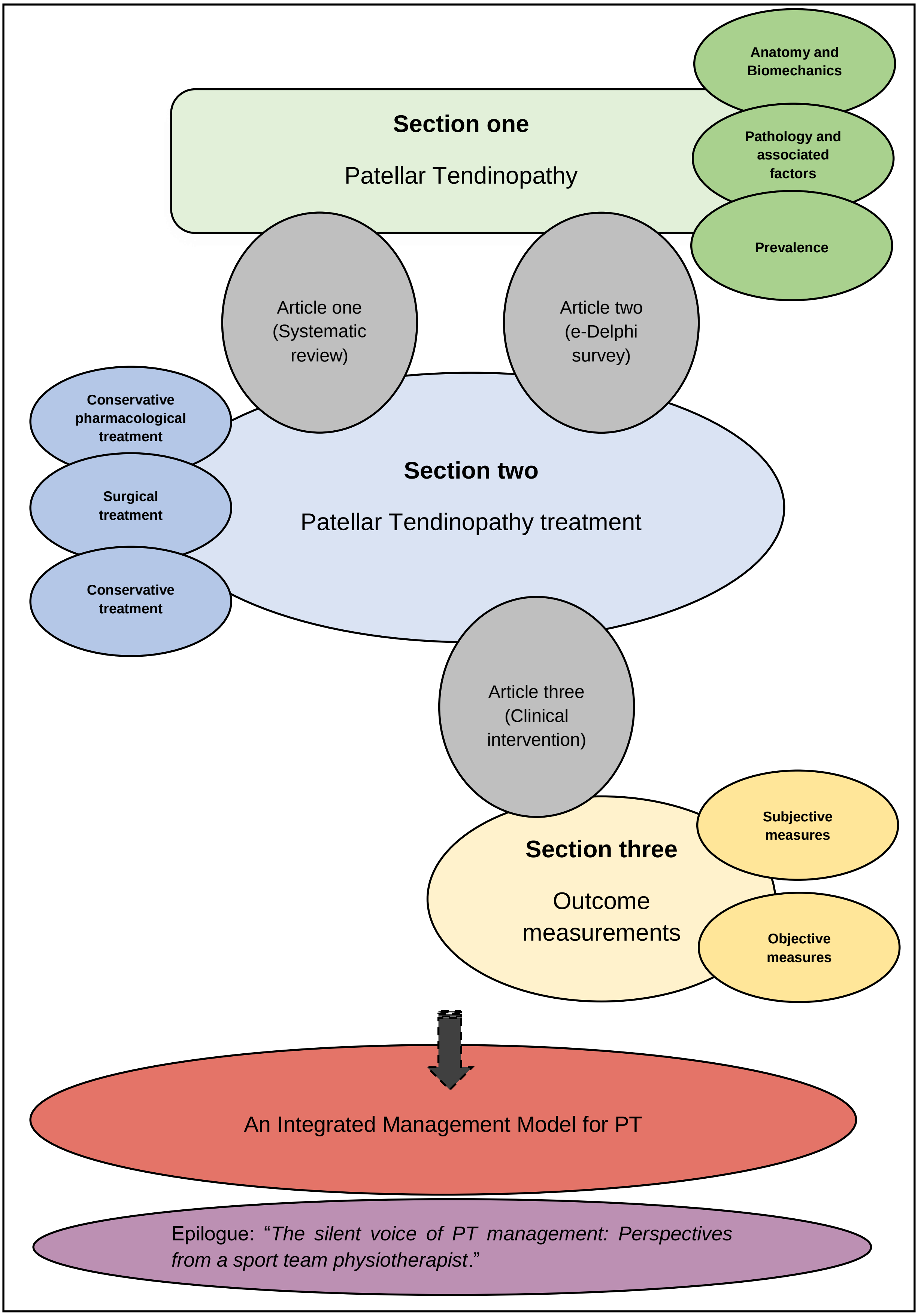

Figure 2.1: Overview of the study indicating the literature relevance

2.2 Section one: Patellar tendinopathy

2.2.1 Introduction

The popularity of sport participation has increased over the years (Clarsen *et al*., 2010:1), which has led to a high incidence of acute and chronic injuries (Yang *et al*., 2012:198-199). Brukner and Khan (2007:16) highlight the fact that acute injuries are characterised by symptoms of sudden pain and swelling, usually associated with a single traumatic incident, for example, an ankle sprain. Chronic injuries, however, indicate a more gradual onset and are the result of overusing one area of the body for a prolonged period. Due to the serious nature of chronic injuries, it is no surprise that an extensive amount of time and resources have been allocated to research towards the epidemiology of so-called overuse musculoskeletal injuries in sport (Brukner & Khan 2007:16).

Studies by DiFiori *et al*. (2014:3) and Reinking (2012:3) support the fact that overuse tendon pain, as a result of overtraining, is related to sustained high-load training and has become a serious concern for both elite and recreational athletes, a major concern being absence from training and matches for up to four weeks or longer (Hägglund *et al.,* 2011:1908). Overuse injuries are commonly susceptible in the patellar tendon in the knee, Achilles tendon and posterior tibialis in the lower limb, as well as the rotator cuff, long head of the biceps and the wrist extensors in the upper limb (Reinking, 2012:3). The knee is the anatomical site that accounts for the most overuse injuries in runners, tri-athletes and military recruits, resulting in a high prevalence of specifically patellar tendinopathy (PT) (Powers, 2010:42). PT is an aggravating soft-tissue injury of the patellar tendon, due to overloading (Hägglund *et al.,* 2011:1906) and lengthy repetitive stress (Zwerver *et al.,* 2011:1191) of the tendon beyond its limits. This results in structural damage, which involves the extensor apparatus of the knee (Ferretti *et al.,* 1985:240) and is the result of forceful contraction of the quadriceps muscle (Lavagnino *et al.,* 2011:297). The mechanism of injury is associated with rapid deceleration, acceleration, jumping and landing on the lower extremities (Ferretti *et al*., 2002:2180).

2.2.2 *Anatomy of the patellar tendon and biomechanics*

The muscles of the upper thigh are attached to the sesamoid bone of the patella by four tendons, namely the rectus femoris, vastus lateralis, vastus medialis and vastus intermedius (Torres *et al.,* 2012:7). The structure between the inferior pole of the patella bone and the tuberosity of the tibia is known as the patellar tendon or infrapatellar ligament (Flandry & Hommel, 2011:82). It is formulated out of fascicles (collagen fibril bundles) and the epitenon (connective tissue layer) which contains nerves, blood and lymph vessels. Fatty areolar tissue lined with synovial cells, the paratendon, encircles the patellar tendon which lessens friction on the surrounding tissues and supports the elasticity of patellar tendon. This is called the paratendon. The biomechanics of the knee joint is also dependant on additional structures, like the infrapatellar fat pad which acts as a shock absorber (Torres *et al.,* 2012:7).

The extensor mechanism of the knee is a compound structure consisting of three interlaced structures, namely the quadriceps muscle and tendon, patella and patellar tendon. Additionally, the mechanism also consists of the patellar retinacula, restrictor ligaments, Hoffa's fat pad and the pre-patellar tissue. Astur *et al*. (2011:490) state that the main function of the mechanism is extension of the knee and stabilisation of the patellofemoral joint, and that a decrease of joint synergy and stability among the patella and femur results in abnormalities.

2.2.3 *Intrinsic causative risk factors contributing to Patellar Tendinopathy*

Literature on multifactorial aetiology confirm that PT consists of a variety of intrinsic biomechanical factors. PT can be caused by intrinsic causative risk factors such as genetics (McCreesh & Lewis 2013:243-244), age, gender (Sànchez-Ibàñez, 2015:1; refer to 2.2.10), weight, body mass index (Schwartz *et al.,* 2014:415), metabolic factors (McCreesh & Lewis 2013:247-248), obesity, increased waist circumference, diabetes, hypertension, dyslipidaemia (Murtaugh & Ihm, 2013:175), muscle weakness (Stasinopoulos, 2014:e15301), quadriceps and hamstring inflexibility (Stuhlman *et al.,* 2016:e1028; refer to 2.3.17), misalignments (Stasinopoulos, 2014:e15301), joint laxity (Murtaugh & Ihm, 2013:176), height, increased patella lateral-medial mobility, increased knee laxity, limb-length discrepancy, patella alta (Stuhlman *et al.,* 2016:e1028) and pathology in the arch height of the foot (Schwartz *et al.,* 2014:415). These intrinsic causative risk factors act from within the body (Malliaras & O'Neill, 2017:71), and although individually different, each in some way has an impact on the patellar tendon (Rutland *et al*., 2010:167) and intensifies the probability of developing patellar tendinopathy (Witvrouw *et al.,* 2011:190).

2.2.4 Patellar tendinopathy pathology

The development of the pathological process of chronic pain has been widely investigated over the last decade (Scott *et al*., 2013:536), with PT being shown as one condition typically displaying no inflammatory process (i.e. no increase in the presence of fibroblasts, no disorganised collagen, no absence of prostaglandins and no inflammatory cells) (Stasinopoulos 2014). Furthermore, in chronic tendinopathy, a common aspect is neovascularisation, which can be defined as new vasculature growth in zones of poor blood supply. Pain perception might therefore be due to neovascularisation. These facts counteract the previous view of physicians who once thought that PT was actually an inflammatory condition (Rutland *et al*., 2010:167).

Rowan and Drouin (2013:302,308) emphasise that identifying the stage of PT is important in order for the histological components involved to be recognised and the appropriate treatment intervention to be chosen. PT can be defined as acute (onset in less than (<) two weeks) (Rosso *et al.,* 2015:99), where repetitive strain on the patellar tendon cause inflammatory molecules from tenocytes associated with micro ruptures of the collagen fibrils; subacute (onset between two and six weeks) with some degree of reversibility, in combination with the appropriate rehabilitation environment; or chronic, which is the final stage of the pathology with disrupted collagen, extensive cell death, neovessel and nerve ingrowth into the tendon, resulting in an irreversible pathology (McCreesh & Lewis, 2013:245).

Whilst investigating the pathogenesis of PT, the importance of overuse in the development of this pathology (refer to 2.2.5) was revealed. The main cause of PT has been found to be repetitive micro-trauma, resulting in the “overuse pathology” (Rosso *et al*., 2015:99).

2.2.5 Extrinsic causative risk factors for Patellar tendinopathy

Extrinsic causative risk factors that contribute to PT include excessive mechanical load (e.g. an escalation in frequency, duration or intensity of an athlete’s training intervention; Hägglund *et al*., 2011:1908), training mistakes (e.g. type of running surface, rapid progression of training, poor technique and overtraining), inappropriate equipment (e.g. incorrect seat height, racquets or foot wear) (Murtaugh & Ihm, 2013:176), environmental conditions (Stuhlman *et al.,* 2016:e1028) and diverse pharmacological agents (Sànchez-Ibàñez, 2015:1).

Furthermore, as Lewis and Cook (2014:425) point out, antimicrobial medications such as fluoroquinolones are known to cause tendinopathies and can also cause tendon rupture. Fluoroquinolone-related tendon symptoms can present within hours of beginning treatment or up to six months after cessation.

2.2.6 Mechanism of Patellar tendinopathy injury

All athletes regardless of the sports disciplines can sustain musculoskeletal injuries with different factors contributing to these injuries (Saragiotto *et al*., 2013:137). Excessive (Rosso *et al*., 2015:99), high-impact ballistic (Vetrano *et al*. 2013:796) and repetitive mechanical overload (Rowan & Drouin, 2013:302) on the patellar tendon that surpasses the reparative capacity, is a distinctive cause in the development of PT. It is associated with activities like change in direction, jumping, running, landing, rapid acceleration and deceleration (Rosso *et al*., 2015:99; Rutland *et al*. 2010:167; refer to 2.2.5), which according to Vetrano *et al*. (2013:796) indicate a direct link between load on the tendon and the development of PT (refer to 2.3.3).

2.2.7 Patellar tendinopathy symptoms

Murtaugh and Ihm (2013:175) reiterate that tendinopathy is a well-known source of pain in sports medicine. The symptoms of PT have a gradual onset (Reinking, 2012:5), which is often deceptive (Rosso *et al*., 2015:99) and unexpected, with a repetitive incidence (Sànchez-Ibàñez, 2015:1) associated with phases of increased activity (Rosso *et al*., 2015:99-100), and can also be elicited by a single load increase (Scott *et al*., 2013:2). PT is characterised by extended anterior knee pain (Sànchez-Ibàñez, 2015:1) or discomfort with a localised sharp pain (Vetrano *et al*., 2013:797) in the involved area (Pečina *et al*., 2010:278) and a loss of strength in the patellar tendon (Rosso *et al*., 2015:99-100; refer to 2.3.13; 2.3.14). The pain influences the functional ability of the lower limb (Pečina *et al*., 2010:278) with stiffness present during stair climbing, running, knee squatting and kneeling (Rowan & Drouin, 2013:302), and occurs immediately, during or after repetitive activity (Romero-Rodriquez *et al*., 2011:43), easing after a resting period with the symptoms settling down spontaneously only to reoccur later (Scott *et al*., 2013:2) mostly during or after physical activity (Vetrano *et al*., 2013:797). Symptoms are aggravated by lengthy knee flexion (Rosso *et al*., 2015:99-100), functional activities (Rowan & Drouin, 2013:302) like hop and squat (Stasinopoulos, 2014:e15301) and in severe cases the pain is experienced during daily living activities (Rosso *et al*., 2015:99-100).

2.2.8 Anatomical site of Patellar tendinopathy

The most common anatomical site for PT is the inferior patellar tendon (Rosso *et al*., 2015:100) with a 70% prevalence (Vetrano *et al*., 2013:795; refer to 2.3.14), which can also be present at the tibial tuberosity (Stasinopoulos, 2014:e15301) in 10% of the cases, with 20% prevalence at the superior pole of the patellar tendon (Vetrano *et al*., 2013:795). As indicated in the literature under review, the mid-portion of the patellar tendon is, however, an uncommon site for PT symptoms (Stasinopoulos, 2014:e15301).

2.2.9 Duration and progression of Patellar tendinopathy symptoms

Saithna *et al*. (2012:553) determined through their research that approximately one third of athletes affected by PT can experience symptoms and limitations and may not be able to return to sport for a period of six months or longer (Stuhlman *et al*., 2016:e1029; refer to 2.3.21). For most athletes, symptoms reoccur for several years (Saithna *et al*., 2012:553), with 15% of these athletes suffering from anterior knee pain for up to 15 years after the initial diagnosis (Rosso *et al*., 2015:99). The mean duration of absence from activity for recreational athletes is said to be 19 months and an astonishing 32 months for elite athletes. The reoccurrence rate of PT symptoms is unfortunately high (23%) in athletes who had already successfully completed an extensive and intensive rehabilitation programme (Stuhlman *et al*., 2016:e1029) and is frequently associated with a period of inactivity (two weeks or longer) by the athlete and a return of symptoms when sport participation is resumed. Rudavsky and Cook (2014:123) attribute this to the deconditioning of the patellar tendon. The prognosis of healing from PT in male athletes is poor with 53% of all athletes eventually ending their sporting career due to a failed healing process and reoccurring of symptoms (Mautner *et al*., 2013:173).

2.2.10 Prevalence of Patellar tendinopathy

Mautner *et al*. (2013:169) states that overuse tendon pain is associated with 30% – 50% of all sport-related injuries. The knee is the anatomical site accounting for the most overuse injuries in runners, tri-athletes and military recruits with a high tendency of PT (Powers, 2010:42). The frequent pathology of PT (Sosa *et al*, 2014:27) in both elite and recreational athletes (McCreesh & Lewis 2013:244) has been pointed out by a number of researchers and it is clear that it affects people in repetitive-related occupations (Sànchez-Ibàñez, 2015:1), which can ultimately be disabling (Rosso *et al*., 2015:99) and have a significant impact on the athlete's performance and quality of life (Rowan & Drouin, 2013:307; refer to 2.2.9).

A 14% PT prevalence rate occurs in all athletes participating in a variety of sporting codes, whereas the overall estimation of PT prevalence in recreational athletes is 8.5% due to the lower intensity of their training programmes (Hägglund *et al*., 2011:1906; Vetrano *et al*., 2013:1). However, the prevalence of PT is much higher among elite athletes at 13% – 20% (Stuhlman *et al.,* 2016:e1028), reaching a percentage as high as 40% in athletes participating in sports with high demands (Abat & Sanchez-IbaÑez, 2014:1) on the extensor mechanism of the knee (Steunebrink *et al*., 2013:34). The prevalence of PT in jumping sports like volleyball for instance is 45% due to the fact that they jump approximately 300 times per match (Visnes *et al*., 2012:503), and up to 32% in basketball (Murtaugh & Ihm, 2013:175), and it is quite a common pathology in professional rugby (Wilson *et al.,* 2014:672; refer to 2.2.11), soccer, sprinting (Stuhlman *et al.,* 2016:e1028), stair climbing, hiking, squatting, tennis, figure skating and skiing (Pedrelli *et al*., 2009:73), in contrast with sports where there are a low load on the patellar tendon, such as cycling (Vetrano *et al*., 2013:796).

Overall, PT accounts for 15% of all soft tissue knee injuries (McDaniel *et al*., 2012:1), and literature further indicates that the prevalence of PT in men is twice as high as in females, with male volleyball and basketball athletes who are more prone to develop PT during their careers than females (Stuhlman *et al.,* 2016:e1028). Furthermore, Hägglund *et al*. (2011:1908) refers to the fact that in 40% of cases, PT is recorded in the dominant leg of the athletes compared to 3% of injuries in the non-dominant leg.

2.2.11 Patellar tendinopathy in elite rugby players

As pointed out by Gamble (2014:10), rugby is an irregular collision sport with several work:rest ratios with high physical demands on individual players (Duthie, 2006:2; refer to 2.2.5; 2.2.6). A rugby player's progression is based on the development of anthropometric and physical qualities and relies on work capacity by improving strength, power and speed, optimising body size and developing muscularity for specific positions required during game play. The sport also entails aerobic fitness and anaerobic qualities in order for players to attain and reproduce high levels of work output during repeated high-intensity efforts (Duthie, 2006:5). Individual assessments to identify strengths and weaknesses are followed by training regimes (refer to Table 2.1) utilised to improve performance and the integration of specific training methods for each aspect of physical conditioning. This can attribute to the successful physical conditioning (Duthie, 2006:11) of a well-conditioned elite rugby player, displaying characteristics such as endurance, speed, agility, power, flexibility and sport-specific skills (Vaz *et al.,* 2013:230).

Rugby players are divided into forward and backline players, where forward players spend 12% – 13%, and backline players 4.5%, of a match in high-intensity work (Vaz *et al.,* 2013:226). Backline players are more involved in running and forward players are mainly responsible for contesting possession at the restart phases during scrums and lineouts. This set-piece phases place high demands on the forward players in terms of physical work, especially on the lower limbs. The predominant biomechanical load is the synchronised triple extension of the hips, knee and ankles with transference of the force through the shoulders during contact. This is characterised by high-powered dynamic actions, which involves high force and fast movement speed associated with jumping and tackling. To obtain this triple-action extension movement, the focus is on strength (heavy load) training and explosive power training (Gamble 2014:10-11; refer to 2.2.6). A typical training regime for rugby players is set out in the table that follows.

Table 2.1: Training regime for rugby players

Strength training	The preparation of rugby players involving the development of hypertrophy and strengthening of the upper and lower limb muscles is critical in order to prepare the players for the strenuous demands of the game. Furthermore, sport-specific skills training is another focus point achieved through gymnasium work and closed kinetic chain exercises.
Core stability	In rugby, high speed running and changes in direction requires good motor control and core stability so as to maintain the trunk posture. A further necessity is proper lumbo-pelvic stability and core strength during collision aspects of the play of rugby which will prevent injuries.
Sprint training	Running mechanics can be improved through sprint running and includes activities such as assisted downhill running, running attached to bungee ropes, resisted sprinting uphill or towing sleds (refer to 2.2.5; 2.2.6).
Conditioning games	In-season fitness, by means of cardiovascular training (with the aim to maintain match fitness), is achieved by conditioning games. This type of training involves an ample amount of running (refer to 2.2.6).
Agility training	Low hurdle work and ladder drills are excellent exercises to improve agility (refer to 2.3.20).
Plyometric training	In preparation for matches during the in-season, depth jump exercises (plyometric training) are performed in the pre-season to simulate game play (refer to 2.2.6).
Stretching	Long-tern flexibility in muscles is dependent on adequate and continues stretching of the upper and lower body muscles.

Source: Gamble, 2014:10-18

The professional rugby arena with its high-level rugby tournaments (Vaz *et al*., 2013:227) and ever-increasing incentives, naturally lead to more intensive training loads and lengthier training periods (Gamble, 2014:12; refer to 2.2.5; 2.2.6). Training rugby-specific skills can be repetitive and occasionally impair the athlete's physical condition (Vaz *et al*., 2013:227; refer to 2.2.5), and players are placed in a position where they have to continue participating with chronic and reoccurring injuries to maintain the incentives being offered (Gamble, 2014:12). As a result, there is an escalation in injury prevalence to diverse body parts of the players, which could result in absence from games for prolonged periods of time (Vaz *et al*., 2013:227; Gamble, 2014:12).

Reoccurring injuries are related to the nature of the game, player position, level of participation (Ras & Puckree, 2014:1346), increased volumes, intensity and duration of training sessions and tournaments (Durcan *et al*., 2014:173; refer to 2.2.5). Ras and Puckree (2014:1346-1349) estimate injury prevalence in rugby to be approximately 55% and injuries are most commonly sustained in the knee, ankle and shoulder areas. The knee is the anatomical site that accounts for the most serious injuries sustained in rugby (Durcan *et al*., 2014:173; refer to 2.2.8), and this is directly linked to an extended absence from training and match participation (Gamble, 2014:12).

The amplified load factors on the tendons as mentioned in Table 2.1 have been resulting in a higher acute injury rate and an increased prevalence of tendinopathies. Emphasis has been placed on the prevalence and mechanisms of acute rugby injuries, as opposed to chronic injuries, although there is a 13% PT prevalence rate amongst elite rugby players (refer to 2.2.10). There is a clear lack of research in this field, which highlights the need for further investigation (Durcan *et al*., 2014:173).

2.2.12 Diagnosis of Patellar tendinopathy

Many athletes with the onset of symptoms, initially consult with a medical practitioner and/or physiotherapist (Scott *et al*., 2013:537; refer to 2.3.1). The diagnosis of PT is based mostly on the medical history and clinical findings of healthcare professionals, but ultrasound and magnetic resonance imaging (MRI) are valuable tools in assisting with the diagnosis (Vetrano *et al*., 2013:795). These tools contribute to the identification of the location of tendon thickening or other structural changes and can provide guidance for proper treatment (Sànchez-Ibàñez, 2015:1).

Ultrasound imaging of the patellar tendon illustrates the classic echogenicity of the fibrillary structure with degradation and disorganisation of collagen fibres and a hypo-echogenic zone frequently related with tendon thickening. Colour and Power Doppler imaging is valuable in assessing intratendinous neovascularisation (Rosso *et al*., 2015:100). PT shows a typically increased signal intensity on an MRI (Rowan & Drouin, 2013:302) and it can be used to indicate partial tears (Rosso *et al*., 2015:100). In comparison, when making the most accurate diagnosis of tendinopathy, research indicates that an ultrasound is more accurate than an MRI due to the superior spatial resolution of ultrasound imaging. The ultrasound is 83% accurate in making a correct pathology diagnosis. However, 22% of images showing abnormalities in the patellar tendon are not associated with clinical symptoms and athletes may appear to be symptom free. However, as Scott *et al*. (2013:537) emphasizes, elite athletes in particular are at high risk of developing pain and symptoms at a later stage. It is advisable to perform a more advanced investigation to support the clinical diagnosis of elite athletes (Murtaugh & Ihm, 2013:176).

2.3 Section two: Treatment for Patellar tendinopathy

2.3.1 Role of physiotherapy in Patellar tendinopathy rehabilitation

Damgaard *et al*. (2013:1) and Footer *et al*. (2017:9) agree that musculoskeletal pathologies (refer to 2.2.4) affects quality of life, and physiotherapists as medical professionals have substantial skills and knowledge to contribute positively in the rehabilitation of athletes.

Physiotherapy is the most commonly prescribed form of conservative treatment to assist in the recovery of sports injuries, including acute or chronic pain, with widely reported successes. It consists of a variation of scientifically-based clinical skills that can be combined to treat various pathologies (Khalid *et al*., 2015:107-108), including rehabilitating athletes, enabling and supporting them to accomplish their goals (Grant *et al*., 2014:66) by assessment and initial diagnosis (refer to 2.2.12), treatment to encourage healing, rehabilitation for successful return to their respective sporting disciplines, prevention by identification and addressing deficiencies as well as educating athletes and enriching their knowledge of the respective pathologies (refer to 2.3.23). For this reason, physiotherapy plays in integral role as part of the multi-disciplinary team in the treatment of elite as well as recreational athletes with PT (Clark, 2015:48; refer to 2.2.10; 2.2.11).

The escalation in literature on PT indicates that PT is a troublesome overuse injury of the patellar tendon, and as no consensus has been reach over the last decade on the most appropriate manner in which to treat this pathology (Hoksrud *et al*., 2012:542), mainly due to the ineffective results from several different treatment modalities (Hägglund *et al*., 2011:1906), researchers agree that this emphasises the need for further investigation and persistent and in-depth research into more effective manners of treatment for the pathology (Crisp *et al*., 2008:1,5-6).

Though the majority of physiotherapy treatment modalities used in PT rehabilitation are evidence based (Ali, 2012:88), they do vary (Grant *et al*., 2014:66), with dissimilar theoretical mechanisms of working. There is, however, a common aim of improving the pathology (Stasinopoulos, 2016:1011). The next section alludes to a number of these interconnected modalities in the comprehensive treatment of PT.

2.3.2 Individualised rehabilitation intervention based on functional ability

The planning of an individualised rehabilitation intervention for PT is part of physiotherapy rehabilitation and entails multifaceted clinical reasoning with attention to detail (Scott *et al*., 2013:538-539). Malliaras *et al*. (2015:894) and Scott *et al*. (2013:538-539) agree that the basis must be on a functional assessment, with the long and short-term rehabilitation goals established on functional targets in order to ensure individualised management interventions. Early functional treatment is important (Frizziero *et al*., 2014:47) to obtain positive therapeutic outcomes such as functional strength during PT rehabilitation (Scott *et al*., 2013:538). These improvements should be based on the acceptable progression of load training (refer to 2.3.3), taking each individual athlete in consideration (Díaz, 2016:64) and keeping the specific adaptation to imposed demand principle in mind (Better Movement, 2009:1).

2.3.3 Load tolerance and modification

Rehabilitation plays a vital role in load tolerance and modification (refer to 2.3.1), which are the fundamental focus points of PT rehabilitation aiming to lessen the progression of PT (Reinking, 2016:857) by means of the modification of the kinetic chain, musculoskeletal unit and tendon load. Load modification is necessary in order to reduce pain levels, and high-load activities must be limited in terms of volume and intensity (Malliaras *et al*., 2015:890). However, complete rest of the patellar tendon should be avoided as this would have an adverse effect on tendon strength (Reinking, 2016:857). Pain levels must also be monitored in relation to the load throughout a 24-hour period, although some pain is acceptable during and after activity. Pain response (refer to 2.2.7) can be monitored by a pain-provocation test (single leg decline squad) on a daily basis at the same time throughout the entire rehabilitation intervention. The load tolerance principle can be described if the pain level on the pain-provocation test has returned to the baseline within 24 hours after activity or rehabilitation exercises, which would indicate that the patellar tendon has tolerated the load. Should the pain be aggravated, it would mean the load has been exceeded (Malliaras *et al*., 2015:890-891). Load progression during PT rehabilitation must be adapted to each individual athlete's response to load (Stasinopoulos, 2016:1011; refer to 2.3.21).

2.3.4 Cryotherapy

Cryotherapy is a physiotherapy electrotherapeutic modality, which according to Stasinopoulos *et al*. (2011:424) and Gosens *et al*. (2012:1942) is predominantly used for its analgesic effect. It counteracts the neovascularisation process in PT (refer to 2.2.4), although a number of variables influence ice treatment, including temperature, duration and depth of cooling. One contraindication for cryotherapy is that it must not be used shortly before the athlete participates in sport as it has a negative effect on motor function and masks pain, which can result in re-injury (Schwartz *et al*., 2014:416). Cryotherapy can also be applied during the latter stages of healing of the tendon to reduce the pain (Rowan & Drouin, 2013:305).

2.3.5 Low-level laser

Low-level laser can minimise inflammation and pain in PT and encourage tissue regeneration when the recommended dosage is used (Liu *et al*., 2014:1; Rutland *et al*., 2010:173).

2.3.6 Iontophoresis

Iontophoresis is a method of forcing a pharmaceutical agent through the skin by direct electric current. It can decrease pain and improve function in PT temporarily (Reinking, 2016:861), however, it has not been found effective in the long-term treatment of PT (Rutland *et al*., 2010:173).

2.3.7 Extracorporeal shock wave therapy

Extracorporeal shock wave therapy (ESWT) is a promising treatment modality for PT, which can have an analgesic effect on the patellar tendon and lead to functional improvement after even a single application in some cases according to Vetrano *et al*. (2013:797) and Schwartz *et al*. (2014:416). This is due to generation of forces in the tendon, which could result in benefits such as mechanical disintegration, calcium deposits and the stimulation of tissue repair (Schwartz *et al*., 2014:416). The positive results of ESWT in chronic PT (Rowan & Drouin, 2013:306) is reflected in the results of the Victorian Institute of Sports Assessment for Patellar Tendinopathy questionnaire (VISA-P) (Maier *et al*., 2013:1344; refer 2.4.1; Annexure E).

2.3.8 Therapeutic ultrasound

Musculoskeletal pathologies in sport can be treated by therapeutic ultrasound. Ultrasound rapidly accelerates the healing proses by increasing the synthesis of collagen and general protein in fibroblast (Tsai *et al*., 2011:1068), however, Reinking (2016:860) found that there was no concrete evidence that supports the success of this modality in chronic PT.

2.3.9 Manual therapy

Myofascial manipulation of the knee extensor muscle group has a positive effect on PT symptoms (Rudavsky & Cook, 2014:127; refer to 2.2.7; 2.2.9) as deep friction massage lessens adhesions in the tendon and improve normal realignment of collagen fibres (Reinking, 2016:860).

2.3.10 Eccentric-concentric exercise and heavy-slow resistant loading

Athletes with prominent concentric weakness may benefit from eccentric-concentric exercise due to the specific way in which muscle contract, and isolated eccentric exercise (EE) may be less effective. Heavy-slow resistant loading (HSR) is indicated for athletes with PT in the later degenerative stage of the pathology, which is more probable to attain tendon adaptation (Malliaras *et al*., 2013:282).

2.3.11 Maintenance of exercise

A maintenance exercise programme should be followed once an athlete has returned to sport, which Malliaras *et al*. (2015:893) suggests must contain strengthening exercises at least twice a week, isometric exercises, flexibility exercises for the lower limbs and any exercises for other biomechanical defects that need to be addressed and maintained.

2.3.12 Rest from activity

A brief period of rest from activity can improve symptoms in PT (Gosens *et al*., 2012:1942; refer to 2.2.7; 2.2.9) as this will reduce stress on the patellar tendon (Torres *et al*., 2012:14). Unfortunately, rest for too long a period can also have a negative effect and can result in muscle atrophy (Schwartz *et al*., 2014:415) and complete immobilisation resulting in biological and psychological effects. It is at this point were initial strengthening is of utmost importance. Torres *et al*. (2012:14) rightly suggests that the duration of the rest period must be determined by the stage of the PT. Stage-three PT, where symptoms are present during and after activity and restricts exercise capability, indicates that an extensive rest period of three months or longer is required, whereas stage-one PT, will only require a rest period of approximately three weeks (Torres *et al*., 2012:14).

2.3.13 Isometric exercise

Isometric exercise is usually the first strengthening aspect to be included in a PT rehabilitation programme, which inhibits pain immediately for up to 45 minutes due to cortical changes and motor-neuron pool recruitment and reduces the production of inflammatory signs and is driven by changes at soft-tissue level, without a reduction in muscle strength (Rio *et al*., 2015:1280). Loading of the muscle-tendon unit is also initiated with isometric exercises when pain restricts the ability to perform isotonic exercises (Malliaras *et al*., 2015:891) during the in-season, pre-activity or post-activity phases (Rio *et al*., 2015:1282). Five maximal voluntary contractions for 45 seconds at mid-quadriceps muscle through a functional range are beneficial (Stasinopoulos, 2016:1011). Once pain in the patellar tendon has lessened, EE can be continued (Malliaras *et al*., 2015:892).

2.3.14 Eccentric exercises

Eccentric exercises (EE) has formed part of the rehabilitation process since the 1980's (Steunebrink *et al*., 2013:34) and is the most widely investigated (Murtaugh & Ihm, 2013:176), popular (Saithna *et al*., 2012:554) and thoroughly researched therapeutic treatment for PT (Murtaugh & Ihm, 2013:176). This modality has been used extensively, especially over the past 15 years, and has been proven to have a high rate of success (Sosa *et al*., 2014:27).

There are three basic principles on which EE is based, namely, the length of the tendon, load on the tendon and speed of the EE movement. A progressive eccentric protocol can be developed by modifying these basic principles, and Basas *et al*. (2014:42), Reinking (2012:7) and Stasinopoulos (2014:e15301) amongst other researchers, are in agreement that EE has been proven to decrease pain levels (refer to 2.2.7), and increase functional ability (Sosa *et al*., 2014:27) and normalisation of the tendon (Murtaugh & Ihm, 2013:176). The treatment is highly effective if the pathology is at the inferior pole of the patellar tendon (Stasinopoulos, 2014:e15301; refer to 2.2.8).

An EE of a single-leg squat on a 25º decline board with some level of discomfort (Saithna *et al*., 2012:554) has proven to permit superior load through the tendon and lesser hip and knee stop angles compared with standard EE. This decline squat has a 94% possibility of positive results comparing compared to the 41% of standard EE (Schwartz *et al*., 2014:416), and it provides a 50% – 70% possibility of improving knee function and reducing pain in athletes, which allows the athletes to return to their pre-injury sporting levels (Visnes & Bahr, 2007:212,219). EE must be performed in three sets of 15 repetitions once or twice per day for at least 12 weeks, which can provoke pain in some cases, but this is a normal and expected response (Murtaugh & Ihm (2013:179). Progression of the EE in terms of load (refer to 2.3.3) is based on the ability to tolerate the amount of repetitions (Stuhlman *et al.,* 2016:e1029). Stuhlman *et al*. (2016:e1029) predicts a 50% success rate for an EE strengthening programme with adequate progression. It must be noted though that an athlete's symptoms must always be a guideline in making decisions regarding the most effective rehabilitation modalities (Murtaugh & Ihm, 2013:176). The rehabilitation staff must be aware of any tendon tears, and progress slowly with the EE if this is the case.

In addition, an athlete's symptoms can also be improved with supplementary treatment modalities (Dragoo *et al*., 2014:611) such as hip (Silva *et al*., 2015:899) and abdominal strengthening (Ras & Puckree, 2014:1346), lower-limb stretching (Stasinopoulos, 2016:1), proprioception (Groot *et al*., 2014:228), cardiovascular exercise (Reinking, 2016:857), plyometric exercises, sport-specific skills exercises (Rudavsky & Cook 2014:127), return to sport activities (Stasinopoulos *et al*., 2011:427), bracing or strapping (Lavagnino *et al*., 2011:296), as well as educating athletes regarding PT (Silva *et al*., 2015:903).

2.3.15 Hip strengthening

Weakness in the hip muscles can increase the hip joint susceptibility to dysfunction in all anatomical planes (Powers, 2010:43). Compensation movements occur to accommodate the weak muscles at the hip due to the lack of pelvic control with an influence on movements at the knee (Powers, 2010:48). Hip strengthening decreases pain and disability in PT (Silva *et al*., 2015:899), with the gluteus maximus muscle being the most important hip extensor muscle that needs strengthening during PT rehabilitation (refer to 2.2.3). It is advised to begin with non-weight-bearing exercises and progress to more advanced exercises, which will contribute to improved lower limb biomechanics during landing kinematics (Silva *et al*., 2015:899,903,907).

2.3.16 Abdominal strengthening

It is pointed out frequently in literature that there has been an increased emphasis on "core" strengthening, especially in the sport of rugby, not only to improve performance, but also to prevent injuries (Ras & Puckree, 2014:1346; refer to Table 2.1). The foundation of training the core musculature for athletes at all levels of sport, is with targeted exercise (Cug *et al.,* 2012:468). Abdominal strengthening must first target individual muscles and progress to a more integral approach in order to facilitate functional movements when the abdominal muscles are activated. The starting point is activation of the transvers abdominis and multifidus muscles, with the athlete's long-term goal being the ability to automatically activate these muscles while taking part in sport (Brukner & Khan, 2007:165-170). Rutland *et al*. (2010:172) and Resteghini and Yeoh (2012:93) emphasise that abdominal strengthening is also required to improve proximal lower limb and core stability for controlled movement at the knee.

2.3.17 Increased flexibility

As highlighted by Carvalho *et al*. (2012:2451) and Rogan *et al*. (2013:2), stretching is essential for athletes in order to optimise their performance during training and competitive sport, prevent injuries and reduce delayed onset muscle soreness, and has been standard practice throughout the years for physiotherapists and coaches. Improved flexibility is a necessity in PT rehabilitation due to injured athletes having a greater variation in flexibility deficits (O'Sulivan *et al*., 2012:843; refer to 2.2.3). Special attention must be paid to improving the flexibility of the hamstring, quadriceps and heel cord muscles (Vetrano *et al*., 2013:796) as this may very well assist in a faster return to sporting activities (O'Sulivan *et al*., 2012:838; refer to 2.3.21).

2.3.18 Proprioception

The physiological role of proprioception is providing conscious sensation and adjusting movement programmes in order to limit the risk of injury in any situation (Nagai *et al*., 2013:31). Proprioception is a component of joint position sense (JPS) and assists in stability of the knee joint by coordinating different muscle (Segal *et al*., 2010:2082). In athletes affected by PT, they often have impaired proprioception in their injured leg when compared to their non-injured leg (Groot *et al*., 2014:228).

Introducing a proprioception programme (as part of a general rehabilitation protocol) for ten weeks or longer, with instability resistance training on unstable platforms using body weight as resistance, improves knee proprioception as well as trunk flexion and extension strength in athletes with PT. According to research, the improvement of proprioception of the knee joint after a rehabilitation programme such as this can last up to nine months after the initial rehabilitation (Cug *et al*., 2012:471) and decreases the possibility of PT reoccurrence (Brukner & Khan, 2007:186; refer to 2.2.9).

2.3.19 Cardiovascular exercises

Cardiovascular exercises are also essential in maintaining the athlete's fitness levels during PT rehabilitation (Vetrano *et al*., 2013:800). Activities exerting low loads on the patellar tendon is preferable for example swimming, pool running and cycling (Reinking, 2016:857).

2.3.20 Plyometric and sport-specific skills

Plyometric training can be defined as quick lengthening of a muscle just prior to a contraction, which results in forceful concentric and eccentric muscle contraction. This type of training is one of the most effective approaches for the development of explosive power in any sports, with the optimal connection between strength and speed training, and can only commence if a basic strength level is attained during routine training two to three times a week (Rao & Rao, 2016:144). Lower limb biomechanics during plyometric exercises is another important aspect in PT rehabilitation, where incorrect take-off and landing patterns are altered (Kulig *et al*., 2015:419) to produce a "soft landing" and reduce the load on the tendon. This can be achieved by sufficient trunk/hip flexion and the eccentric loading of the quadriceps muscle during landing, with knee flexion that stimulates the development of type one collagen synthesis and reduces the prevalence of neovessels (refer to 2.2.4).

Sport-specific skills and exercises can be used to improve the physical and technical development of athletes (Vaz *et al*. 2013:227; refer to 2.2.11) and must form part of the rehabilitation programme of PT (Rudavsky & Cook, 2014:127). Plyometric and sport-specific skills training could include skipping, jumping and hopping, progressing to agility tasks, direction changes, sprinting and bounding movements (Rudavsky & Cook, 2014:127). It is vital that the physical demands of a particular sport are well understood by the medical staff responsible for the rehabilitation of athletes, in order for rehabilitation to be adapted to include sport-specific training and exercises (Vaz *et al*., 2013:227).

2.3.21 Return to sport

It is important to recognise and efficiently manage factors that could be responsible for reoccurrence of particular injuries, and return to sport can only commence after an encompassing rehabilitation intervention (O'Sullivan *et al*., 2012:838). It is advised that active participation must only resume after tendon healing is complete (Stasinopoulos *et al*., 2011:427), which could take approximately 12 weeks or longer (Frizziero *et al*., 2014:60). The load on the patellar tendon must also be tolerated with no pain on the pain-provocation test over a 24-hour period (Malliaras *et al*., 2015:893). This is supported by Frizziero *et al*. (2014:70) who agree that return to sport should be based on an individualised assessment of recovery of function (refer to 2.3.2), and that an athlete should return to their particular sport when they are able to replicate the sport-specific skills, volume and intensity of the demand required (refer to 2.3.3).

2.3.22 Bracing or strapping

Bracing or strapping in PT has been described in literature for the last 30 years due to the reduction of anterior knee pain it provides in the short term. The long-term benefits are, however, still largely unclear (Lavagnino *et al*., 2011:296). The mechanism reveals that bracing or strapping have a positive outcome on the tendon by minimising the patellar tendon strain and enhancing proprioception in the knee (refer to 2.3.18). In addition to traditional bracing or strapping, foot orthoses has also shown some success in PT rehabilitation, but unfortunately there is no concrete evidence of its long-term benefit (Reinking, 2016:861).

Though there is a clear short-term benefit in the use of strapping, it has unfortunately been proven to have a negative impact on the structure of the tendon when the effect is typically analgesic, as increased load and stress are placed on the tendon due to the minimised pain experienced (De Vries *et al*., 2015:6). As a result, De Vries *et al*. (2015:6) also mention that these methods of treatment have led to a so-called ‘nobility effect’ during sport participation as the focus of the athlete is more on the sport than on the pain experienced in the knee, which could eventually lead to long-term damage (Reinking 2016:861).

2.3.23 Education

The starting point of any rehabilitation intervention is the rehabilitation staff educating the athlete and coach/trainer regarding PT pathology and the management of symptoms, and to present them with realistic expectations for short and long-term goals for rehabilitation (Rudavsky & Cook, 2014:127; refer to 2.3.1). The most effective rehabilitation results can be achieved when a supervised, though expensive, rehabilitation intervention route is followed (Stasinopoulos, 2016:3). As Stasinopoulos (2016:3) points out, compliance of athletes during home-based rehabilitation shows a poor results as athletes often discontinue exercises without due reason. Regular follow-up phone calls, exercise monitors and self-management education may assist in curbing this trend.

Withdrawal or continuation of training is also often a contentious matter in PT rehabilitation. Withdrawing athletes from sport can have possible negative consequences, which can include both psychological distress (for instance mood disturbance, confusion, depression, low self-esteem and anxiety) and physiological and sport-specific skill impairments (Saithna *et al*., 2012:556). Apart from the psychological and physiological consequences, withdrawal can also have other implications, for example the financial impact (sport contracts for the upcoming season), team selection and success in the overall dynamics of the group or entire squad (Saithna *et al*., 2012:556). In contrast, withdrawal from sport can also have positive results as ample time will ensure tendon recovery through a comprehensive rehabilitation intervention (Sosa *et al*., 2014:27). A possible solution would be to allow the athlete to continue with sport participation whilst participating in an on-going isometric exercise programme, which will assist in avoiding muscle deconditioning (Rio *et al*., 2015:1283). The Visual Analog Scale (VAS) (refer to Annexure D) guideline as referenced by Silva *et al*. (2015:903) may be of use when participation is continued, which measures pain experienced during activity, of which the level should preferably not exceed three out of ten.

The above-mentioned conservative treatment modalities usually form part of the initial treatment approach (Van Ark *et al*., 2013:124), which accentuates the key role that physiotherapists play in the treatment of athletes with PT, as pain reduction and improvement of function are two core treatment modalities in physiotherapy (World Confederation for Physical Therapy, 2014:1-56).

2.3.24 Pharmacological treatment for Patellar tendinopathy

Rees *et al*. (2006:513) state that the use of anti-inflammatory medications during the chronic stages of PT has been controversial. Though it can be beneficial during the first seven to 14 days of the pathology (refer to 2.2.4), when the pathology arrives at the chronic stage with histopathology findings and a lack of inflammatory cells, these kinds of medications have been found to no longer have a healing effect, and anti-inflammatory medications (Schwartz *et al*., 2014:416) such as Ibuprofen seem to not have much, if any, positive effects on symptoms (Dragoo *et al*., 2014:611). However, Glyceryl trinitrate (GTN) patches as an alternative non-operative treatment, are easy to apply and supply nitric oxide to the tendon, which may assist in tissue healing

(Schwartz *et al*., 2014:416), with minimal associated side-effects (Assem & Arora, 2015:3).

2.3.25 Injection therapy for Patellar tendinopathy

Injection therapy for PT with the use of ultrasound-guided injection therapy in the late/degenerative stages of PT (Rowan & Drouin, 2013:303) has been described as another possible treatment option, showing some promising results (Pascarella *et al.,* 2011:1976; Van Ark *et al.,* 2011:1073).

2.3.26 Platelet-rich plasma

The use of platelet-rich plasma (PRP) as a treatment method (Filardo *et al*., 2010:910), which promotes the body's own natural healing process, has increased significantly during recent years (Mautner *et al*., 2013:170). The treatment modality has shown some significantly positive results, with accelerated recovery in the late/degenerative stages of PT in elite athletes (De Vos *et al.,* 2010:144). Mautner *et al*. (2013:171) remark that recent findings indicate that 59% of athletes who received PRP treatment were satisfied with the treatment, and reported moderate to complete resolution of their symptoms. This treatment also has a shorter recovery period compared to surgery (refer to 2.3.33) and is more affordable in comparison. The long-term effectiveness of PRP treatment is unfortunately still unclear (Rowan & Drouin, 2013:303).

2.3.27 Sclerotherapy

Reider (2012:510) promotes sclerotherapy with polidocanol as another form of injection therapy to treat PT, which improves knee function and decreases pain (Hoksrud *et al*., 2012:546) with an improved subjective score on the VISA-P scale (Maier *et al*., 2013:1344; refer to 2.4.1). Patients have indicated that this treatment has moderately positive results (Hoksrud *et al*., 2012:546).

2.3.28 Corticosteroid injections

Corticosteroid injection is an extremely controversial treatment modality, with little evidence to support its effectiveness in the treatment of PT (Loppini & Maffulli, 2011:135). It reduces inflammation and oedema in the patellar tendon on ultrasound imaging, however, as stated by Van Ark *et al*. (2011:1072) it cannot repair degenerative changes. Relapse of the injury after a few weeks and up to six months after the injection is a common occurrence (Maier *et al*., 2013:1343).

2.3.29 Aprotinin™

Aprotinin™ injection treatment is "a proteinase inhibitor (including matrix metalloproteinase [MMP] inhibitor)" used in the treatment of PT. It has had positive clinical results in tendinopathies (Orchard *et al*., 2008:1625,1628), including Achilles tendinopathy as a conservative first line intervention (Maffulli *et al.,* 2015:110).

2.3.30 Dry-needling in combination with autologous blood injections

An inflammatory process is triggered by a needle which is repeatedly passed through the patellar tendon. The hypothesis behind this is that an internal bleeding is stimulated due to disruption of the collagen fibres. Strengthening of the tendon is also essential for the formation of granulation tissue during the inflammatory process. During the healing cascade, cell proliferation and synthesis of angiogenic factors is encouraged by autologous which consists out of growth factors which act as humoral mediators. For this reason, dry-needling is used in combination with autologous blood injections. This type of treatment has had favourable results and is a possible treatment for PT in conjunction with a rehabilitation intervention following the treatment (James *et al.,* 2007:519,521).

2.3.31 EPI® technique

The EPI® technique uses a flow of cathodic current, which focuses solely on the area of the degenerated patellar tendon through an ultrasound-guided needle. It produces a controlled local inflammatory reaction to assist in an organic reaction that assists in facilitating a rapid regeneration of the degenerated tendon. The EPI® technique has had positive results in functional enhancement (Sànchez-Ibàñez, 2015:1).

2.3.32 High-volume injection therapy

High-volume injection therapy is used to disrupt the neovascularisation (refer to 2.2.4) between the Hoffa's body and the border of the posterior aspect of the paratendon of the patellar tendon, and by means of large volumes of fluid injected into the area where the neovessels penetrate the tendinopathic lesion. Immediately after the injection a

Doppler ultrasound has shown the disappearance of the neovascularisation and clinically reduced symptoms (Crisp *et al*., 2008:1626,1630).

2.3.33 Surgical treatment for Patellar tendinopathy

Should conservative and injection therapy prove to be ineffective, the last resort in PT treatment usually involves surgery (Rodriguez-Merchan, 2013:79-80). Rodriguesz-Merchan (2013:79-80) emphasizes that PT surgery is only indicated for athletes who have undergone a comprehensive conservative rehabilitation intervention of at least three to six months (Pascarella *et al*., 2011:1976), without success, and are still unable to participate in sport. Although it has been proven that surgery can improve symptoms (Pascarella *et al*., 2011:1976; refer to 2.2.7), it is only recommended in approximately 10% of all cases of elite and recreational athletes, with a mean age of approximately 28 years, who suffer from PT (Pečina *et al*., 2010:278). Either open or arthroscopic methods can be used during surgery (Pascarella *et al*., 2011:1976) and seem to be equally effective in ensuring return to sport after surgery recovery (Maier *et al*., 2013:1342).

In comparison with conservative treatment, it would seem that arthroscopic surgery has a shorter recovery rate of approximately four to six weeks before the athlete is able to return to sport, whereas conservative treatment methods may take much longer to have an effect (Maier *et al*., 2013:1344). However, Mautner *et al*. (2013:170) and Zwerver *et al*. (2011:1192) reiterate that although surgery has a moderate success rates, outcomes may vary, and there is still a 10% possibility that symptoms may reoccur after arthroscopic surgery.

2.4 Section three: Outcome measures in Patellar tendinopathy

2.4.1 Subjective questionnaires used in Patellar tendinopathy rehabilitation

The Visual Analog Scale (VAS) (refer to Annexure D) and Victorian Institute of Sports Assessment for Patellar Tendinopathy (VISA-P) questionnaires (refer to Annexure E) are popular subjective questionnaires utilised in PT research (Da Cunha *et al*., 2012:167; Rudavsky & Cook, 2014:127; Vetrano *et al*., 2013:795).

The VAS is a reliable and sensitive (Vetrano *et al*., 2013:797) one-dimensional questionnaire that measures the intensity of pain (refer to 2.2.7) in adult athletes, and as mentioned by Hawker *et al*. (2011:S240) and Price *et al*. (1994:217), is used for a variety of pathologies with a high accuracy and success rate (Vetrano *et al*., 2013:798). The clinical value of the VAS in PT is that it can be used to determine the athlete's clinical pain and symptoms during the rehabilitation intervention and provide accurate estimates of pain intensity ratios and the percentage of change in pain. Experts agree that the symptoms of PT are difficult to quantify (refer to 2.2.7) and that the VISA-P questionnaire is currently the only disease-specific questionnaire that assesses functionality in PT. It is also the only published clinical scale validated for PT (Vetrano *et al*., 2013:797-798) in athletes where the pathology prevents them from playing sport (Lohrer & Nauck, 2011:180).

2.4.2 Objective measurement used in Patellar tendinopathy rehabilitation

Quadriceps Electromyography (EMG) techniques enable researchers to obtain valuable information regarding the neuromuscular electrical activity in the moving muscles of the body (Massó *et al*., 2010:122), as well as the intensity of muscle contractions (Shenoy *et al*., 2011:41).

According to research performed by Pietrosimone *et al*. (2011:621) and Romero-Rodriquez *et al*. (2011:43) amongst others, quadriceps muscle activation is inhibited in patients with anterior knee pain pathologies and PT, and this dysfunction in neuromuscular quadriceps may be the result of reflex inhibition of the muscle, which can put athletes at risk for supplementary injuries (Bolgla *et al.,* 2008:1; Pietrosimone *et al*., 2011:621). Quadriceps muscle weakness, specifically weakness in the vastus medialis muscle, can affect daily activities like walking, squatting and climbing stairs (Bolgla *et al.,* 2008:1). The quadriceps muscle furthermore plays a vital role in preparing the knee for extension during functional activities (Scurr *et al.,* 2011:247).

EMG can be utilised for an accurate evaluation and diagnosis of quadriceps activation. Preferred EMG testing must be performed in a functional position (Balachandar *et al.,* 2011:2) due to the effective mechanism of strengthening of the quadriceps muscle (Balogun *et al*., 2010:5; refer to 2.3.13; 2.3.14). The quadriceps EMG test must be performed on the vastus medialis muscle, vastus lateralis muscle and rectus femoris muscle (Balogun *et al*., 2010:1; Katakura *et al.,* 2011:13). Unfortunately, as Scurr *et al*. (2011:248) point out, factors like electrode size and placement, and different angles in the knee joint may affect the results.

2.5 Conclusion

This literature review presents a comprehensive insight into the available literature regarding PT pathology, as well as the conservative treatment for PT, which formed the background for the planning and completion of this study. In the subsequent three chapters the literature under review, contributed to and was utilised to formulate three articles.

2.6 *References*

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CHAPTER THREE (ARTICLE 1): CAUSATIVE FACTORS AND REHABILITATION OF PATELLAR TENDINOPATHY: A SYSTEMATIC REVIEW

3.1 Introduction

The intent of this systematic review was to address objective one by investigating all the evidence applicable to the intrinsic and extrinsic causative factors and rehabilitation of PT, and then integrate and link rehabilitation to the main identified causative factors. The article was published in the South African Journal of Physiotherapy with citing reference:

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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 causative risk factors were identified, with the main intrinsic causative risk factors being muscle flexibility and strength, and extrinsic causative 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 causative 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 causative risk factors for and treatment of PT can be challenging and unsatisfying (Silva *et al*. 2015). A number of causative 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 causative 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 causative 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 causative 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 causative 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 causative 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 “jointinstability*” 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.

<u>**Inclusion criteria**</u>
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)

<u>**Exclusion criteria**</u>
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.

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 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 causative 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).

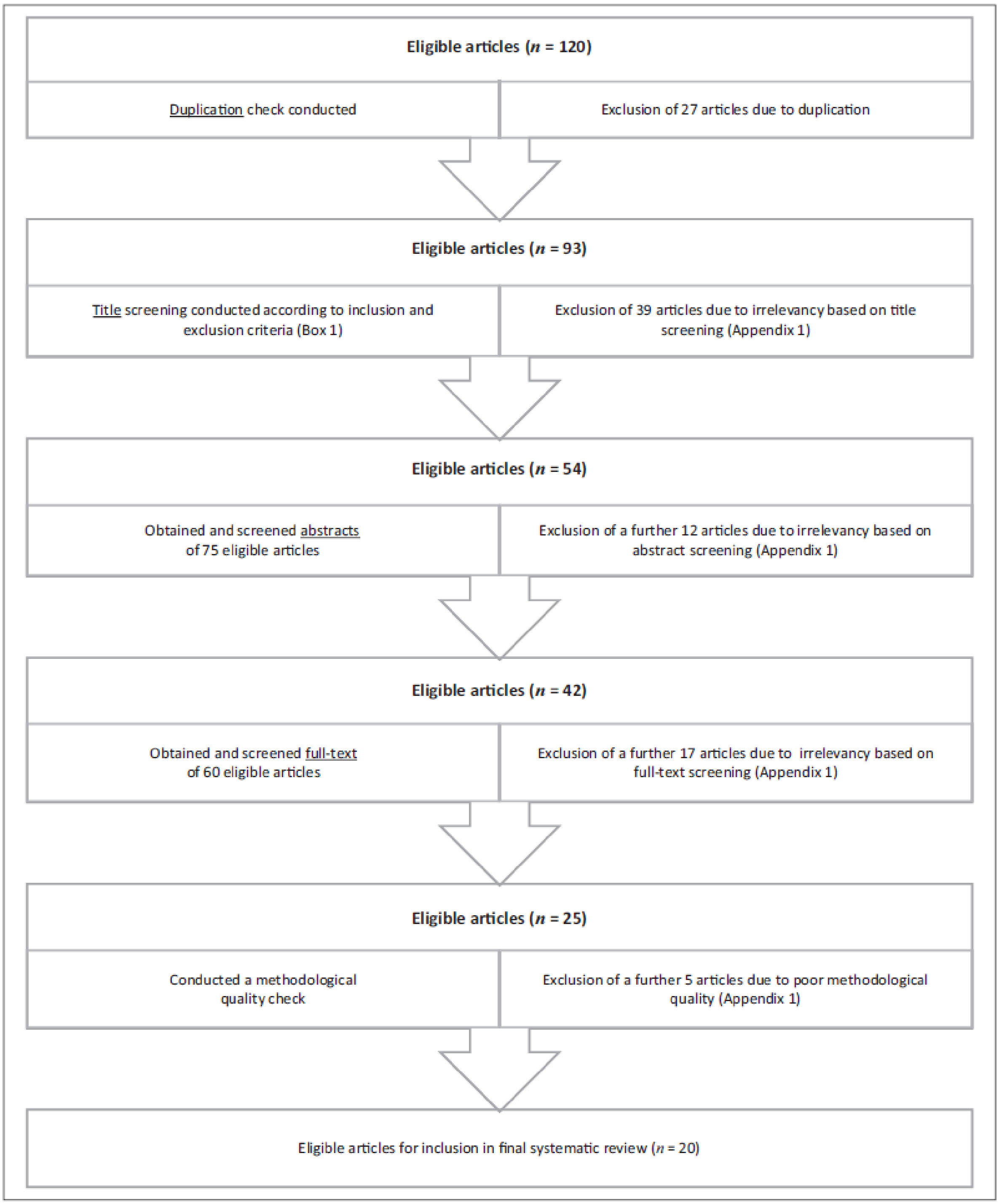

FIGURE 1: Flow diagram of search strategy to determine the final sample of the articles for the review.

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 (n = 4)	71% (n = 4)	• No *priori* 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 (n = 3)	76% (n = 3)	• Less than 50% on methodology quality scoring
Non-randomised clinical trials	Downs & Black Checklist	16/27–20/27 (n = 3)	68% (n = 3)	• Less than 50% on methodology quality scoring
Qualitative research	Methodology Checklist – Qualitative	10/14–13/14 (n = 5)	82% (n = 5)	• Less than 50% on methodology quality scoring
Quantitative research	National Institute for Health and Excellence Checklist	15/27–21/27 (n = 5)	63% (n = 5)	• 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 *et al*. (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 *et al*. (2015b)	Randomised clinical trail	**Age:** 18–50 years **Gender:** Male > female	*Not included*	**Strapping or orthosis:** ↓ PT pain, ↑ proprioception, female > male ↑ outcome
Toppi *et al*. (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 *et al*. (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 *et al*. (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 *et al*. (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 *et al*. (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*

TABLE 3: Rehabilitation of patellar tendinopathy.

Authors (year)	Study design	Study participants	Rehabilitation
Mani-Babu *et al*. (2015)	Systematic review and meta-analysis	*Not included*	Extracorporeal shock wave therapy
Frizziero *et al*. (2014)	Review and meta-analysis	*Not included*	Eccentric training
McCreesh, Riley and Crotty (2013)	Case report	**Age:** 34 years **Gender:** Male	Eight-week programme of eccentric training, twice/day, 10 repetitions
Malliaras *et al*. (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 *et al*. (2012)	Randomised controlled study	**Age:** 18 years **Gender:** 14 male, 3 female	Eccentric training: 12 weeks with or without pain
Van der Worp *et al*. (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 *et al*. (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 *et al*. (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 *et al*. (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

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 causative 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). It is anticipated that greater quadriceps muscle contraction is desired to avoid further knee flexion (Van der Worpe *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 causative 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 causative 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 additisports (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

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 (Zwerver *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 causative 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 causative risk factors were identified. The main intrinsic causative risk factors identified were muscle flexibility and strength. Regarding the extrinsic causative risk factors, acquisition and level of skills were the prominent factors. Evidence for all the other risk factors was indecisive. Although several causative 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 causative 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 causative 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 highmethodological 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 1

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

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CHAPTER FOUR (ARTICLE 2): PATELLAR TENDINOPATHY: AN INTERNATIONAL E-DELPHI PERSPECTIVE

4.1 Introduction

The main purpose of this portion of the research study was related to objective two by utilising an e-Delphi survey, as a unique approach, to formulate a rehabilitation framework for PT. The evidence obtained in Chapter three laid the foundation for the formulation of the e-Delphi survey and served as a relevant connection and overlap. This was accomplished by collecting qualitative opinions, supplemented with some quantitative elements, from eight experts representing South African and international views on PT management.

The fourth chapter comprises the article on the international e-Delphi survey. The article was submitted to the South African Journal of Research in Sport, Physical Education and Recreation on the 13th of July 2017.

Abstract

Patellar tendinopathy is a chronic pathology of the anterior knee related to overloading of the patellar tendon. The purpose of the study was the formulation of a rehabilitation framework for patellar tendinopathy based on data from South African and international experts in the medical field. An e-Delphi survey was conducted with a mixed methods study design to obtain the opinions of eight experts. The e-Delphi survey consisted of three rounds, where the first two rounds focused on collecting opinions from the experts as a basis for the development of a rehabilitation framework that were evaluated in the third and final round. Consensus was reached regarding load tolerance, addressing individual athletes' needs, response to load progression principle, rest from activity, lower limb flexibility, hip and core strengthening, proprioception training, sport-specific skills training, return to sport assessment and functional ability of the athletes. Partial consensus was gained regarding isometric training, eccentric exercise, cardiovascular training, rehabilitation adaptation for out and in season, patella strapping is important during rehabilitation and expectations from the trainer and/or coach influencing rehabilitation. This research is of important value as it presented a unique and collated perspective of internationally recognised experts regarding a patellar tendinopathy rehabilitation framework.

Key words: Patellar tendinopathy; e-Delphi; Rehabilitation framework.

Patellar tendinopathy: an international e-Delphi perspective

INTRODUCTION

Patellar tendinopathy is a chronic pathology of the anterior knee (Saithna *et al*., 2012) related to overloading (Malliaras *et al*., 2015) and frequently associated with sports that involve jumping. It can affect athletes in a variety of sporting codes, is characterised by pain and functional impairment, and may even be a career-ending pathology in some cases (Saithna *et al*., 2012). These issues highlight the necessity for the continuous in-depth investigation of this complex pathology. An extensive body of literature is available on the pathology and management of patellar tendinopathy in the clinical set-up, with limited information on experts' combined opinions or related frameworks for patellar tendinopathy, despite their comprehensive knowledge on the topic. This identified the need for a research study suggesting a framework for the treatment of patellar tendinopathy through the collation of experts' opinions. An e-Delphi survey was constructed to incorporate the opinions of international experts for the formulation of a patellar tendinopathy rehabilitation framework.

PURPOSE OF THE RESEARCH

Taking into consideration the diverse and evolving role that conservative rehabilitation plays in the management of patellar tendinopathy (Reinking, 2016), the main aim of the research was to use an e-Delphi survey as a unique approach to formulate a rehabilitation framework for patellar tendinopathy. This was accomplished through the collection of qualitative opinions, supplemented with some quantitative elements, from eight experts representing South African and international views.

METHODOLOGY

The e-Delphi process

The e-Delphi methodology is an interactive and iterative process which can continue for several rounds (Donohoe *et al*., 2012). Its foundation is based on anonymity and the free expression of participants' opinions by allowing reconsideration and refined opinions through controlled feedback (Giannarou & Zervas, 2014). It is frequently used in the health sciences environment (Donohoe *et al*., 2012).

In this study, the e-Delphi survey consisted of three rounds. The first two rounds focused on collecting opinions from the experts on the rehabilitation of patellar tendinopathy as a basis for the development of a rehabilitation framework that was evaluated by these experts in the third and final round.

Methods

A mixed methods research design was used applying primarily a qualitative research approach for the e-Delphi survey, supplemented with some quantitative elements. This is seen as a promising methodology to explore critical issues when the investigation outcomes require isolated opinions from experts on an explicit subject (Habibi *et al.*, 2014). In this study, it equipped the researchers with information relevant to patellar tendinopathy rehabilitation as the basis for the formulation of a patellar tendinopathy rehabilitation framework, as presented in this article.

Selection of experts

The selection of experts for this e-Delphi survey was based on a recently published systematic review on patellar tendinopathy (Morgan *et al.*, 2016) that was used as a screening tool to identify individuals to serve on the e-Delphi panel. The literature states that prudent selection of an appropriate panel of experts forms the cornerstone of an e-Delphi survey, as this maximises the quality of the responses obtained, lessens potential bias and assists in the credibility of the results (Nworie, 2011). It has been suggested that a panel of experts selected for an e-Delphi survey should consist of individuals from heterogeneous educational backgrounds, selected due to their high educational qualifications (Donohoe *et al*., 2012), special expertise (Nworie, 2011) and extensive knowledge of the subject matter (Donohoe *et al*., 2012). The international experts (n=5) were authors of previous publications on the topic (see Morgan *et al*., 2016) and the South African experts (n=3) were selected from different South African universities having publications in the field of sport and sport science. The experts' credentials correlated strongly with the literature. An adequate number of experts is five to ten participants (Habibi *et al*., 2014), although a larger panel size would decrease group errors and reinforce decision quality (Giannarou *et al*., 2014). Demographic details of the panel members are summarised in Table 1.

Table 1. Demographic details of the e-Delphi participants.

Variable	Distribution of participants (n=8)
Gender	Male (n=4) Female (n=4)
Nationality	The Netherlands (n=1) Korea (n=1) United States of America (n=1) Brazil (n=1) Australia (n=1) South Africa (n=3)
Profession	Physiotherapist (n=5) Medical doctor (n=3)
Field of expertise	Patellar tendinopathy (n=6) Sport (n=2)

Ethical considerations

Ethical clearance was obtained from the Ethics Committee of the Faculty of Health Sciences (ECUFS 181/2015) of the University of the Free State, South Africa. Written informed consent was also obtained from all Delphi panel members before commencement of data collection.

Data collection

The primary focus of the e-Delphi survey was to collect the opinions of the selected panel on the rehabilitation of patellar tendinopathy by means of a semi-structured online questionnaire. Items included in the questionnaire for round one of the survey were based on the data collected in the prior systematic review (Morgan *et al*., 2016). SurveyMonkey™ software was used and the identified panel of experts were invited via email. The email included an information letter regarding the study, ethical information, the e-Delphi survey itself, and information on how to use the electronic software for the completion of the questionnaire. Attrition bias was limited in subsequent rounds by only including experts who responded to the invitation in the first round of the e-Delphi survey. This reply was regarded as an agreement of consent to participate for the full duration of the survey (Slade *et al*., 2014).

The questionnaires were only available online, having a set deadline (two to three weeks) with a reminder email sent weekly. The completion of the questionnaires took approximately 40 minutes, with the option to complete the questionnaires over consecutive sessions. The option to save the data was available and the experts could review their answers before final submission.

The questionnaires for rounds one and two consisted of a three-point Likert scale (agree/partially agree/disagree) (i.e. quantitative component). This was followed by an open-ended question at the end of each section whereby additional comments or suggestions could be given (i.e. qualitative component). The questionnaire included four sections, namely (i) establishing the components of a patellar tendinopathy rehabilitation programme; (ii) establishing the suggested basis of decision-making on components of a patellar tendinopathy rehabilitation programme; (iii) inclusion of components in the patellar tendinopathy rehabilitation based on a time-based approach; and (iv) inclusion of components in the patellar tendinopathy rehabilitation based on a pain-based approach. The results of round one were used for the development of the questionnaire for round two. Round two questionnaires had the same structure and main sections as the previous questionnaire. Questions on which consensus had been reached were indicated as such in the questionnaire. If consensus was not reached, the question was included in the following round for further consideration. In some cases, slight adaptations were made such as combining questions or making questions more specific, based on the feedback received from the e-Delphi panel.

After completion of these two rounds of the e-Delphi survey, the results were used to compile a draft framework for the rehabilitation of patellar tendinopathy. This draft framework indicated consensus, partial agreement or disagreement percentages (i.e. quantitative elements) on components included in the framework. Round three provided the e-Delphi panel with a final opportunity to review the draft framework and to provide feedback. This feedback was qualitative in nature and incorporated in the development of the final framework presented in this article.

Validity of the e-Delphi survey

The validity of the e-Delphi survey intrinsically relied on the panel of experts who were carefully selected after an in-depth systematic review (Morgan *et al.*, 2016). This review disclosed the eligibility of members to be included on the panel of experts having suitable competence and knowledge of the research subject. Flexibility also enhanced the validity of the captured data through the substantial time between rounds which the experts could use in considering the questions.

Analysis of data

The responses from the experts on the questionnaires used in rounds one and two were quantitatively analysed in SurveyMonkey™ and descriptive statistics were calculated. Group consensus for each question was defined as a total cumulative agreement of 80% and more, and was considered indicative of overall agreement. Feedback on the draft patellar tendinopathy rehabilitation framework was analysed qualitatively and included in the final patellar tendinopathy rehabilitation framework presented in this article.

RESULTS

Eight experts contributed to the first two rounds (n=8), of which six (n=6) experts participated in round three of the e-Delphi survey. The response rate was 100% (n=8) for the first and second rounds, and 75% (n=6) for round three.

Table 2. Delphi round one results (n=8).

Aspect	Agree	Partially agree	Disagree
Aspects on which consensus was reached			
• Rest from activity in the 1st and 2nd weeks	87%	13%	0%
• Lower limb flexibility/stretching	87%	13%	0%
• Hip strengthening	87%	13%	0%
• Core strengthening	87%	13%	0%
• Proprioception training	87%	13%	0%
• Sport-specific skills training	87%	13%	0%
• Return to sport assessment	100%	0%	0%
Aspects on which consensus was not reached			
• Eccentric exercise (EE)	50%	50%	0%
• Cardiovascular training in the 1st – 2nd week	75%	25%	0%
• Time-based rehabilitation approach (no consensus)	0%	0%	0%
• Pain-based rehabilitation approach (no consensus)	0%	0%	0%

Table 3. Delphi round two results (n=8).

Aspect	Agree	Partially agree	Disagree
Aspects on which consensus was reached			
• Load tolerance principle	87%	13%	0%
• Individual needs addressed during rehabilitation programme	87%	13%	0%
• Progression of the rehabilitation programme must be accordingly to response to load	87%	13%	0%
Aspects on which consensus was not reached			
• Isometric training (no consensus, qualitative results)	0%	0%	0%
• Eccentric exercise (EE)	63%	12%	25%
• Patella strapping is important during rehabilitation and return-to-sport	50%	37%	13%
• Expectations from the trainer and/or coach influence rehabilitation	62%	38%	0%
• Time-based rehabilitation approach (no consensus)	0%	0%	0%
• Pain-based rehabilitation approach (no consensus)	0%	0%	0%

In the third and final round, the experts who responded to the patellar tendinopathy draft framework were in support of this framework, but made some additional remarks. The panel indicated that currently there is no specific model for patellar tendinopathy rehabilitation, which rather relies on an individual assessment with regular re-evaluation. They also suggested that plyometric (high impact loading of the patellar tendon from a stable base) and sport-specific skills (required to prepare the athletes for return to sport after a long period of downtime) (Rudavsky & Cook, 2014), be combined during the rehabilitation intervention to avoid work overloading of the patellar tendon in terms of frequency, intensity and duration. Furthermore, they specified that return to play will take time during patellar tendinopathy rehabilitation.

DISCUSSION

The results quantified three central aspects (Figure 1), namely functional abilities, individualised rehabilitation and load tolerance, to form the foundation of the rehabilitation framework. Specifically, load tolerance, is the single most important aspect of the framework and was a principal conclusive result. Load tolerance can be achieved by establishing the load via loading specific to the individual's functionality. The experts were of the opinion that although acceptable, all rehabilitation activities are arguably not necessary and may be viewed as secondary, as long as the athlete can tolerate the load on the tendon, but it might assist faster return to sport, reduce re-occurrence and improve overall function. The load tolerance principle implies that pain on the provocation test must return to baseline within 24 hours after activity or rehabilitation, which indicates that the patellar tendon has tolerated the load. The results of this e-Delphi were comparable with literature that also focussed on load tolerance on the tendon, musculoskeletal unit and the kinetic chain during rehabilitation (Malliaras *et al*., 2015).

The entire expert panel stated that functional activities are particularly highly valued (100%) and can be beneficial if used in combination with the important approach of load tolerance. This was supported by literature that functional muscle strength (Murtaugh & Ihm, 2013) and abilities are impaired in athletes with patellar tendinopathy and need to be addressed in rehabilitation (Pećina *et al*., 2010).

The individual athlete's needs must be addressed in the rehabilitation programme, which was a prominent aspect emphasised in the e-Delphi survey and therefore included in the patellar tendinopathy framework. These results correlated with Rudavsky and Cook (2014) who stated that individually, an athlete's needs can be achieved through a comprehensive evaluation by the sports rehabilitation personnel to identify areas of special needs and short-comings in the biomechanical chain. The formulation of an individualised rehabilitation programme must take special consideration in that elite athletes require more intense rehabilitation than amateur athletes for successful return to sport and avoiding of relapse of the pathology due to the amplified training demands and level of participation (Rudavsky & Cook, 2014).

The results revealed explicit consensus on a variety of components that should form part of the rehabilitation framework. When the components were investigated in isolation, it confirmed a robust consensus amongst the e-Delphi experts that athletes should rest from any activity that aggravates pain during the first and second weeks of rehabilitation, although they may continue with functional activities. This finding confirmed that rest from activity and monitoring of pain are important (Malliaras *et al*., 2015), since it may have a positive effect on reducing the progression of patellar tendinopathy by unloading the patellar tendon (Reinking, 2016). This rest period can also be spent valuably in educating the athlete about patellar tendinopathy and planning of the treatment intervention (Kulig *et al*., 2015).

Lower limb flexibility as a component of patellar tendinopathy rehabilitation was also a point of consensus among the experts. This related to literature specifying that flexibility insufficiencies in the lower limb have the capacity to support a larger overload on the knee extensor mechanism, with the possibility of developing patellar tendinopathy (Scattone Silva *et al.*, 2016). The extensor mechanism of the knee consists of the tibial tuberosity, four quadriceps muscles, patella and the patellar tendon, and is almost involved in any functional movement of the lower limbs. Injuries to this apparatus of the knee is commonly observed by medical personnel and can be devastating to daily life or sport participation of the athlete (Haddad & Raja, 2013). The focus area of flexibility during patellar tendinopathy rehabilitation must be the knee and ankle (Scattone Silva *et al.*, 2016).

It is always a necessity to address strength deficits in athletes with patellar tendinopathy (Kulig *et al*., 2015), and there was a strong predisposition (87%) towards hip strengthening as a component of the rehabilitation programme. This result was in agreement with previous findings that patellar tendinopathy is associated with weak hip extensor muscles and poor lumbopelvic control, and has the probability to modify the load distribution on the lower limb kinetic chain (Stasinopoulos, 2016). Rehabilitation interventions aiming to improve hip extensor muscle strength in patellar tendinopathy is a valued asset (Scattone Silva *et al*., 2016).

Further consensus was reached regarding core strengthening. This finding was exceptional in this patellar tendinopathy e-Delphi survey as minimal previous evidence in the literature identified weak core muscle strength as a statistically significant predisposing factor for patellar tendinopathy. However, Powers (2010) identified that weak core muscle strength has an adverse effect on knee movement. Literature proposes interventions that focus on strengthening of the trunk and abdominal muscles as an effective feature in managing or preventing overuse pathologies affecting the knees (Lebec *et al*., 2014) and enhancing sport performance (Cuğ *et al*., 2012). Impaired proprioception in athletes with patellar tendinopathy leads to a decreased ability to detect passive motion in the injured leg when compared to the non-injured leg (Groot *et al*., 2016). It is furthermore associated with a reduced awareness of force signals required for weight judgement (Torres *et al*., 2017). This literature supported the experts' consensus in this e-Delphi study about proprioception re-training as part as the rehabilitation programme, which assists to improve articular position sense function, flexibility and balance of the knee (Park *et al*., 2014). Once functional strength, kinetic chain shortfalls and movement patterns have been restored, sport-specific training can commence (Rudavsky & Cook, 2014). Sport-specific skill training develops the athlete's expertise needed for participating in a specific sport (Davies *et al*., 2015) and consensus was reached on the inclusion of sport-specific skills as a component in the rehabilitation programme for patellar tendinopathy. This links to the literature describing that sport-specific skills can begin when slow progression load is tolerated and it is possible to duplicate the demands of the sport in terms of volume and intensity (Malliaras *et al*., 2015). One particular recommendation from the e-Delphi survey round three was that plyometric and sport-specific skills should be combined to avoid overloading the tendon, with constant monitoring for the duration and frequency of the activities.

For a successful return to sport, a comprehensive rehabilitation programme addressing all the identified deficits in the assessment is necessary (Rudavsky & Cook, 2014). It correlates with the results of this e-Delphi survey where consensus was reached that return to sport assessment should form part of the rehabilitation programme to ensure that all deficits have been addressed. Rehabilitation personnel should discuss the specific goals for the athlete's return to sport (Dragoo *et al*., 2014) and load progression to avoid overloading of the patellar tendon. In the absence of such an approach, the athlete will be susceptible to active tendinopathy upon resumption of sport participation (Scott *et al*., 2013). Being patient until fully recovered is a key aspect for successful return to sport in patellar tendinopathy (Rudavsky & Cook, 2014).

The experts also agreed (87%) that the load on the patella tendon must first be tolerated before any progression of the rehabilitation programme can take place, and this includes all exercises and activities related to sport. The e-Delphi participants also made it clear that the athlete could have good function and strength in the lower limbs although the patella tendon might still not be comfortable with the load, which would result in signs and symptoms of pain and discomfort. This was another original and important result in this e-Delphi survey that once again highlighted the prominence of the load tolerance principle, indicated by the experts to be the core aspect of the rehabilitation framework. Furthermore, progression relies strongly on load tolerance as a pivotal point of consensus in the e-Delphi survey. Malliaras *et al*. (2015) suggested that progression of the rehabilitation program must be based on pain, strength and function, with advancement mainly based on pain monitoring. This differs from the e-Delphi finding of the load tolerance principle. The experts already specified in round one of the survey that reduction of pain via rest from activity is a secondary objective of rehabilitation, with the emphasis being primarily on load tolerance rather than on pain.

Loading of the patella tendon, however, must not commence in isolation because a variety of specific impairments might also be present and need to be addressed in the kinetic chain (Malliaras *et al*., 2015). That is why all the secondary identified components in the e-Delphi survey play an equally vital role and must not be overlooked as they all add to the rehabilitation process. Closer investigation into other possible components for the rehabilitation framework based on partial consensus from the e-Delphi survey revealed that although no consensus was reached on isometric training, some of the e-Delphi experts were still of the opinion that isometric exercises should be high on the hierarchy of the holistic treatment programme, as expressed in their open-ended comments. Because patellar tendinopathy in athletes is difficult to manage, the inclination to use isometric exercises can be important initially in the clinical setting, as it is safe and not likely to cause any further injury (Rhyu *et al*., 2015). Isometric exercise reduces pain in the patellar tendon almost immediately, and this prevents muscle atrophy until isotonic exercise can commence (Rio *et al.*, 2015).

With regard to eccentric exercises (EE), partial consensus was obtained among participants. EE still plays a respected part in patellar tendinopathy rehabilitation, being one of the most comprehensively discussed modalities for the treatment of patellar tendinopathy over the years. Diaz (2016) recently added that the main focus during EE training should be to load the patella tendon. The mechanism of EE is to encourage the creation of tendon collagen fibres, enable its remodelling with a pain reduction of 60% to 90% and general satisfaction in athletes (Diaz, 2016). The fact that EE was not an aspect of total consensus among the experts was an interesting finding in this e-Delphi survey, because EE has always been regarded as the cornerstone of patellar tendinopathy rehabilitation (Scattone Silva *et al*., 2015). This result might have been influenced by the expert's clinical reasoning from previous experience in patellar tendinopathy rehabilitation, to move away from the traditional treatment modalities in the search for novel approaches to manage this challenging pathology. The two components of isometric training and EE could be incorporated in the rehabilitation since these are clinically designated to reduce pain in patellar tendinopathy (Van Ark *et al*., 2015).

Cardiovascular training must also be included in the rehabilitation programme during the first and second weeks. Literature specifies that cardiovascular ability can be maintained by decreasing the load on the lower limbs by using cross-training activities such as cycling, swimming or pool running instead of over-ground running and jumping (Reinking, 2016). Another aspect of agreement among the experts was that patella tendon strapping plays a part during the rehabilitation and return to sport in patellar tendinopathy. This type of treatment modality has been described in the literature dating back many years (Schwartz *et al*., 2015). It is supported by De Vries *et al.* (2015) that a patella strap or sports tape decreases pain in the short-term, although it is not more effective than placebo taping. Nevertheless, the long-term effects remain inconclusive (De Vries *et al*., 2015) with the working mechanism being to alter the angle between the patella and the patellar tendon (Schwartz *et al*., 2015).

Lastly, partial agreement was reached in the e-Delphi survey with regard to the influence of the expectations of the trainer and/or coach on the rehabilitation of patellar tendinopathy. This might be due to the experts being from different professions, their roles in rehabilitation and the level of participation of the athlete with whom they engage as contributing factors, as previously described by Kulig *et al*. (2015). One aspect that can be useful in addressing this matter is to involve and inform the trainer and/or coach about the short- and long-term goals and time frame of the rehabilitation programme to ensure realistic expectations. Another aspect is to enhance the knowledge of the trainer and/or coach about patellar tendinopathy pathology (Scott *et al*. 2013), unloading and reloading of the patella tendon and prevention strategies, extrinsic factors, load management and realistic rehabilitation goals and time frames (Kulig *et al*., 2015). Based on the results from this survey and the integration of these results with existing literature, a framework for the rehabilitation of patellar tendinopathy was developed and presented in Figure 1.

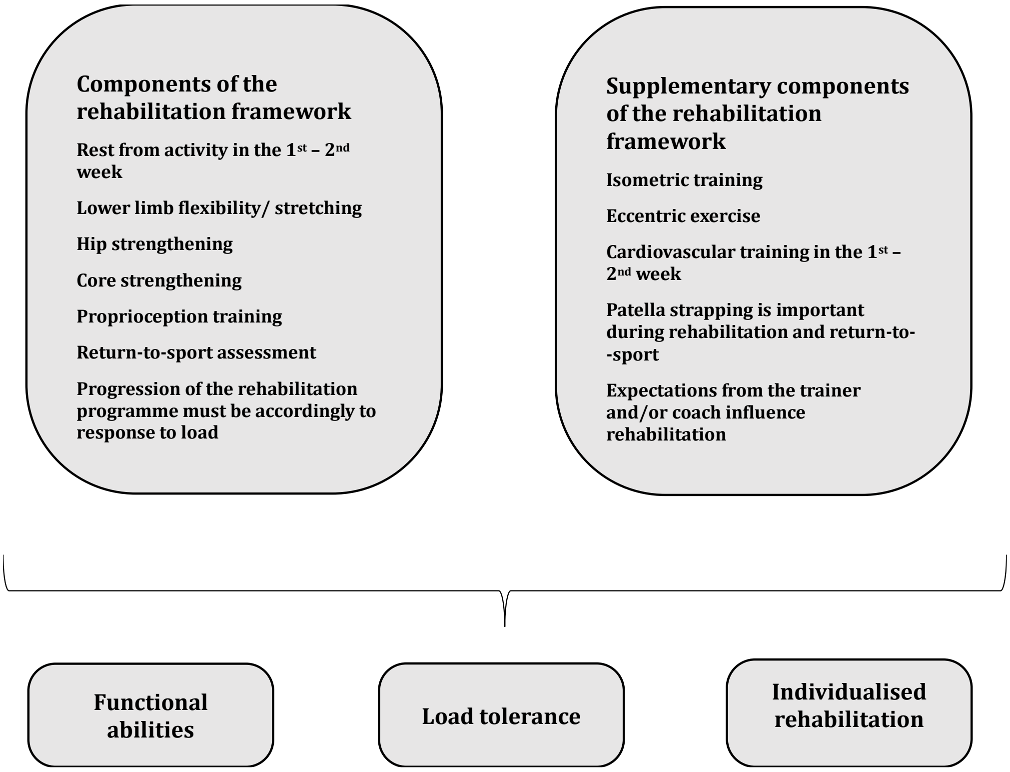

Figure 1. Patellar tendinopathy rehabilitation framework.

This e-Delphi survey thus makes a unique contribution by means of a patellar tendinopathy rehabilitation framework compiled from the opinions of international experts in the field of sport, rehabilitation and more specifically patellar tendinopathy. The research is further enhanced through the use of a robust theoretical framework for the e-Delphi methodology (Habibi *et al*., 2014).

The experts included in this e-Delphi survey are influential researchers who have contributed to the development of knowledge on the topic. This is advantageous, as the data captured were of superior quality because of the experts' knowledge and experience in patellar tendinopathy through their continuing academic investigation in the subject. Definite tendencies were apparent through the research process, probably because five out of the eight experts specialise and are constantly involved in patellar tendinopathy research. Nevertheless, it is important to note that the opinions of these experts regarding the patellar tendinopathy rehabilitation framework presented here, might not have been unconditionally true or necessarily the best guidelines, but rather a framework that this group of experts considered appropriate for patellar tendinopathy rehabilitation.

The experts described this e-Delphi survey as "innovative, interesting and extremely relevant" to patellar tendinopathy research and confirmed that the outcome of this research by means of the patellar tendinopathy rehabilitation framework is an excellent treatment summary. They warned, however, that the framework should be considered as guidelines rather than a "recipe" since there is no one specific protocol for patellar tendinopathy rehabilitation.

Advantages, challenges, strengths and limitations of the e-Delphi survey

The electronic collection of data was an effective medium between the experts and the researchers due to geographical separation. It enabled cost-effective data collection (Donohoe *et al*., 2012), anonymity and the distribution of information from previous rounds (Slade *et al*., 2014). The e-Delphi survey created an opportunity to create an environment to identify trends in the formulation of the patellar tendinopathy rehabilitation framework. The number of experts in the panel was deemed adequate with a low withdrawal rate leading to rich and diverse data collection in the survey. This might also be because experts related well to the subject as it was directly linked to their field of interest and research.

A challenging feature of the e-Delphi survey was to obtain consensus on a topic such as patellar tendinopathy rehabilitation. Unfortunately, two experts dropped out in round three, but six did complete the e-Delphi survey in its entirety. The success of retaining the majority of the e-Delphi panel was accomplished by constant communication via email.

A limitation of this e-Delphi survey was that some experts initially declined the invitation due to other work-related responsibilities. A second constraint of the patellar tendinopathy rehabilitation framework was the diversity of viewpoints of the experts regarding patellar tendinopathy.

CONCLUSION AND PRACTICAL IMPLICATIONS

This research is of important value as it presented a unique and collated perspective of internationally recognised experts regarding a patellar tendinopathy rehabilitation framework. The outcomes of this research suggest that load tolerance, functional assessment and an individualised rehabilitation programme will be vital to successful patellar tendinopathy rehabilitation intervention. Load tolerance is deemed most critical and forms the foundation of the patellar tendinopathy framework (see Figure 1).

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Competing interests

The authors declare 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 e-Delphi survey, discussed the construction of the article, performed three rounds of the e-Delphi 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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CHAPTER FIVE (ARTICLE 3): PATELLAR TENDINOPATHY: A REHABILITATION INTERVENTION IN ELITE RUGBY UNION PLAYERS

5.1 Introduction

The article presented in this chapter reports on the exploratory implementation of the e-Delphi-based rehabilitation intervention among elite rugby players of a South African rugby union, based on a 12-week rehabilitation intervention, and addressed objective three.

The articles in the previous two chapters provided the author with much insight into the literature and the opinions of experts about the rehabilitation of patellar tendinopathy, and this information was incorporated into the clinical setup.

The article reports on the outcomes of the clinical intervention and was submitted to the South African Journal of Research in Sport, Physical Education and Recreation on the 13th of July 2017.

Title

Patellar tendinopathy: a rehabilitation intervention in elite rugby union players

Abstract

Patellar tendinopathy is a chronic pathology with a prevalence of 10% to 15% in professional rugby union players. The aim of this study was to determine the outcomes of a 12-week rehabilitation intervention, as proposed by an international e-Delphi panel, in elite rugby union players in South Africa. A pre-test, post-test pilot clinical trial was performed on 16 male participants with patellar tendinopathy. Subjective and objective measurements were performed at baseline and 12 weeks upon completion of the rehabilitation intervention, which included a subjective questionnaire, the Victorian Institute of Sports Assessment – Patella (VISA-P) questionnaire, Visual Analog Scale (VAS) and electromyography (EMG) measurement of three muscles of the quadriceps femoris muscle group. The participants' mean age was 21.8 years (standard deviation [SD] 1.7 years), with the majority having patellar tendinopathy for the first time and a 75% dominant leg involvement. The duration of symptoms varied between four weeks and six months, with the mechanism of injury identified as jumping, running, change in direction, with increased intensity, frequency and duration aggravating the symptoms. The mean VAS score for pain (p=0.001), quadriceps femoris EMG (p=0.002) and VISA-P score (p=0.001) improved significantly over the 12-week period. The intervention showed a statistically significant improvement in pain and functionality.

Key words: patellar tendinopathy, sport rehabilitation, elite rugby union players

INTRODUCTION

Tendinopathy in the lower limbs poses a considerable challenge in any sports population (Barker-Davies *et al*., 2017), with athletes participating in competitive sport having an increased chance of suffering from patellar tendinopathy (Horstmann *et al*., 2017). This condition is a painful pathology of the patellar tendon associated with overuse (De Vries *et al*., 2017) and is classified as a degenerative pathology with no inflammatory process. In the majority of cases, pain is displayed at the inferior pole of the patellar tendon and can be replicated with certain clinical tests and palpation of the patellar tendon (Stasinopoulos, 2016).

Temporary overuse of the patellar tendon may lead to early-onset tissue damage that can return to normal once the load on the tendon is adjusted. Persisting high loads on the patellar tendon, however, may result in the development of chronic pathology, which is an unfavourable outcome (De Vries *et al*., 2017). Between 13% and 20% of elite athletes, whose occupation it is to compete professionally, are affected by patellar tendinopathy (Kumar et al., 2016; Stuhlman et al., 2016). Similarly, the era of professionalism in rugby union has been related to an amplified prevalence of injuries, particularly in the knee. The knee accounts for the anatomical structure in the human body sustaining the most injuries in rugby union and is responsible for the most absent days from training (Durcan *et al*., 2014) with a reported incidence of patellar tendinopathy in rugby players of 10% to 15% (Barker-Davies *et al*., 2017).

Talented young rugby players are stationed at elite rugby academies and unions, competing and training at high levels with increased volume, intensity and frequency (Durcan *et al*., 2014). In these players, the main mechanism of injury responsible for patellar tendinopathy is mechanical overload of the patellar tendon (Tas *et al*., 2017), which may lead to weakness of the tissue and sometimes catastrophic failure of the tendon (Schwartz *et al*., 2014). These advanced training regimes are responsible for the more frequent prevalence of patellar tendinopathy as a chronic injury (Wilson *et al*., 2014). Despite the increasing prevalence, chronic injuries in rugby union are reported less frequently in the literature than acute injuries (Durcan *et al*., 2014).

Patellar tendinopathy can have an adverse effect on the economic position and the quality of life of elite rugby union players (Castro *et al*., 2016). Although patellar tendinopathy is a common chronic pathology in rugby union (Wilson *et al*., 2014) with well-defined medical signs and symptoms (Stasinopoulos, 2016), a paucity of evidence and data are available in the literature regarding the treatment of elite rugby players with this injury (Fairley *et al*., 2014). It has an erratic nature by virtue of its poor association between pain, function and pathological stage, a situation that necessitates critical planning for the elite rugby player involved (Barker-Davies *et al*., 2017).

A diversity of treatment options is available for patellar tendinopathy, however, no specific ideal treatment modalities that assure comprehensive recovery have been described in literature, and the symptoms can often become long-term (De Vries *et al*., 2017). Even with contemporary treatment, the symptoms do not resolve rapidly, with the majority of athletes experiencing long-lasting symptoms for up to 32 months (Fu & Tsang, 2017). Stuhlman *et al*. (2016) described this tendency as unacceptable in today's competitive sport environment, which warrants continuous investigation of this pathology.

This limited availability of research and evidence within the elite rugby union clinical environment, as well as the continuous poor and disappointing outcomes of patellar tendinopathy rehabilitation, necessitated this investigational study. A 12-week rehabilitation intervention was developed based on the findings of an international e-Delphi survey (Morgan *et al*., unpublished). This article reports on the exploratory implementation of the proposed rehabilitation intervention among elite rugby players of a South African rugby union.

METHODS

A pre-test, post-test pilot research design was utilised in this study to determine the outcomes of the international e-Delphi based rehabilitation intervention on patellar tendinopathy symptoms (Morgan *et al*., unpublished). The study population consisted of elite rugby union players having professional rugby as their occupation. Due to ethical considerations and to provide each player with the opportunity to receive the best effective treatment to continue successfully with their professional careers, the group was not divided into an experimental and control group.

Study population

The study sample consisted of 16 elite rugby union players who met the inclusion criteria for the study (see Table 1).

Table 1. Inclusion and exclusion criteria for the selection of study participants.

Inclusion criteria	Exclusion criteria
• Diagnosed with patellar tendinopathy • Pain or tenderness of the patellar tendon affecting their performance in rugby • A squat or a jump test that leads to patellar tendon pain • 18 years or older • English literate	• Any previous knee surgery or other knee pathologies, except patellar tendinopathy • Bilateral patellar tendinopathy • Other concurrent lower limb pathologies

Ethical considerations

Ethical clearance was obtained from the Ethics Committee of the Faculty of Health Sciences at the University of the Free State, South Africa (ECUFS181/2015) before commencement of the study. The rugby medical manager and all the participants provided written informed consent and participation was voluntary.

Data collection

The research and data capturing were conducted in Pretoria, South Africa. The rugby union medical manager (team physician) was informed about the study and requested to identify injured elite rugby players with patellar tendinopathy. The players were also informed about the contribution they could make should they be willing to participate in the research study. An appointment was arranged between the injured players and the principal researcher (S.M.) at a suitable venue. The first appointment was one hour and the follow-up sessions were 30 minutes.

A subjective questionnaire compiled by the researcher was used to capture demographic information, injury pattern of patellar tendinopathy, load tolerance and level of sport participation. Secondly, knee pain and functionality of the elite rugby players were subjectively measured by means of the Visual Analog Scale (VAS) and the Victorian Institute of Sport Assessment – Patellar (VISA-P) questionnaire, which have shown respectable reliability and validity in research (Vetrano *et al*., 2013). The objective outcomes measures included height and weight measurements according to the International Standards for Anthropometric

Assessment (International Society for the Advancement of Kinanthropometry, 2001), and three muscles of the quadriceps femoris surface electromyography (EMG).

Bipolar configuration quadriceps femoris EMG (mV) testing was performed during a maximal voluntary contraction of the vastus medialis oblique (electrode placement: ⅘ from the anterior spinae iliaca to the joint space before the anterior border of the medial collateral ligament), vastus lateralis oblique (electrode placement: ⅔ from the anterior spina iliaca to the lateral border of the patella) and rectus femoris muscle (electrode placement: mid-point from the anterior spinae iliaca to the superior border of the patella) (Hu *et al.*, 2006) during a single leg 25º decline squat (Balachandar *et al*., 2011). The input impedance was minimised and the electrode placement and location were in accordance with the Surface EMG for Non-Invasive Assessment of Muscles (SENIAM) (Scurr *et al*., 2011). The surface electrodes were 50 X 50 mm^2 and two centimetres apart, with the ground electrode placed on the ipsilateral proximal tibial tuberosity. EMG data were recorded at a synchronous channel at a frequency of 10 Hertz, ten seconds work / rest selection. The time phase of the work / rest was 100 seconds with a pulse width of 240 µS, and both the ramp-up time and ramp-down time were two seconds.

Figure 1 shows a diagrammatic representation of the measures performed at baseline (prior to commencement of the rehabilitation intervention) and at 12 weeks (after completion of the intervention).

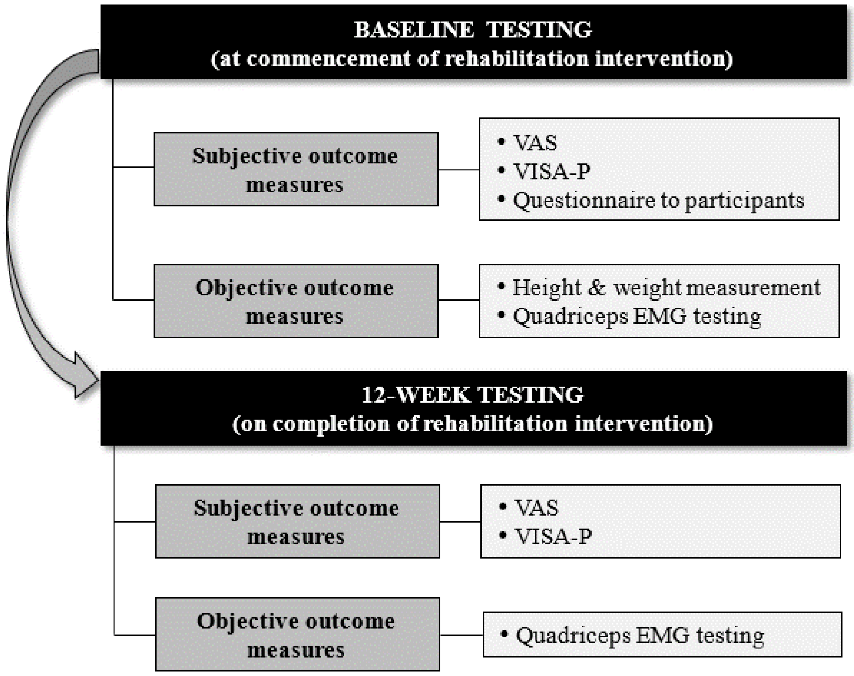

Figure 1. Subjective and objective outcomes measures used in the study.

Rehabilitation intervention

The proposed integrated management model for patellar tendinopathy was designed and developed by the researchers, based on the models of Bahr & Krosshaug (2005), Meeuwisse *et al.* (2007) and Brukner & Khan (2007) and further supplemented with the findings of the systematic review on the causative risk factors and rehabilitation for patellar tendinopathy (Morgan *et al*., 2016) and the international e-Delphi survey (Morgan *et al*., unpublished).

This model is presented in Figure 2 and consists of three core elements: risk factor identification, prevention and rehabilitation. Only the elements of rehabilitation identified by means of the e-Delphi rehabilitation framework (Morgan *et al*., unpublished) were implemented and applied in the clinical set-up of the elite rugby players and discussed in this article. The other two supplementary core elements, namely risk factor identification and prevention, were discussed in Morgan *et al*. (2016). According to the model, the three key aspects of rehabilitation that were applied to this study are load tolerance of the patellar tendon during any activity, functional ability of the elite rugby player and individualisation of the rehabilitation intervention to address the specific biomechanical and rehabilitation needs of the elite rugby player. The load tolerance principle is superior to the other two themes and implies that pain on the provocation test must return to baseline within 24 hours after activity or rehabilitation, which will indicate that the patellar tendon has tolerated the load (Malliaras *et* *al.*, 2015). The entire rehabilitation intervention, regardless of the activity, was guided by this central principle.

The three key aspects comprise subcomponents which are the secondary components of the rehabilitation intervention. These components of the rehabilitation intervention consist of rest in the 1st–2nd week from any lower limb physical activity that aggravates the symptoms of the pathology, cardiovascular training (swimming) in the 1st–2nd week that does not put load on the patellar tendon to assist in fitness maintenance, lower limb flexibility/stretching, isometric training of the quadriceps femoris muscle, eccentric training of the quadriceps femoris muscle, lower limb flexibility/stretching, hip muscle strengthening, core muscle strengthening, lower limb proprioception training, progression of the rehabilitation programme based on load tolerance, patellar tendon strapping, sport-specific techniques, return-to-sport assessment and athlete, trainer/coach education (Morgan *et al.*, unpublished). All these components were integrated into an encompassing individualised rehabilitation intervention for each elite rugby player. The elite rugby players were exposed to three rehabilitation sessions per week each lasting 30 minutes, for a duration of 12 weeks. This added up to a total of 36 sessions each, all of which were documented.

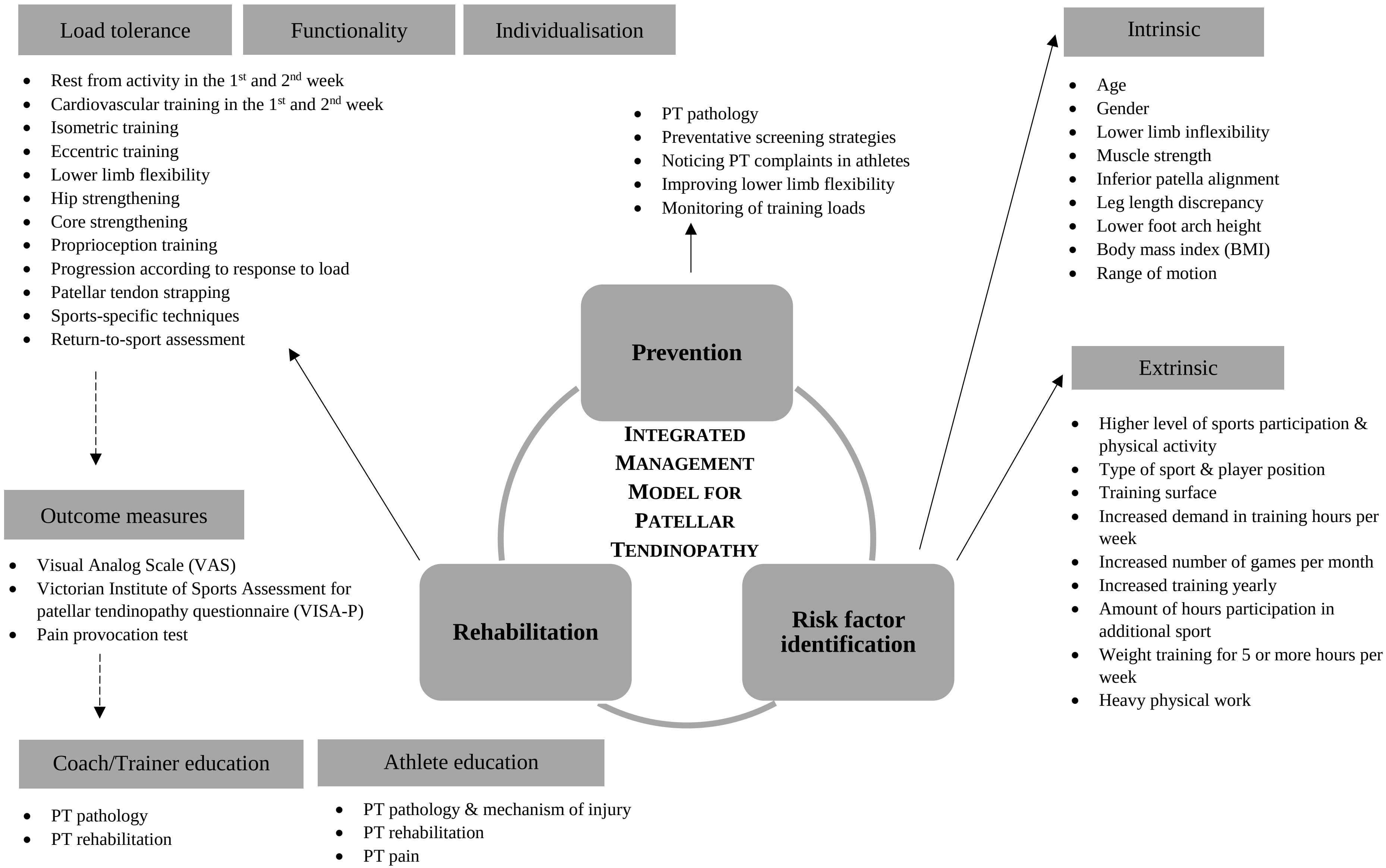

Figure 2. An integrated management model for patellar tendinopathy.

Statistical analysis

Quantitative variables such as weight and body mass index (BMI) for forwards and backline players were obtained and compared using the Student t-test. A result was deemed significant (i.e. the null hypothesis of equality was rejected) when the p-value from the test was less than 0.05.

The scores obtained from the VISA-P and the VAS questionnaires as well as the EMG results at baseline were compared with the corresponding measurements after the 12-week rehabilitation intervention using a binomial sign test (Hogg & Tanis, 1997). This is a nonparametric test for paired data and indicates whether the median VISA-P, VAS and EMG scores changed over the 12-week intervention period.

RESULTS

The study included 16 elite male rugby players (mean age 21.8 years, standard deviation [SD] 1.7 years; range 19–26 years) with confirmed signs and symptoms of patellar tendinopathy. They all successfully completed the 12-week rehabilitation intervention programme without any participant dropouts or rehabilitation sessions missed. The participants were homogeneous with respect to training regime, with 37% being involved in international and 63% in provincial level of sport participation.

Notable differences were observed between forward and backline players. Their overall mean body weight was 93.5 kg (SD 13.5 kg; range 75–118 kg) and their mean BMI was 27.2 kg/m^2 (SD 3.5 kg/m^2; range 20.9–33.7 kg/m^2). Forward players (n=8) had a higher mean weight of 101 kg (SD 12.9 kg; range 79–118 kg) and BMI of 29.0 kg/m^2 (SD 3.1 kg/m^2; range 25.6–33.7 kg/m^2) respectively, compared to backline players (n=8) with a mean weight and BMI of 86 kg (SD 9.4 kg; range 75–104 kg) and 25.4 kg/m^2 (SD 3.2 kg/m^2; range 20.9–29.7 kg/m^2), respectively. The specific injury patterns for the study participants are presented in Table 2.

Table 2. The specific injury patterns of the participants (n=16) self-reported at baseline.

Variable	**n (%)**
Player position	
• Forward	8 (50.0)
• Backline	8 (50.0)
Leg dominance and PT	
• Dominant leg	12 (75.0)
• Non-dominant leg	4 (25.0)
Injury history	
• New injury	12 (75.0)
• Recurring injury	4 (25.0)
Onset of symptoms	
• Acute onset	0 (0)
• Gradual onset	16 (100)
Duration of symptoms	
• 1–2 weeks	0 (0)
• 2–4 weeks	0 (0)
• 4–8 weeks	4 (25.0)
• 8–12 weeks	5 (31.3)
• 3–6 months	3 (18.8)
• More than 6 months	4 (25.0)
Mechanism causing injury	
• Jumping	15 (93.8)
• Running	14 (87.5)
• Change in direction	13 (81.3)
• High volume training	12 (75.0)

Outcome measures

The mean VISA-P score at baseline was 37.1 (SD 16.2; range 10–67). When the group was stratified by player position (forward or backline player), a mean VISA-P score at baseline of 29.6 (SD 13.1; range 10–48) for forwards and 44.5 (SD 16.2; range 21–67) for backline players was obtained, which was significantly different (p=0.032). After the 12-week rehabilitation intervention, the overall mean VISA-P score increased to 66.6 (SD 16.5; range 25–89); the mean VISA-P score of the forwards increased to 60.1 (SD 20.0; range 25–89) and the backline players to 73.1 (SD 9.2; range 59–84), which was also a relatively substantial difference between forward and backline players (p=0.063). The VISA-P score improved for all 16 players over the 12-week rehabilitation period, with a mean increase of 29.5 (SD 20.4; range 8–69) in the score (p=0.001).

Two questions on the VISA-P regarding the experience of pain during a full weight-bearing lunge and a squat were analysed separately for forward and backline players. The mean pain rating of the lunge exercise at baseline was 1.6 (SD 0.8; range 1–3) for forwards and 3.3 (SD 1.6; range 1–6) for backline players, which was a statistically significant difference (p=0.019). After the 12-week rehabilitation intervention, the mean scores improved for both forwards and backs to 5.8 (SD 2.4; range 1–8) and 7.9 (SD 1.3; range 5–9), respectively (p=0.020).

Equally, the mean pain rating of the squatting exercise at baseline was significantly different (p=0.028) between the forwards (mean score 1.5; SD 1.0; range 1–3) and backline players (mean score 2.8; SD 1.3; range 1–5). After the 12-week rehabilitation programme the mean scores improved for both forwards and backline players to 6.5 (SD 2.0; range 2–8) and 7.6 (SD 1.7; range 6–10) respectively (p=0.12).

The VAS questionnaire measures pain in athletes with patellar tendinopathy (Da Cunha *et al*., 2012), with higher scores indicating a greater degree of pain. The overall mean VAS score for the elite rugby players at baseline was 7.9 ± 1.3 SD out of 10 (range 5–9 out of 10), while after the 12-week rehabilitation intervention, the mean score was significantly lower (p=0.001) at 2.3 ± 1.5 SD out of 10 (range 1–7 out of 10).

As summarised in Table 3, the EMG on work average and work peak for the vastus medialis oblique, rectus femoris and vastus lateralis muscles all showed a significant improvement from baseline to after the 12-week intervention program (p=0.002) (see Table 3).

Table 3. EMG findings of the quadriceps muscle at baseline and after completion of the 12-week rehabilitation intervention.

Variable	Muscle: EMG findings (mV)		
	Vastus medialis oblique	**Rectus femoris**	**Vastum lateralis oblique**
Mean work average			
Baseline	60.1 (SD* 32.3; range 24.6–127.9)	52.0 (SD 52.0; range 7.8–189.4)	61.3 (SD 32.1; range 17.2–124.5)
After 12 weeks	79.6 (SD 45.7; range 31.4–207.1)	71.1 (SD 42.3; range 25.7–164.3)	79.8 (SD 38.2; range 38–167.3)
p-value	0.004	0.004	0.001
Mean work peak			
Baseline	415.8 (SD 390.8; range 94–1554)	285.4 (SD 174.4; range 41–654)	302.6 (SD 99.0; range 107–427)
After 12 weeks	541.6 (SD 417.5; range146–1842)	454.0 (SD 201.1; range 235–881)	444.6 (SD 131.3; range 198–665)
p-value	0.001	0.001	0.001

*SD: standard deviation.

DISCUSSION

The profile of the participants in this study with patellar tendinopathy showed resemblance with profiles previously described in the literature with regard to BMI, gradual onset of symptoms, reoccurrence of the pathology and mechanism of injury (Durcan *et al*., 2014; Ferretti *et al*., 2002; Reinking, 2016; Stuhlman *et al*. 2016).

The forward rugby players' mean BMI was significantly greater than the backline players', which was similar to results reported by Durcan *et al*. (2014). This finding could be attributed to the fact that forward players are expected to be heavier than the backline players to meet the requirements of functional positional play (Duthie *et al*., 2003). This BMI finding also agreed with previous reports on patellar tendinopathy, which specified that an elevated body weight and BMI are potential risk factors for patellar tendinopathy (Durcan *et al*., 2014; Schwartz *et al*., 2014).

Patellar tendinopathy occurred in the dominant leg in 75% of the elite rugby players in this study, despite the opposite being found by Hägglund *et al*. (2011), where 40% of patellar tendinopathy injuries were recorded in the dominant leg of football athletes, and 48% in the non-dominant leg.

The outcomes of the elite rugby players' subjective baseline questionnaire disclosed a recurrence rate of this pathology in 25% of players. According to Stuhlman *et al*. (2016), the reoccurrence rate of patellar tendinopathy symptoms is 23% in athletes who already have completed an extensive, intensive rehabilitation programme. This literature corresponds with the study results and supports the statement by Reinking (2016) that patellar tendinopathy is a challenging pathology to treat.

The onset and duration of patellar tendinopathy symptoms in this study showed a relation to previous literature. Gradual onset of patellar tendinopathy symptoms was a prominent finding. It is typical to the nature of chronic injuries (Brukner & Khan, 2012) that have a slow onset, especially patellar tendinopathy (Reinking, 2016). The symptoms of patellar tendinopathy are often deceptive (Rosso *et al*., 2015) and unexpected, with a repetitive onset (Sànchez-Ibàñez, 2015). This study showed the duration of symptoms to be prolonged in some of the elite rugby players with 19% experiencing symptoms for between three and six months and 25% with persisting symptoms for six months or more. It was similar to previous studies reporting that patellar tendinopathy is characterised by lengthy (Sànchez-Ibàñez, 2015) anterior knee pain (Vetrano *et al*., 2013), with one third of the athletes affected by patellar tendinopathy experiencing symptoms and limitations (Saithna *et al*., 2012) and being unable to return to sport for a period of six months or longer (Stuhlman *et al*., 2016).

Jumping, running, change of direction and intense training regimes were contributing factors to the mechanism of injury in this study. It has been reported that patellar tendinopathy is associated with rapid deceleration, acceleration (Ferretti *et al*., 2002), jumping (Zhang *et al*., 2014) and landing on the lower extremities (Ferretti *et al*., 2002). Excessive mechanical overload on the patellar tendon (Rosso *et al*., 2015) that exceeds its reparative capacity (Rowan & Drouin, 2013) is a distinctive factor for the development of patellar tendinopathy (Rosso *et* *al*., 2015). The results also confirmed that an increase training volume is associated with patellar tendinopathy (Durcan *et al.*, 2014) and modern elite rugby players are involved in increased volume, intensity and duration of training and competitions (Durcan *et al*., 2014). Our study found that increased intensity (100% incidence), frequency (94% incidence) and duration (100% incidence) contributed to the amplified load on the patellar tendon which supports Hägglund *et al*. (2011) who identified increased load as an extrinsic causative risk factor for patellar tendinopathy.

EMG

The EMG testing on the three muscles of the quadriceps femoris in our study participants provided noteworthy findings based on the values obtained (Table 3). The single leg 25º decline squat provided improved activation results after the 12-week rehabilitation intervention with significantly greater muscle recruitment. It has been reported previously that a single-legged squat on a 25º board is associated with clinical improvements in patellar tendinopathy athletes (Ribeiro *et al*., 2007). Furthermore, the literature specifies that successful rehabilitation programmes include strength training, which reduces pain and facilitates return to sport (Rio *et al*., 2015), with quadriceps femoris muscle strength and endurance one of the vital aspects for normal knee joint function (Hart *et al*., 2010).

These results confirm that the rehabilitation intervention made a statistically significant difference in the mean scores of the VAS and VISA-P at baseline compared to 12 weeks after intervention. This research did not determine the precise rehabilitation component in isolation that was accountable for the major improvement, but rather illustrated that a variety of rehabilitation components were responsible for the significant improvement in the elite rugby players' symptoms. It can therefore be argued that conservative treatment, especially exercise, is still the leading approach to rehabilitation intervention for patellar tendinopathy (Schwartz *et al*., 2014) and plays a key role in the recovery process of elite rugby players. The load tolerance principle was the cornerstone of this study, which highlights again that traditional rehabilitation approaches are evidence-based (Reinking, 2016).

Functionality

The VISA-P score improved for all 16 participants over the 12-week rehabilitation period. This finding relates to literature describing that athletes affected by patellar tendinopathy experience increased pain and impaired functionality (Rosso *et al*., 2015), but the symptoms will improve with rehabilitation (Rudavsky & Cook, 2014). Initially, the forward players had an overall lesser functionally based on their mean VISA-P score than backline players, which agrees with previous findings reported by Durcan *et al*. (2014).

One can reason that both forwards and backline players perform core skills such as tackling and rucking, but there is a variation in movement patterns, physical condition in terms of BMI and skill demand for forwards and backline players. This implies that forward players are more involved in set play aspects such as scrum and lineouts (Tee & Coopoo, 2015). This set play of rugby movements is related to the mechanism of injury of patellar tendinopathy and may clarify the lower VISA-P score seen in forwards compared to backline players at baseline. It is also reflected in the VISA-P specific questions that evaluated functional movements screening, such as squat and lunge, where the forward players' functional movements scores were significantly lower than the backline players at baseline. This type of activities forms a key aspect of set play in a forward rugby player position.

Pain

After completion of the 12-week rehabilitation intervention, improvement in symptoms and pain was a prominent outcome. A significant reduction in pain ($p<0.001$) was found when comparing baseline pain to the degree of pain after a 12-week rehabilitation intervention. This finding agrees with Rudavsky and Cook's (2014) statement that an active exercise rehabilitation intervention with slow progression will reduce pain in athletes with patellar tendinopathy.

Another notable finding from our study was the trend that decreased muscle activation results on the EMG at baseline seemed to accompany lower scores on the VAS and VISA-P, an indication that insufficient muscle strength and inability to control the muscle activity could be linked to an undesired outcome such as pain and poor performance (Rio *et al*., 2015). This further highlights the fact that pain and functional dysfunction on the VAS and VISA-P scores were associated with load on the tendon, which was responsible for provoking symptoms (Zhang *et al*., 2014). Taking into consideration that the central focus of the rehabilitation intervention was the load tolerance principle, it once again emphasises that load tolerance plays an important role in patellar tendinopathy rehabilitation and was a contributing factor in obtaining positive results in this study.

CONCLUSION

The limited research on patellar tendinopathy within the elite rugby union environment, as well as the continuous poor outcomes of PT rehabilitation, necessitated further investigation of this pathology. Building on an initial compilation of a 12-week rehabilitation intervention based on the findings of an international e-Delphi survey, this article reports on the exploratory implementation of that intervention among elite rugby players of a South African rugby union. The rehabilitation intervention was founded on three principles, namely the functional ability of the elite rugby player, individualising the rehabilitation intervention according to the participant's specific biomechanical deficiencies and load tolerance of the patellar tendon. The outcomes of this study demonstrate improvement in pain and functionality in elite rugby union players with patellar tendinopathy.

STRENGTHS, LIMITATIONS AND RECOMMENDATIONS

One of the strengths of this study lies in the e-Delphi survey experts' opinions (Morgan *et al*., unpublished), which led to the development of this intervention model that outlined promising results in terms of decreased pain and increased functionality. A limitation identified in this study was the exclusion of participants with bilateral patellar tendinopathy involvement, and the exclusion of a long-term follow-up of participants, which could be addressed in future research. A follow-up study is recommended with a larger study population and with the inclusion of a number of other variables, such as a distinction between junior and senior elite rugby players, as well as in- and out-season rehabilitation.

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Competing interests

The authors declare 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. implemented the rehabilitation intervention into the clinical set-up, discussed the construction of the article and F.F.C. 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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CHAPTER SIX: AN INTEGRATED MANAGEMENT MODEL FOR PATELLAR TENDINOPATHY

This last content chapter serves as the overall summary of the findings of the study in the form of an integrated management model for Patellar Tendinopathy (PT). The main purpose of this study was to formulate an integrated management model for PT by utilising both quantitative and qualitative methods of data collection. Data were processed and interpreted for each of the three articles and will now be presented collectively in this chapter, in order to describe how the outcomes of the study were achieved. Recommendations and limitations forthcoming from this research will also be included.

6.1 Introduction

Science may be described as the process of creating and predicting theoretical models. Within this framework, the undertaking of research should create robust models, as a result of which accurate predictions of relationships and structures in the real world will be forthcoming (Gilbert, 1991:73). Sports medicine can be fittingly classified as a science, with the creation of effective rehabilitation interventions, which are often being considered an “art” (Brukner & Khan, 2007:174). It can be distinguished as a medical area of expertise with its key purpose being to promote, protect and re-establish the health of elite athletes, which includes the rehabilitation of chronic injuries (Prins *et al.,* 2015:75). A frequent musculoskeletal pathology in modern sports is chronic tendon pathology (McCreesh & Lewis, 2013:242), and more specifically PT, as discussed in this study (refer to 2.2.4; Article1). Clinical and scientific rehabilitation of tendinopathy can be challenging, and there is broad consensus among sports medical staff that some aspects require further research and a better understanding. This may explain why clinical trials still yield ambiguous results (McCreesh & Lewis, 2013:242) in terms of the interaction among structure, pain and function in tendinopathy (Cook *et al.,* 2016:1187).

The integrated management model for PT comprised a complex process, whereby various components were used in combination to achieve the main purpose of the study (refer to 1.3). This proposed model is based on the etiological sports injury model of Meeuwisse *et al*. (2007:215-219) and the injury prevention model of Bahr and

Krosshaug (2005:324-329), supported by the rehabilitation model presented by Brukner and Khan (2007:174-175; 224-29), according to whom injury prevention can be characterised by a sequence of four key steps (refer to Figure 6.1 below). Initially, the sports injury must be identified and categorised in terms of the extent of the injury, its prevalence and severity. Secondly, the risk factors and mechanism pertaining to the injury should be ascertained. Thirdly, the purpose is to implement features that minimise the injury risk and the severity of injury, and lastly, the outcomes of such features should be assessed by repeating the first step (Bahr & Krosshaug, 2005:324-325).

Figure 6.1: Four-step sequence of injury prevention research

Source: (Bahr & Krosshaug, 2005:225)

A critical aspect of the above sequence is to determine the underlying causes by means of risk factor identification and mechanism of injury. For an enhanced understanding of the injury causation, a multifactorial nature of addressing injuries is essential (Bahr & Krosshaug, 2005:324-325), in order to explain the interaction of numerous intrinsic and extrinsic causative risk factors, as proposed by Meeuwisse *et al.* (2007:215-216; refer to Figure 6.2). The emphasis is on the identification of intrinsic predisposing causative factors and extrinsic causative factors that interrelate to make an athlete predisposed to injury, before an injury actually occurs. In the sporting environment, an athlete's risks to sustain an injury often change. Furthermore, their exposure to an intrinsic causative risk factor may increase their injury predisposition, or an exposure to a variety of extrinsic causative risk factors may result in many different susceptibilities to injury. This creates a milieu of re-occurrence, where an athlete may periodically participate in an event with a dissimilar set of risk factors, even though the majority of factors in their playing context remains unchanged. Every athlete has certain unique individual intrinsic causative risk factors, for example, bone strength, age and former injury history. It might be possible to limit such risk factors by adapting to the context, or by preventing possible injurious situations during sports participation. The same principle applies to extrinsic causative risk factors, for example, athletes' response to other athletes, or equipment modification during particular match circumstances. Addressing such intrinsic and extrinsic causative risk factors may have a direct effect on decreasing the susceptibility to sustain an injury (Meeuwisse *et al.,* 2007:216). Each type of sport has its own individual characteristics, and a robust literature review was thus essential in determining the typical aspects of the mechanism of injury (refer to Chapter 2).

For a comprehensive approach, the etiological sports injury and the injury prevention models were integrated (Brukner & Khan, 2007:79) to form a comprehensive injury causative model. A limitation of this model, however, is the lack of information on athletes' training regimes and tournaments, and how these contribute to injuries. A further limitation is that the model mainly describes acute injuries. In terms of chronic injuries, the provocative event may occasionally be quite distant from the outcome, due to prolonged time before chronic injuries become symptomatic. This model is therefore of value when utilising as a risk factor analysis in identifying individualised risk factors in athletes in a specific type of sport, and is vital for planning preventative strategies, especially to avoid chronic injuries. A risk factor analysis will also predict that the risk for injuries may be more evident in training transition phases, and that each phase has certain aspects that may intensify the risk for injuries. The results of such an analysis can be utilised to prime the athlete for possible inciting events (Brukner & Khan, 2007:79-81).

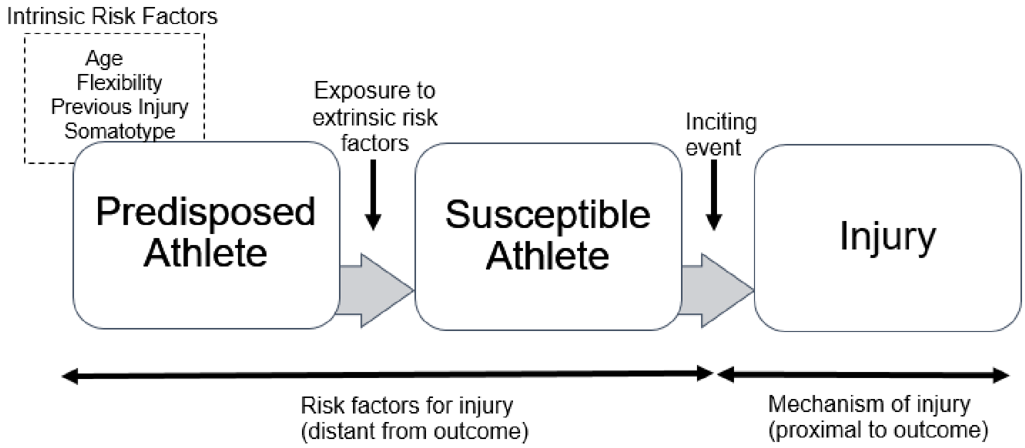

Figure 6.2: A dynamic, recursive model of aetiology in sports injury

Source: (Meeuwisse et al., 2007:217)

The third model mentioned as another pillar of this study defines rehabilitation as *"restoration to a former capacity or standing, or rank, rights and privileges lost or forfeited"* (Brukner & Khan, 2007:175) and is the essence of sports medicine practice. The entire injured musculoskeletal unit necessitates active rehabilitation of the athlete, to enable their return to sport with full functionality in the least possible time. Inadequate rehabilitation exposes the athlete to re-injury of the involved anatomical area, an inability to perform at pre-injury level, while predisposed athletes may be exposed to injuries in different anatomical areas of the body (Brukner & Khan, 2007:175). In this rehabilitation model individual components are integrated into a progressive rehabilitation programme (Brukner & Khan, 2007:175), the main purpose being to establish a basis from where rehabilitation should commence (refer to figure 6.3 below).

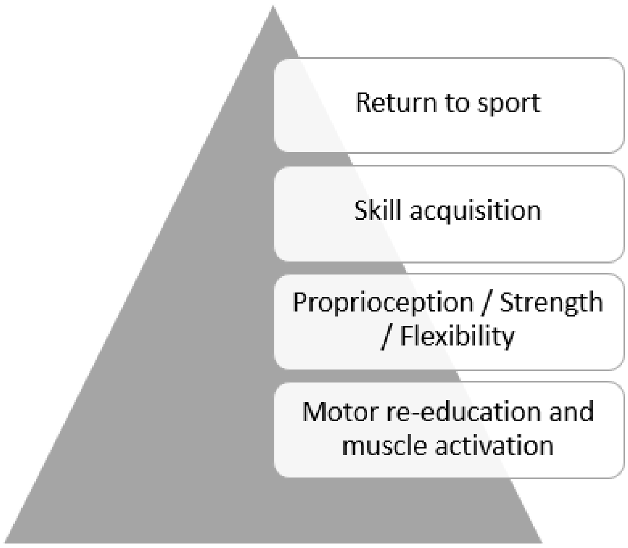

Figure 6.3: Integration of individual components into a progressive rehabilitation programme

Source:(Brukner & Khan, 2007:175)

The proposed integrated management model for PT was designed and developed by the researcher, based on the abovementioned models (Bahr & Krosshaug, 2005:324-329; Brukner & Khan, 2007:174-175; Meeuwisse *et al.,* 2007:215-219), and supplemented with the findings of the study in the systematic review, international e-Delphi survey, and the implementation of the e-Delphi rehabilitation framework in the clinical set-up (refer to 1.3; Articles 1 – 3). The three key elements of the model were identified from the three abovementioned models and included injury prevention, risk factor identification and rehabilitation. Within the integrated management framework for PT, each of these key elements has a number of subdivisions. The remainder of the discussion is based on the three key elements, their subdivisions and inclusion in the final, integrated management model for PT, forthcoming from this research.

6.2 Discussion

6.2.1 An integrated management model for PT

Healthcare has always been an important research aspect in eclectic disciplines, with the purpose, as emphasised by Fichman *et al*. (2011:419), of improving the quality of care and inventing novel treatment strategies. This study contributed to the collective values of improving sports medicine by means of rehabilitation and successful sports participation of athletes with PT, as described in the integrated management model for PT.

Article one of the study presented a literature review in terms of a systematic review, in order to attain a clear and distinct theoretical understanding of PT, especially the causative risk factors and rehabilitation regarding PT. This systematic review enabled the researcher to establish the pathways and tendencies with respect to PT, recorded in universal research during the past five years. The systematic review was the starting point for the final result of the integrated management model for PT. Even though PT is a widely researched field of study, a review of prior research studies, yet again, emphasised the fact that inadequate evidence was available, with particular emphasis on the most effective rehabilitation methods for the treatment of PT. Furthermore, little evidence existed in the form of South African research. As stated in 2.2.3, 2.2.5 and Article one, though the fact that PT pathology had a wide-ranging aetiology of intrinsic and extrinsic causative risk factors with a direct link to overloading of the patellar tendon (Hägglund *et al.,* 2011:1906), one of the most noteworthy findings was the diverse treatment options available for treating PT, with supplementary research remaining a necessity (Stasinopoulos, 2016:1010).

This integrated management model for PT, formulated with the abovementioned pillars in mind, described the all-inclusive stages of PT management, from early identification of the pathology up to the final education of athletes and sports medical staff. The model provides valuable guidelines to determine the starting point, short-term and long-term goals for rehabilitation, and the final preparation for return to sports. It is relevant and highly clinically based, for relatively smooth application in the clinical environment. It also may be useful to professional sports medical staff in serving as a framework for continuous PT management and increased knowledge in general.

The purpose of the model was to accomplish good interaction between the three key elements and gain a rational understanding of the rehabilitation of this pathology, thereby enabling tool-orientated therapists to systematically work through the key elements during the rehabilitation programme. This multi-faceted model can be adjusted in the clinical context, specifically with regard to the diagnosed stages of PT and the planning of rehabilitation. In the proposed model, a specific sports population was not explicitly depicted, since it was envisaged that it could be applied to practically any sports population, due to the PT management ideologies remaining similar. The model's applicability and adaptability has already been tested in the clinical context (refer to Article 3), but will only prove its value if accepted by sports clinicians (McCreesh & Lewis, 2013:243). Unfortunately, there is a large gap between proven scientific research and its practical implementation in the clinical context. It can take from one to two decades for clinical medical research to be implemented successfully in routine practice (Bishop, 2008:254). The three key elements of the model were: risk factor identification, prevention and rehabilitation, as presented in Figure 6.4 below.

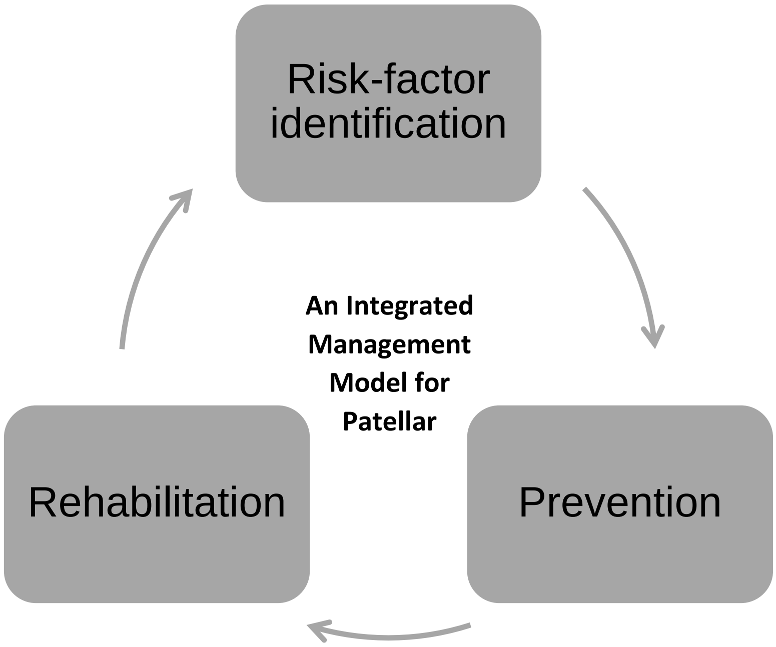

Figure 6.4: Three key elements of the integrated management model for Patellar tendinopathy

Source: (Researcher's own construct)

6.2.2 Risk factor identification

The first key element of the integrated management model for PT is risk factor identification, which was discussed in the literature review and article one (refer to 2.2.3; 2.2.5; Article 1). If the mechanical pathophysiological theory, as discussed previously, is taken into account, it clearly indicates that all intrinsic and extrinsic causative risk factors for PT are responsible for loading the patellar tendon in various ways. If the intrinsic and extrinsic causative factors could be identified and addressed in rehabilitation, the load on the tendon could be minimised, and improvements in pain and function would be noticeable. Such causative risk factors play a key role in prevention, planning and motivation in an individualised rehabilitation programme (Morgan *et al*., 2017).

Intrinsic causative risk factors are age and gender, and account for the non-modifiable intrinsic causative risk factors (refer to 2.2.3; 2.2.5; Article 1). Such risk factors can be defined as lower limb inflexibility with regard to the Iliotibial band; quadriceps and hamstring tendons; muscle strength by means of increased vastus medialis oblique strength or quadriceps muscle atrophy; anatomical alignment in terms of an inferior patellar pole alignment; leg-length discrepancy and lower foot arch heights; body composition implied by an increased body mass index (BMI); and joint range movement decreasing at the ankle in relation to dorsiflexion. Modifiable or non-modifiable intrinsic causative risk factors may play a role in preventing injuries as well. Brukner and Khan (2007:79) agree that modifiable risk factors may be addressed by training approaches, while non-modified risk factors (gender) may be directed to specific players, who are at risk for developing injuries by means of intervention strategies. Extrinsic causative risk factors are: skills acquisition and level in terms of higher sports participation levels and physical activity; player position; type of sport; training on hard surfaces; an increased demand for training hours per week; number of games per month, increased year-to-year training; number of hours participating in additional sports; weight training for at least five hours; and possibly also being heavy physical exercise.

6.2.3 Prevention

The intention of research is to increase epidemiologic injury data of all pathologies in different types of sport, in an attempt to prevent injuries by means of risk factor identification and injury patterns. By using such valuable data, the athletes, coach and medical team will be able to plan modifications of training regimes, in order to decrease the risk of athletes sustaining injuries (MacQueen & Dexter, 2010:142). As was noted in articles one and two of the study, prevention strategies were a key concept in PT and were considered the second notable aspect in the integrated management model for PT. The focus was on PT pathology, preventative screening strategies, noticing PT complaints in athletes, improving lower-limb flexibility and monitoring training loads.

An in-depth understanding of a pathology was necessary (Kollock *et al.,* 2016:920), as the management of PT could be compromised for both therapist and athlete due to a poor understanding of the essence of the pathology (Rudavsky & Cook, 2014:122; refer to 2.2.4). The development of screening measures and prevention strategies (Kollock *et al.,* 2016:920) by the therapist might be very helpful in PT pathology. A musculoskeletal screening and functional testing by a therapist to expose some underlying musculoskeletal restrictions, which might potentially predispose an athlete to sustain an injury could form the basis for a prevention strategy and should be part of their preparation (Bird & Markwick, 2016:785).

From the therapist's point of view, PT prevention might be achieved by taking cognisance of athletes' complaints. Kulig *et al*. (2015:411) reiterate that awareness and early identification of the PT symptoms would enable therapists to recognise it in athletes' complaints, such as "nagging" about anterior knee pain. This could also be achieved by monitoring athletes individually, in order to identify any symptoms (refer to Articles 1; 2).

Another aspect of prevention was sufficient lower-limb flexibility (Reinking, 2016:856), which was an essential component in the limiting of PT pathology (refer to 2.3.17; Article 1). Lastly, the training parameters in terms of intensity, frequency and duration in any sport should be assessed on a regular basis to determine the load, in order to prevent chronic injuries. These three aspects were the major causes of PT. According to Rutland *et al.* (2010:167), a rule of thumb in preventing PT, was that progression of a training regime should not exceed a ten per cent increase each week in terms of intensity, frequency and duration. A proposal made in the literature referred to cross-training, involving swimming, cycling and pool running, which could be used as alternative cardiovascular training, in order to decrease training loads (Reinking, 2016:856-857). Another idea would be to monitor the training load and improve the lower-limb flexibility by a multidisciplinary approach involving the team doctor, trainers and coach.

6.2.4 Rehabilitation

The focus of the final key element of the integrated management model for PT was rehabilitation. Article two was combined with article three to achieve this objective (refer to Articles 2; 3). Evidence-based medicine may be defined as an approach in healthcare, using the current most appropriate evidence cautiously to enable decision-making about the healthcare of individual patients. Evidence-based practice assimilates specific clinical knowledge with the best accessible clinical evidence from methodical research. Health professionals combine the art of attending to patients with the finest medical science (Brukner & Khan, 2012:12). A rehabilitation intervention for PT should always follow an evidence-based approach in clinically judging medical staff and athletes' values, while integrating the most appropriate up-to-date evidence into a comprehensive rehabilitation plan (Reinking, 2016:857).

Rehabilitation of PT should be based on three fundamental factors, namely: firstly, the functional abilities of the athlete, secondly, load tolerance and thirdly, an individualised rehabilitation programme. However, load tolerance was more critical than the other two abovementioned components, as load was distinctively responsible for the development of PT, as could be clarified by the mechanical theory (refer to Articles 1 – 3; 2.3.3). These three factors continue to represent the main guidelines throughout the entire rehabilitation programme, and according to Cook *et al*. (2016:1190), load management and exercise still formed the essence of PT rehabilitation. The integrated management model for PT can be optimised by adapting the rehabilitation programme of every individual athlete, due to the heterogeneous clinical appearance of PT in terms of pain and dysfunction. That is why the therapist's clinical reasoning should be individually based (Reinking, 2016:857) in customising an individual rehabilitation programme to suit an athlete's specific needs, and to improve the quality of their life and sports participation after rehabilitation (Brukner & Khan, 2007:174).

The key element of rehabilitation could be divided into additional components, which were indicated in the framework for PT by the e-Delphi survey and discussed in the literature chapter (refer to Article 2; 2.3.2; 2.3.3). The components were: rest from activity in the 1st – 2nd week; cardiovascular training in the 1st – 2nd week; isometric training; eccentric exercise; lower-limb flexibility; hip strengthening; core strengthening; proprioception training; progression of the rehabilitation programme according to response to load; patella strapping or orthosis imported in return-to-sport: sport-specific technique: and return to sports assessment.

The Visual Analog Scale (VAS) and Victorian Institute of Sports Assessment for Patellar Tendinopathy (VISA-P) questionnaires were popular subjective questionnaires utilised in PT rehabilitation (refer to 2.4.1), and a subdivision of the rehabilitation key elements. The clinical value of the VAS in PT was that it could be used to determine athletes' clinical pain and symptoms during the rehabilitation intervention, while providing accurate estimates of pain intensity ratios and percentage change in pain. As the symptoms of PT were difficult to quantify, the VISA-P questionnaire was the only disease-specific questionnaire to assess functionality in PT. It was the only published clinical scale validated for PT in players, where pathology prevented them from playing sport. Both these subjective questionnaires could play a vital role in determining improvement of the pathology. It was important to educate players about the pain provocation test in order to enable them to take self-responsibility for pain monitoring (refer to Article 3; 2.4.1). A practical way of managing pain monitoring would be to keep a daily notebook.

Another entity of the key elements of rehabilitation was education of the coach/trainer in terms of PT pathology and rehabilitation. The trainer's/coach's expectations might actually influence the PT rehabilitation (refer to Article 3). Their expectations could be influenced favourably by means of education regarding PT pathology, including edification of short- and long-term goals: realistic timeframes for the rehabilitation programme; unloading and reloading of the patellar tendon; extrinsic causative risk identification; load management; and athlete and trainer/coach collaboration in planning preventive strategies.

Another key concept and purpose was firstly, to increase the athletes' knowledge regarding PT pathology; the activities which caused PT; PT pain; PT rehabilitation goals; and a PT maintenance programme (Rutland *et al*., 2010:168). A comprehensive explanation of PT pathology would always be a good starting point. Secondly, athletes' education regarding PT symptoms, and advice regarding pain and its possible link to psychosocial factors would be important (refer to 2.2.4; 2.2.6; 2.2.7; 2.2.9). Thirdly, players should be informed that pain in the patellar tendon was not always harmful, and that some pain during rehabilitation could actually be expected and was acceptable (Malliaras *et al.,* 2015:894).

Education regarding especially passive interventions for managing PT, was important, in order to teach players that exercise was the most successful evidenced-base treatment modality for PT, and not manual or electrotherapy physiotherapy modalities (Malliaras *et al.,* 2015:894; refer to Article 1). In addition, athletes' education regarding unrealistic rehabilitation timeframes should also be a priority in managing PT. Malliaras *et al.* (2015:894) agree that this was of particular importance in view of the fact that athletes were keen to return to sport as soon as possible. This matter could be addressed by managing the key element of rehabilitation, namely load tolerance, as progression in all components was linked to the response to load (refer to Article 2; 2.3.21).

A PT maintenance programme following on the treatment intervention was also a necessity and eccentric exercise must be performed at least twice a week with isometric exercise on a regular basis if pain arises. Alternatively, flexibility of the lower limbs and hip strengthening should be a continuous process in PT maintenance (Malliaras *et al*., 2015:893). Another important aspect was to share information about the risk of the of re-occurrence of PT after a period of muscle deconditioning with athletes, for example, during a rest period from training – especially if an athlete had a history of PT, and they returned to sport. This emphasised the importance of the maintenance programme during the off-season (Malliaras *et al*., 2015:893-896; refer to 2.2.9; 2.3.11).

Another valuable tool developed from this research was the PT-Smart Assessment Checklist (see Table 6.1). This tool could be utilised throughout the rehabilitation process, beginning with the initial assessment. The purpose of the PT-Smart Assessment Checklist was to assist therapists in identifying causative risk factors (being either intrinsic or extrinsic) during the assessment, determining the pain and functionality by means of the VAS and VISA-P, and monitoring the athlete's progress by repeating the outcome measurements. The PT-Smart Assessment Checklist was a tailor-made checklist developed from the integrated management model for PT in this study. The PT-Smart Assessment Checklist could be a most valuable tool in remedying PT, especially if the therapist was familiar with using the checklist. It could be seamlessly and practically implemented in the operational context. A strategic plan for the future would be to possibly launch the PT-Smart Assessment checklist to all possible stakeholders in the South African medical community.

Table 6.1: PT-Smart Assessment Checklist

Patellar Tendinopathy (PT)-Smart Assessment Checklist

Name:

Type of Sports Participation:

Intrinsic causative risk factors

- [ ] Increased age
- [ ] Gender (Male > Female)
- [ ] Lower-limb Inflexibility (ITB / Quadriceps/Hamstring muscles)
- [ ] Reduced Quadriceps muscle strength
- [ ] Inferior patella alignment
- [ ] Leg-length discrepancy
- [ ] Lower foot arch height
- [ ] Increased BMI
- [ ] Reduced dorsiflexion

Extrinsic causative risk factors

- [ ] Increased level of sports participation and activity (Elite > Amateur)
- [ ] Type of sport
- [ ] Player position
- [ ] Training on hard surfaces
- [ ] Increased training hours per week
- [ ] Increased number of games per month
- [ ] Increased annual training
- [ ] Participation in additional sports
- [ ] Weight training of five or more hours per week
- [ ] Heavy physical work
- [ ] Increased general load on patellar tendon
- [ ] Increased intensity in sports participation
- [ ] Increased frequency in sports participation
- [ ] Increased duration of sports participation

Outcome measures

VAS	/10
VISA-P	/100
Pain provocation test	/10

Comments:

Source: (Researcher's own construct)

6.2.5 An integrated management model for PT

Resulting from the extensive research conducted, an integrated management model for PT was designed in order to achieve the main purpose of the study. This model is presented in Figure 6.5 – including the three key elements, as well as the sub-components associated with each of the key elements.

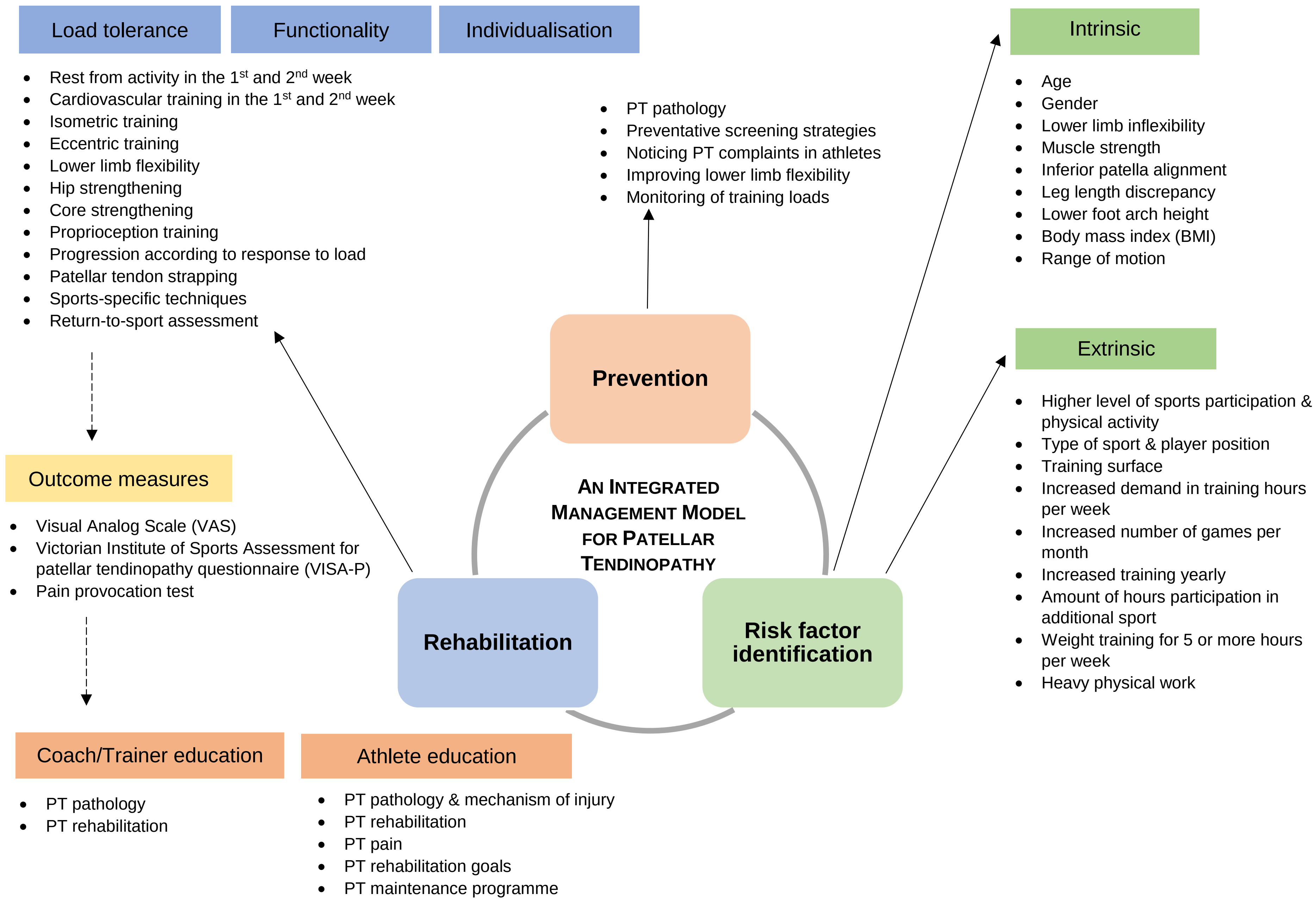

Figure 6.5: An integrated management model for Patellar Tendinopathy

Source: (Researcher's own construct)

6.3 Recommendations

Future treatment of PT should be undertaken in an innovative and extraordinary manner. This study has created a modernistic platform for future research, whereby researchers with a passion for chronic injuries could impart their knowledge and increase the chances of successful outcomes. It was important that the recommendations of any study should be based on realistic and achievable goals regarding PT. Additional clinical research, such as randomised clinical trials, as well as risk factor identification research, would be necessary regarding elite and amateur rugby players suffering from PT. Such research could also be implemented at junior sports participation levels.

In clinical studies, the follow-up period for study participants could possibly be extended from six to 12 months. A further recommendation would be that an amendment could be made to the current study by including elite rugby players from various rugby unions in South Africa. This might implicate and highlight statistical differences among participating teams, which could possibly be explained in terms of training regimes that might impact on the load on the patellar tendon. Another research opportunity would be to utilise the research principles in a diverse sports population of athletes at different levels of sports participation. As there is a paucity of epidemiology data concerning female rugby union players, epidemiology research should be recommended. An additional recommendation would be to monitor training load in athletes with PT by means of a GPS tracking device, which could provide scientific outcome measures to estimate the particular load on the patellar tendon. Ultrasound or MRI diagnosis to determine the stage of PT could also be valuable for future research executed at a similar standard.

Research findings pertaining to the integrated management model for PT could also be used as a basis for providing a strategy for managing tendinopathy in athletes during the competitive season. In future, additional well-designed e-Delphi research, as well as expert knowledge regarding causative risk factors for specific types of sport would be desirable in the field of PT prevention. Another recommendation would be that the e-Delphi survey panel should include more experts and more consecutive rounds to enrich the results even further.

The PT-Smart checklist could also be used as a data capturing method to determine PT prevalence and response to rehabilitation over consecutive seasons, and could be incorporated into a publishable article, thereby increasing the knowledge base of PT. Furthermore, the rehabilitation components of the integrated management model for PT could be used as a basis for further research. Alternatively, the integrated management model could be incorporated seamlessly as a tool to enhance future PT models.

6.4 Limitations

It is important to bear in mind that all research will always have some degree of limitation. Limitations of this study amounted to the following:

- A lack of PT injury surveillance databases for comparative studies on a similar athlete population and at a similar level of participation.
- The limited number of study participants for article three of the research study.
- The relatively short follow-up period of 12 weeks. An extended follow-up period would have shown the re-occurrence rate of PT in athletes.
- The systematic review of article one could have been conducted over a longer inclusion period.

6.5 Conclusion

The integrated management model for PT, which was presented as the overarching outcome of this study, made a novel contribution to the PT knowledge base, as it integrated a number of important aspects in the management of PT, into a single model.

Another major contribution was highlighting the importance of risk factor identification, which could be addressed by means of the PT-Smart Assessment Checklist. This Checklist had the dual purpose of identifying risk factors and of monitoring athletes' progress. The disclosure of load tolerance as the single most important aspect in athlete rehabilitation also contributed to the prevention and management of PT.

The purpose of using the PT-Smart Assessment Checklist was to assist the therapist in identifying the causative risk factors (being either intrinsic or extrinsic) during the assessment, thereby determining the pain and functionality by means of the VAS and

VISA-P, and monitoring the progress of the athlete by repeating the outcome measurements.

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CHAPTER SEVEN: EPILOGUE: "THE SILENT VOICE OF PT MANAGEMENT: PERSPECTIVES FROM A SPORTS TEAM PHYSIOTHERAPIST."

As a physiotherapist with a Master's degree in sports physiotherapy, I am actively involved in sport, having a special interest in team sports – especially rugby union. I was involved in the medical team set-up as a team physiotherapist for almost seven years at one of South Africa's elite provincial rugby unions.

7.1 Introduction

The purpose of this final chapter was for me to reflect on my actions and to scrutinise what had been achieved by me in this study with regard to my desire to improve both personally and professionally. I perceive self-reflection as a measurement of self-development, reflective practice being an educational strategy that includes making sense of one's actions and also being a principle of continuous professional growth. In the modern environment of accountability, it has become essential for physiotherapists to establish evidence-based practice in their occupation. Personal and professional development only becomes effective if critical self-appraisal (through reflection) in terms of analysing and evaluating experiences is done, thereby creating innovative understandings and positive work attitudes in the clinical set-up while interacting with people in general. Currently, a shift towards a holistic approach in managing awareness of psychosocial issues is becoming apparent, including psychology and sociology, within the physiotherapy framework (Ramli *et al.,* 2012:787). The experiential learning cycle, together with the entire structure of debriefing aspects of description, feelings, assessment, analysis, conclusion and action plan (Gibbs, 1988:49) formed the basis of my self-reflection as a sports team physiotherapist in this chapter.

7.2 Description

In recent years, several innovative initiatives have been promoting improvement in the healthcare system (Remme *et al*., 2010:6). This will only be achieved by dedicated, focused and passionate researchers making valuable contributions. For me, research in essence represented a resolute exploration – searching for evidence – identifying problems, obtaining answers and explanations to questions, and searching for general principles of treatment to apply in dissimilar situations for the purpose of controlling the outcomes and predicting the future. Learning (and researching), at any level, was a spontaneous undertaking for me, enriching my mind and skill-set as life unfolded, and I continuously developed as a person. Learning (and knowledge) changes day-by-day and year-by-year, and it is one of my principal aims in life to stay abreast of the most relevant evidence in sports – therefore embracing lifelong learning. This is because, as a physiotherapist, I strive to provide the best possible service and care to my patients.

By its very nature, all types of sport are highly competitive at all levels (Sabato *et al.*, 2016:99) and as a professional sport, rugby union has grown into one of the most popular team sports worldwide. Since the birth of the professional era in rugby union in October 1995, rugby players have become professionals, demanding superior training for strength, speed, power, agility, increased body composition and enhancement of rugby set-play skills (Viljoen *et al.*, 2009:97). Rugby is a contact sport (Kaux *et al.*, 2015:22), which implies that numerous injuries can be associated with its aggressive nature, player positions and level of play (Ras & Puckree, 2014:1346). The prevalence of acute injuries in elite rugby players is significantly higher than in amateur rugby players, which can be justified by the bigger size of elite rugby players, the increased speed of the game and greater impact forces on the players (Viljoen *et al.*, 2009:97). Epidemiological surveys to estimate injury prevalence while partaking in rugby union has been indispensable in identifying the risk factors and in putting preventative strategies in place. The predictive rate of rugby union injuries during matches ranges from 30 to 91, or even 120 per 1000 match hours, with injuries occurring less frequently during training (i.e. 6 per 1000 training hours). The most common injuries sustained in rugby union occur in the lower limbs (Kaux *et al.*, 2015:22), these limbs being the human body's anatomical part with the highest incidence of injuries generally occurring during rugby union matches (30% to 55% of injuries). It must be noted that 14% – 20% of elite players' injuries have been recorded in the knee (refer to 2.1.8), which causes several absent days from rugby. Almost half of all such injuries (55%) are soft tissue injuries with serious consequences (Kaux *et al.*, 2015:22, 26). Musculoskeletal injuries such as these have a tremendous negative impact on elite rugby players, and the nature of injuries with an overload component surpassing the aptitude of regeneration or adaptation of the involved musculoskeletal structures has to be considered as serious (Saragiotto *et al.*, 2013:137). As PT is an overload soft tissue injury of the knee, it is an extremely difficult pathology to manage (refer to 2.2.4; 2.2.7). This pathology continues to be under constant investigation and discussion in the field of sports medicine (Abat & Sanchez-Ibañez, 2014:1). This created a curiosity within me and prompted me to partake in further investigation. Management strategies regarding PT sometimes rely heavily on medical professionals' beliefs rather than actual evidence (Kulig *et al.*, 2015:10), and I therefore planned to generate an evidence-based approach as a rehabilitation intervention in the professional clinical set-up in which I worked.

As a physiotherapist with a Master's degree in sports physiotherapy, I am actively involved in sport, having a special interest in team sports – especially rugby union. I was involved in the medical team set-up as a team physiotherapist at one of South Africa's professional provincial rugby unions for almost seven years. The medical team is usually responsible for the rehabilitation of all elite rugby players and includes the team doctor, physiotherapist, trainers, massage therapists and chiropractors (Kulig *et al.*, 2015:10). Data showing the importance of a team physiotherapist in rugby dates back to the early 1990s, and physiotherapy has become an essential aspect of any sport's medical team (McLean, 1990:19).

The role of a team physiotherapist is to safeguard the rugby player through effective healing time prescription in consultation with the doctor, and to provide effective treatment and rehabilitation of injuries, including guidance for performance during injury prevention, recovery and maintenance programmes (Grant *et al.*, 2014:63). A team physiotherapist is an essential asset to any rugby union coach. He/she will be able to assist with the specific dynamics of the team players on match days, such as muscle activation and recovery. Due to rugby players' intense training and match exposure, and thereby being prone to injuries, a scientific prevention, management and rehabilitation approach, which can be offered by an expert professional such as a physiotherapist, has become essential (McLean, 1990:19; refer to 2.2.11; 2.3.1). Physiotherapists have the necessary skills and knowledge to make an invaluable contribution to any sports team. As a result of all my practical experience as a sports team physiotherapist, I have realised my value as a physiotherapist for both the management team and the players. Physiotherapists often work behind the scenes for long hours, with little appreciation, but remain one of the most important reasons why elite rugby players are able to play each weekend during the competition phase of a tournament. I have often thought how fortunate rugby unions are to have such a valuable asset in their management structures.

I have been involved in the rehabilitation of both elite and junior rugby players for some time, and specifically in their preparation during out-season periods and their management during in-season periods. Acute injuries in rugby are the most frequent type of injuries to be recorded in literature (Kaux *et al.*, 2015:22-23), with chronic injuries being reported on less. This can result in a large number of injuries being misreported (or not reported at all) and misleading statistics on the actual number of injuries sustained. I recognised that acute injuries indeed generally take preference over chronic injuries in the rugby union set-up, but also that chronic injuries can be serious and require lengthy treatment and rehabilitation. As a sports physiotherapist, it appeared to me that an increasing number of elite rugby players were being affected by PT, along with long-standing grievances of players previously diagnosed with. Although injured elite rugby players decrease their training regimes and competitive seasons for prolonged time periods, PT has often ruined their performance levels (Lian *et al.*, 2007:561). I realised that the nature of rugby union games involves a multiplicity of intrinsic and extrinsic causative risk factors for PT (refer 2.2.3; 2.2.5). An example of one of the intrinsic causative risk factors in the lower limbs is decreased flexibility and stiffness (Ogon *et al.*, 2017:146), which results from intensive training, especially running. This risk factor is a reality for elite rugby players during their out-season training, and can result in PT. However, a diversity of factors contributes to PT, and this inspired me to investigate ways of rehabilitating this pathology effectively, in order to obtain a better understanding of the causative risk factors for PT, and the particular association of PT with elite rugby players. I decided that the clinical set-up would be the ideal starting point for my research, and during the planning phase, it took many months to conceptualise the idea.

7.3 Emotions

At times during the rugby union tournament phase, I found myself, as a physiotherapist, becoming occupied with rehabilitating the acute injuries in time for each week's match to such an extent, that I neglected to take notice of the rugby team players who complained about anterior knee pain during, for example, a strapping session. A few weeks afterwards, I would receive a referral letter from the team doctor diagnosing the player with PT, and only then would I realise that players' complaints actually referred to painful patellar tendons. I knew from literature and previous experience that this type of pathology did not just simply go away and heal itself overnight. While continuously having to endure a high training load, the pain just aggravated over time. As yet, there was no evidence to reverse this pathology, and it became important to me to identify it in the early stages. Ultrasound sonars for accurate diagnosis by specialised doctors was always an available option at the rugby union (refer to 2.2.7; 2.2.12). This assisted in determining a starting point for rehabilitation, as well as providing an estimated rehabilitation timeframe to the head coach.

The pre-season training period necessitated strength and, rugby skills training, training camps, unofficial matches and focused, individualised conditioning (Viljoen *et al.*, 2009:98). This training load and the number of rugby competitions were substantial for elite rugby players, who had very little time available for resting and recovering from any injury. The number of pre-season training hours was considerably higher than the in-season training hours, and pre-season training was therefore estimated to cause approximately 38% of all training injuries (Viljoen *et al.*, 2009:100). This injury profile corresponded with literature on the mechanism of injury of PT and extrinsic causative risk factors for PT (refer to 2.2.5; 2.2.6; 2.2.11). This made me realise what a valuable contribution I could make in terms of education and load modification, in collaboration with the coaching staff.

From my experience, I believed that there was a lack of knowledge about PT among elite rugby players. To them, the patellar tendon seemed to be a simple, small structure in the knee which would rehabilitate easily. I thought that they did not realise the serious nature of the pathology and its prognosis, which could result in an early end to their careers (refer to 2.2.4; 2.2.9).

It was a challenge to communicate the seriousness of this pathology to the players and to instil within them the idea that they themselves were ultimately responsible for the wellbeing of their bodies. Often young and vibrant, they thought that they would achieve the highest honours in rugby rapidly. Tragically, it often did not work out the way they had anticipated. I had witnessed patellar tendon ruptures in 20-year-old elite rugby players, who were unprepared for the life-changing experience of progressing into a different career.

In essence, I thought that more should be done to educate elite rugby players about the pathology of PT. This was one of the main reasons why I dedicated myself to learning more about PT – to enable me to share my expertise with the players. I thought that conditioning coaches in particular would share this desire, but I was often disappointed. Management staff made assumptions and needed to make important decisions, but unfortunately they sometimes did not seem to really understand (or wish to understand) the concept brought to their attention. I speculated that their sole purpose was for their team to win trophies, often at the expense of broadening their vision to the possibility that certain training regimes could result in chronic injuries. The conditioning coaches were willing to learn about load modification training, specifically in PT rehabilitation, but in the end, this research will hopefully also benefit elite rugby players and their support staff.

One of the problems I experienced with regard to PT pathology was the management of this pathology during the in-season. As PT had a slow response to any treatment modality, it was unrealistic for the medical team as well as the coaching team to expect a full recovery of in-season rugby players while they were being exposed to extreme loads on the patellar tendon. It was even more frustrating that the coaching staff often anticipated tendons to be fixed quickly and effortlessly, which placed unreasonable pressure on me as the physiotherapist and my medical colleagues. Coaching staff would take note of the healing time of a fracture, muscle strains or ligament, but in the case of tendinopathy, their knowledge and insight were limited (Cook & Purdam, 2013:1). Such situations required a great deal of patience from my side and continuous convincing of the coaching staff as to what was best for the rugby player with PT.

Another aspect that concerned me was that PT could be present in the patellar tendon, but be asymptomatic at any given time (Cook & Purdam, 2013:1), and only present symptoms if the load increases. There was a realistic chance that, once diagnosed, the patellar tendon would already be in the late degenerative stages of the pathology. This problematic fact was due to elite rugby players being placed under constant pressure to perform and consequently not being prepared to acknowledge that they experienced pain in the patellar tendon, while in the early stages of the pathology.

Absence from training and matches could have a serious impact on their careers in terms of financing and emotions (refer to 2.2.4; 2.2.11).

Another major challenge I identified from my experiences in rugby union, was to enable elite rugby players to be competitive without compromising their performance on the field. The only way this could be achieved, was by means of a balanced, integrated management model for PT, where all stakeholders were involved by adding positive contributions. I also discovered that the rugby players were constantly exposed to physical and psychological stressors (Sabato *et al.*, 2016:103) during phase three of the rehabilitation programme. Psychological stress reportedly affects sport performance by tapering rugby players' attention and escalating their self-consciousness. The effect of psychological stress caused muscular tension and instantaneously divulged coordination problems, which increased the risk for injuries. Evidence had shown that negative stress accounted for 31% of the injury inconsistency among those who utilised avoidance-focused coping behaviours, and had insufficient social support and a former history of injuries (Sabato *et al.*, 2016:103). Not only was I able to identify the general stressors, but also the impact of such stressors on the rugby players during their 12-week rehabilitation period. At the end of the rehabilitation programme they were irritated, frustrated and determined to return to the playing field. This type of behaviour was related to the work of Sabato *et al.* (2016:104) that indicated that chronic muscle and joint pain becoming visible in personality changes, impaired concentration, exhaustion, depressive mood states and even anxiety. This might have influenced the results of this study slightly, and an objective outcome measurement, like an ultrasound sonar would perhaps indicate better results in terms of an actual improvement in the patellar tendon condition, following the 12-week rehabilitation intervention.

7.4 Analysis

I now realise that initially, when starting out on my research journey four years ago, I was relatively naïve. I did not estimate the amount of time I would need to spend on my studies correctly. It was a new exciting phase of my life, and I was determined, thankful for the opportunity to be able to study and increase the knowledge databases on PT. Managing PT was, however, a wearisome journey, and I only realised this during the first part of my study. I thought it would be reasonably easy to obtain literature outcomes for this pathology, but I was disappointed. There was no "*golden standard"* for the management of PT (Da Cunha *et al.*, 2012:167), and a variety of possible treatment options, with little evidence to support the outcomes. I realised then that there was still ample evidence to discover about this pathology. The deliverables of the study were to write three articles. This was one of the most difficult and daunting aspects for me, but also very satisfying to accomplish successfully. The data analysis and interpretation required intense and rational thinking, in order to formulate results from the information, which was also quite challenging.

The systematic review was interesting, and I enjoyed writing it, but it was somewhat demanding to express all the different views in a condensed article for approval. During my research, I realised that there were specific areas on the theme with plentiful data, while there was a lack of data in other areas, which confirmed the necessity of my study (refer to Article 1).

Another major hurdle during the execution of this study was the second phase, namely the e-Delphi survey. The most challenging aspect was to elect a suitable panel of experts for the e-Delphi survey, in order to achieve the best outcomes (refer to Article 2). At times, this was a frustrating process, as some experts were slow to react to my emails and questionnaires, and it felt like an unnecessary and tedious process. However, I appreciated and understood that these experts had busy schedules, as they were all professionally involved in global universities and internationally recognised for their expertise – this increased the demand for their time and input from different sources even more. The outcome of the e-Delphi survey was largely satisfactory and fulfilling for me, being able to gather information from and interact with world-class experts in the field of PT. Key authors, whose work I had read during my systematic review, were the ones who had interacted with me on that very theme.

Implementation of the rehabilitation framework in the clinical set-up at the rugby union had its own difficulties (refer to Article 3). The individualised assessments of every player assisted in determining a specific rehabilitation programme for each individual. However, it was challenging not to overlook any key biomechanical aspects and to ensure that the data was captured objectively and correctly. This definitely enhanced my learning experience, but it was difficult to be responsible for the whole process.

This encompassing research journey turned out to be comprehensive in all aspects. It was definitely not an individual voyage, as it involved the time, backing and cooperation of many. It also enhanced my general knowledge, and most especially, my knowledge about PT. The study changed my view about research, as I now understand its overall contribution to and value for evidence practice. In future, I will definitely approach research with a positive and expectant attitude. Furthermore, this research study improved my communication and practical skills in the professional environment, and I have learned to be patient, to believe in myself and to never give up. The entire process and experience has enriched my life, and has been worth the time, effort and sacrifice.

7.5 Conclusion

In retrospect, I would probably have done several things differently. In general, and from a practical perspective, I would have saved and made backups of chapters on a more regular basis. I would have learned to utilise Microsoft Excel to my advantage, compiled an efficient article register and attended a basic statistics refresher course. Distance learning, with the researcher and supervisors in different provinces could have been challenging, but was not impossible. This study also made me realise the importance of fostering quality relationships with experienced medical colleagues in the sports environment, who were willing to share their expertise. I recognised that this comprehensive research process of finding answers to questions and formulating the integrated management model for PT required much dedication and hard work.

7.6 Action plan

If I should continue with post-doctoral research within this field, I would firstly increase the systematic review data base from five to ten years to minimise the exclusion of important information. From a future prospective, I would put education first on the hierarchy of a conventional framework for PT in elite rugby players. The education of rugby players such as these would entail an awareness of PT, as well as a positive and strong-minded attitude in those where the pathology already existed. Their education should encompass the pathology, the pathophysiological variations in the tendon, the rehabilitation plan, and the recurring nature of tendinopathy, which is critical. It is particularly important that elite rugby players recognise that pain in the patellar tendon is not identical to damage within the tendon, but a distinctive reaction in a tendinopathic tendon. A discussion on abnormal movement patterns and the accompanying alteration to it will also be a valuable aspect to consider during education (Kulig *et al.*, 2015:15). Another vision is to educate elite rugby players about the pain provocation test, in order to enable them to self-monitor their pain and to utilise pain inhibition exercises (see 2.2.13).

Secondly, I would educate coaching staff in PT pathology and specifically the principles of unloading of the patellar tendon. Initially, a period of unloading would be necessary (no rugby training). However, the duration of unloading might differ due to various reasons, while continuous rehabilitation is in progress. Conflict will properly exist between the correct unloading and the pressures for a quick return to sport and competition (Kulig *et al.*, 2015:15). A suitable agreement among the members of the management team should be reached, should this be the case. Education can be in the form of an information handout regarding PT.

Thirdly, knowledge about prevention strategies for PT in terms of cautious planning of pre-season training intensity, volumes and frequencies should be enhanced. Supplementary, early intervention strategies of diagnosing PT (Cook & Purdam, 2013:5), either asymptomatic, or symptomatic can also be beneficial.

There are still plenty of unanswered questions within the field of PT, but by continuously researching and staying inquisitive, researchers will hopefully be able to provide answers and proposals in the sports milieu. After completing this study, I had many ideas for further research opportunities. Through all the groundwork and planning, exploring new things, frustration and satisfaction, I realised that perseverance was a key aspect of the final destination. Ultimately, it improved my knowledge, augmented my physiotherapy skills and extended my boundaries. It was a great learning curve!

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ANNEXURE A: UFS HSREC ETHICAL APPROVAL LETTER

IRB nr 00006240
REC Reference nr 230408-011
IORG0005187
FWA00012784

11 November 2015

MRS M MORGAN
DEPARTMENT OF PHYSIOTHERAPY
CR DE WET BUILDING
UFS

Dear Mrs Morgan

ECUFS NR 181/2015
PROJECT TITLE: THE INTEGRATED MANAGEMENT MODEL FOR PATELLAR TENDINOPATHY

1. You are hereby kindly informed that, at the meeting held on 10 November 2015, the Ethics Committee approved the following project after all conditions have been met, when the signed permission letter from the Free State Rugby Union was submitted.

2. The Committee must be informed of any serious adverse event and/or termination of the study.

3. Any amendment, extension or other modifications to the protocol must be submitted to the Ethics Committee for approval.

4. A progress report should be submitted within one year of approval of long term studies and a final report at completion of both short term and long term studies.

5. Kindly use the ECUFS NR as reference in correspondence to the Ethics Committee Secretariat.

6. The Ethics Committee functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite), Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the Ethics Committee of the Faculty of Health Sciences.

Yours faithfully

....
DR SM LE GRANGE
CHAIR: ETHICS COMMITTEE

Cc: Dr EC Janse van Vuuren

Ethics Committee
Office of the Dean: Health Sciences
T: +27 (0)51 401 7795/7794 | F: +27 (0)51 444 4359 | E: ethicsfhs@ufs.ac.za
Block D, Dean's Division, Room D104 | P.O. Box/Posbus 339 (Internal Post Box G40) | Bloemfontein 9300 | South Africa
www.ufs.ac.za

ANNEXURE B: UFS HSREC ETHICAL APPROVAL LETTER AMENDMENT ONE

IRB nr 00006240
REC Reference nr 230408-011
IORG0005187
FWA00012784

01 February 2017

MRS S MORGAN
DEPT OF PHYSIOTHERAPY
FACULTY OF HEALTH SCIENCES
UFS

Dear Ms Morgan

ECUFS 181/2015
PROJECT TITLE: THE INTEGRATED MANAGEMENT MODEL FOR PATELLAR TENDINOPATHY

1. You are hereby kindly informed that the Health Sciences Research Ethics Committee (HSREC) took note and approved the following at the meeting held on 31 January 2017:

   - *The applicable questionnaires that were described in approved protocol, have been formulated from the data obtained in phase 1 and phase 2 of the study*
   - *Extension of rehabilitation period of athletes from 6-12 weeks*
   - *VAS, VISA-P and questionnaire to participants for phase 3 of the study*

2. Kindly use the **ECUFS NR** as reference in correspondence to HSREC Administration.

3. The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite), Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the Ethics Committee of the Faculty of Health Sciences.

Yours faithfully

....
DR SM LE GRANGE
CHAIR: HEALTH SCIENCES RESEARCH ETHICS COMMITTEE

ANNEXURE C: UFS HSREC ETHICAL APPROVAL LETTER AMENDMENT TWO

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS·UV
HEALTH SCIENCES
GESONDHEIDSWETENSKAPPE

IRB nr 00006240
REC Reference nr 230408-011
IORG0005187
FWA00012784

25 May 2016

MRS S MORGAN
DEPT OF PHYSIOTHERAPY
FACULTY OF HEALTH SCIENCIES
UFS

Dear Mrs S Morgan

ECUFS NR 181/2015
DEPARTMENT OF PHYSIOTHERAPY
PROJECT TITLE: THE INTEGRATED MANAGEMENT MODEL FOR PATELLAR TENDINOPATHY

1. You are hereby kindly informed that, at the meeting held on 24 May 2016, the Health Sciences Research Ethics Committee (HSREC) approved the following:

   - *Amendment of selection of experts for the Delhi panel*
   - *Amended criteria for the Delphi panel*
   - *Delphi questionnaire for Round 1 of the Delphi survey.*

2. The HSREC functions in compliance with, but not limited to, the following documents and guidelines: The SA National Health Act. No. 61 of 2003; Ethics in Health Research: Principles, Structures and Processes (2015); SA GCP(2006); Declaration of Helsinki; The Belmont Report; The US Office of Human Research Protections 45 CFR 461 (for non-exempt research with human participants conducted or supported by the US Department of Health and Human Services- (HHS), 21 CFR 50, 21 CFR 56; CIOMS; ICH-GCP-E6 Sections 1-4; The International Conference on Harmonization and Technical Requirements for Registration of Pharmaceuticals for Human Use (ICH Tripartite), Guidelines of the SA Medicines Control Council as well as Laws and Regulations with regard to the Control of Medicines, Constitution of the HSREC of the Faculty of Health Sciences.

Yours faithfully

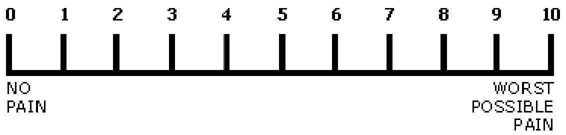
....

PROF WJ STEINBERG
VICE CHAIR: HEALTH SCIENCES RESEARCH ETHICS COMMITTEE

ANNEXURE D: VISUAL ANALOG SCALE (VAS)

Visual Analog Scale (VAS) Questionnaire

Figure 1: Visual Analog Scale



The visual analog scale consists of a horisontal line , with numbers ranging from 0 - 10. Please "cross" the approppriote number to describe your level of pain

Thank you for your participation in this study

For Official Use

Participant number

1-2

3-4

ANNEXURE E: VICTORIAN INSTITUTE OF SPORTS ASSESSMENT (VISA-P) QUESTIONNAIRE FOR PATELLAR TENDINOPATHY

Victorian Institute of Sports Assessment (VISA-P) questionnaire for Patellar Tendinopathy

For official use only

Please mark the appropriote answer in the block provided with a "x"

Participant number

[ ]

1. For how many minutes can you sit pain free?

0 min [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] 100 min
1 2 3 4 5 6 7 8 9 10

Points [ ]

2. Do you have pain walking downstairs with a normal gait cycle?

Strong severe pain [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] No pain
1 2 3 4 5 6 7 8 9 10

Points [ ]

3. Do you have pain at the knee with full active non-weight-bearing knee extension?

Strong severe pain [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] No pain
1 2 3 4 5 6 7 8 9 10

Points [ ]

4. Do you have pain when doing a full weight-bearing lunge?

Strong severe pain [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] No pain
1 2 3 4 5 6 7 8 9 10

Points [ ]

5. Do you have problems squatting?

Unable [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] No problem
1 2 3 4 5 6 7 8 9 10

Points [ ]

6. Do you have pain during or immediately after doing 10 single leg hops?

Strong severe pain/ unable [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] [ ] No pain
1 2 3 4 5 6 7 8 9 10

Points [ ]

7. Are you currently undertaking sport or other physical activity?

[ ] 0 Not at all
[ ] 4 Modified training +/- modified competition
[ ] 7 Full training +/- competition but not at same level as when symptoms began
[ ] 10 Competing at the same or higher level as when symptoms began

Points [ ]

8. Please complete *EITHER* A, B or C in this question
» If you have no pain while undertaking sport please complete Q8A only
» If you have pain while undertaking sport but it does not stop you from completing the activity, please complete Q8B only
» If you have pain that stops you from completing sporting activities, please complete Q8C only

A. If you have no pain while undertaking sport, for how long can you train / practise?

0 min	1-5 min	6-10 min	11-15 min	15 › min
[ ]	[ ]	[ ]	[ ]	[ ]
0	7	14	21	30

Points [ ]

OR

B. If you have some pain while undertaking sport, but it does not stop you from completing your training / practise, for how long can you train / practise?

0 min	1-5 min	6-10 min	11-15 min	15 › min
☐	☐	☐	☐	☐
0	4	10	14	20

Points ☐

OR

C. If you have pain that stops you from completing your training / practise, for how long can you train / practise?

0 min	1-5 min	6-10 min	11-15 min	15 › min
☐	☐	☐	☐	☐
0	2	5	7	10

Points ☐

Total score ☐ 100

Thank you for your participation in this study

ANNEXURE F: REQUEST TO EXPERTS FOR PARTICIPATION IN AN E-DELPHI SURVEY

Request to Experts for Participation in an e-Delphi Survey

I am a qualified physiotherapist, specialising in Sports Physiotherapy for the past nine years. I have a Master's degree in Sports Physiotherapy and currently busy completing my Doctoral degree at the University of the Free State. A research project forms part of this Doctoral study and since my interest lies in sports, the research will also be carried out in this field. The title of my research study is*: An Integrated Management Model for Patellar Tendinopathy.*

My supervisors are:

Promotor: Doctor E.C Janse van Vuuren
Teaching and Learning manager: Economic and Management Science
Phone: 051 401 3691
Email: JanseVanVuurenEC@ufs.ac.za

Co-promotor: Professor F. Coetzee
Adjunct Professor and Head of Department: Exercise and Sport Science
Faculty: Health Science
P.O. Box 339
Bloemfontein
9300
Republic of South Africa
Phone: 051 401 2323
Email: coetzeef@ufs.ac.za

Firstly, a Systematic Review will be piloted on the causative risk factors and rehabilitation for patellar tendinopathy. Secondly, an e-Delphi survey will be conducted to obtain valued opinions from a panel of experts regarding a rehabilitation framework for patellar tendinopathy. Lastly, this framework will be implemented in the clinical set-up on elite rugby players. It will be used to formulate a specific integrated management model for patellar tendinopathy.

Value of the research study

Research in the field of sport forms an enormous part in the development of novel evidence-based assessment, diagnosis and treatment of pathologies. Regardless of the outcome of this research study, it can provide information regarding the causative risk factors, rehabilitation and an integrated management model for patellar tendinopathy to sports medical personnel. The data that is obtained from this research study can be used to contribute to the existing knowledge pool in South Africa, by means of publications.

You have been selected according to predetermined criteria, as having expert knowledge and experience in the field of patellar tendinopathy research. I therefore request your co-operation by consenting to be included in the e-Delphi panel of experts. I am aware that time is a valuable commodity. Completion of the first e-Delphi questionnaire will take approximately 60 minutes, and the follow-up of two or three rounds of questionnaires will take approximately 30 minutes each. The e-Delphi survey and other relevant information will be sent to you via email. Should you have any questions regarding the study, please feel free to contact me:

Cellular phone: 072 912 1744

Email address: duplessis.sanell@gmail.com

Postal address: P.O. Box 1537
Noordheuwel
1756
South Africa

or

Secretary of the Ethics Committee of the Faculty of Health Science, University of the Free State

Telephone number +27 51 405 2812

The different rounds of the e-Delphi survey are scheduled to take place during the period from March to July 2016. The information collected in this e-Delphi survey will be treated in a confidential manner and there will be no references to any names of participants in the presentation of the data. Please be advised that the outcomes of this research study will be published. Participation in the study is voluntary and the participants may withdraw from the study at any time. The participants will not be remunerated for their participation and no expenses will be payable by participants.

Thank you for your time.

Sincerely,

Sanell Morgan

Sports Physiotherapist

UFS registered project 181/2015

ANNEXURE G: INFORMATION DOCUMENT TO THE E-DELPHI EXPERT PANEL

Information document to the e-Delphi expert panel

Dear Colleague

Thank you for agreeing to participate in this e-Delphi survey process of the integrated management model for patellar tendinopathy. Attached please find the first-round e-Delphi questionnaire. Your time and sharing of your expertise is much appreciated.

Questionnaire

Each question or statement in the questionnaire must be evaluated according to your perceived importance thereof as it forms part of the research of the integrated management model for patellar tendinopathy. The data will be captured by means of a semi-structured online questionnaire and Surveymonkey™ software will be used. Questions included in the questionnaire for round one of the e-Delphi survey will be based on the data collected in the prior systematic review. The questionnaire will only be available online with a deadline set and a reminder email will be sent weekly. The option to save the data will be available should you wish to review the answers before final submission. The questionnaires for rounds one and two will consist of a three point Likert scale (agree/partially agree/disagree). It will be followed by an open-ended question at the end of each section whereby additional comments or suggestions can be given. The questionnaire will include four sections, namely i) establishing the components of a PT rehabilitation programme; ii) establishing the suggested basis of decision-making on components of a PT rehabilitation programme; iii) inclusion of components in the PT rehabilitation based on a time-based approach; and iv) inclusion of components in the PT rehabilitation based on a pain-based approach. The results of round one will be used for the development of the questionnaire for round two. Questions on which consensus are reached will be indicated as such in the next questionnaire. If consensus is not reached, the question will be included in the following round for further consideration.

Procedure of the e-Delphi survey

Your opinion as expert panellist is requested for each individual question and to provide additional comments. All the information and your opinions will be treated as strictly confidential. Please note that no panellist will know the identity of any other panellist. The researcher and supervisors alone will know the identity of the panellists. You are also requested to keep all information regarding the research and questionnaire confidential during the entire e-Delphi survey, as the research process may be thus contaminated. Response and feedback will be provided to all panellists after each round of questions. Please answer all the questions in all sections.

The questionnaire in this round should take approximately one hour of your time. Subsequent questionnaires should be considerably shorter. Please contact me in the event of any questions or uncertainties.

Please return the completed questionnaire to me by 30 March 2016. My contact details are as follows:

Cell:	072 912 1744
Fax:	012 420 0956
Email address:	duplessis.sanell@gmail.com
Postal address:	P.O. Box 1537
	Noordheuwel
	1756
	South Africa

Thank you once again for your support and contribution in the integrated management model for patellar tendinopathy.

Sanell Morgan

Sports Physiotherapist

UFS registered project 181/2015

ANNEXURE H: E-DELPHI QUESTIONNAIRE (ROUND ONE)

e-Delphi Questionnaire Round One

Aim 1: Establishing the components of a PT rehabilitation programme
Give your opinion with regard to the inclusion of the following components in the OVERALL rehabilitation programme for PT

1. Rest from any activity

- ○ Agree
- ○ Partial agree
- ○ Disagree

2. Eccentric training

- ○ Agree
- ○ Partial agree
- ○ Disagree

3. Lower limb stretching

- ○ Agree
- ○ Partial agree
- ○ Disagree

4. Core strengthening

- ○ Agree
- ○ Partial agree
- ○ Disagree

5. Hip strengthening

- ○ Agree
- ○ Partial agree
- ○ Disagree

6. Proprioception training

◯ Agree

◯ Partial agree

◯ Disagree

7. Cardiovascular training

◯ Agree

◯ Partial agree

◯ Disagree

8. Plyometric training

◯ Agree

◯ Partial agree

◯ Disagree

9. Sport-specific skills training

◯ Agree

◯ Partial agree

◯ Disagree

10. Return to sport assessment

◯ Agree

◯ Partial agree

◯ Disagree

11. Name any other aspects not mentioned above that should be included in the PT rehabilitation programme

12. Any other comments or suggestions

Aim 2: Establishing the suggested basis of decision-making on components of a PT rehabilitation programme
(Weeks 1 - 12)
Give your opinion with regards to the decision-making on the inclusion of the following components in the OVERALL rehabilitation programme of PT

13. Inclusion of different components based on TIME post-injury (i.e.week 1,2,3, etc)

- ○ Agree
- ○ Partial agree
- ○ Disagree

14. Inclusion of different components based on PAIN experience

- ○ Agree
- ○ Partial agree
- ○ Disagree

15. Inclusion of different components based on FUNCTIONAL abilities

- ○ Agree
- ○ Partial agree
- ○ Disagree

16. Name any other aspects considered when deciding on the inclusion of different components in a PT rehabilitation programme

17. Any other comments or suggestions

Aim 3: Establishing the suggested format of a PT rehabilitation programme (Weeks 1 - 12)
Give your opinion with regard to the decision-making on the inclusion of the following components in the rehabilitation programme of PT should a <u>TIME-BASED</u> approach be followed

Please indicate in which week you would commence with which type of activity (if applicable) when utilising a <u>TIME-BASED</u> approach

18. Rest from activity

- [ ] Week 1 - 2
- [ ] Week 2 - 4
- [ ] Week 4 - 6
- [ ] Week 6 - 8
- [ ] Week 10 - 12

19. Eccentric training

- [ ] Week 1 - 2
- [ ] Week 2 - 4
- [ ] Week 4 - 6
- [ ] Week 6 - 8
- [ ] Week 8 - 10
- [ ] Week 10 - 12

20. Lower limb stretching

- [ ] Week 1 - 2
- [ ] Week 2 - 4
- [ ] Week 4 - 6
- [ ] Week 6 - 8
- [ ] Week 8 - 10
- [ ] Week 10 -12

21. Core strengthening

- [ ] Week 1 - 2
- [ ] Week 2 - 4
- [ ] Week 4 - 6
- [ ] Week 6 - 8
- [ ] Week 8 - 10
- [ ] Week 10 - 12

22. Hip strengthening

- [ ] Week 1 -2
- [ ] Week 2 -4
- [ ] Week 4 - 6
- [ ] Week 6 - 8
- [ ] Week 8 - 10
- [ ] Week 10 - 12

23. Proprioception training

- [ ] Week 1 - 2
- [ ] Week 2 - 4
- [ ] Week 4 - 6
- [ ] Week 6 - 8
- [ ] Week 8 - 10
- [ ] Week 10 -12

24. Cardiovascular training

- [ ] Week 1 - 2
- [ ] Week 2 - 4
- [ ] Week 4 - 6
- [ ] Week 6 - 8
- [ ] Week 8 - 10
- [ ] Week 10 - 12

25. Plyometric training

- [ ] Week 1 - 2
- [ ] Week 2 - 4
- [ ] Week 4 - 6
- [ ] Week 6 - 8
- [ ] Week 8 - 10
- [ ] Week 10 - 12

26. Sport-specific skills training

- [ ] Week 1 - 2
- [ ] Week 2 - 4
- [ ] Week 4 - 6
- [ ] Week 6 - 8
- [ ] Week 8 - 10
- [ ] Week 10 - 12

27. Return to sport assessment

- [ ] Week 1 - 2
- [ ] Week 2 - 4
- [ ] Week 4 - 6
- [ ] Week 6 - 8
- [ ] Week 8 - 10
- [ ] Week 10 - 12

28. Any other comments or suggestions for using a TIME-BASED approach when compiling a PT rehabilitation programme

Give your opinion with regard to the decision-making on the inclusion of the following components in the rehabilitation programme of PT should a PAIN-BASED approach be followed

Pain (Visual Analog Scale) 1, 2, 3, 4, 5, 6, 7, 8, 9,10

Indicate the level of pain (on the VAS) that would be allowed when conducting the following type of activities

29. Rest from any activity

- VAS between 1 - 3
- VAS between 3 - 5
- VAS between 5 - 7
- VAS between 7 - 9
- VAS 10

30. Eccentric training

- VAS between 1 - 3
- VAS between 3 - 5
- VAS between 5 - 7
- VAS between 7 - 9
- VAS 10

31. Lower limb stretching

- VAS between 1 - 3
- VAS between 3 - 5
- VAS between 5 - 7
- VAS between 7 - 9
- VAS 10

32. Core strengthening

- VAS between 1 - 3
- VAS between 3 - 5
- VAS between 5 - 7
- VAS between 7 - 9
- VAS 10

33. Hip strengthening

- VAS between 1 - 3
- VAS between 3 - 5
- VAS between 5 - 7
- VAS between 7 - 9
- VAS 10

34. Proprioception training

- VAS between 1 - 3
- VAS between 3 - 5
- VAS between 5 - 7
- VAS between 7 - 9
- VAS 10

35. Cardiovascular training

- VAS between 1 - 3
- VAS between 3 - 5
- VAS between 5 - 7
- VAS between 7 - 9
- VAS 10

36. Plyometric training

- VAS between 1 - 3
- VAS between 3 - 5
- VAS between 5 - 7
- VAS between 7 - 9
- VAS 10

37. Sport-specific skills training

- VAS between 1 - 3
- VAS between 3 - 5
- VAS between 5 - 7
- VAS between 7 - 9
- VAS 10

38. Return to sport assessment

- VAS between 1 - 3
- VAS between 3 - 5
- VAS between 5 - 7
- VAS between 7 - 9
- VAS 10

39. Any other comments or suggestions for using a PAIN-BASED approach when compiling a PT rehabilitation programme

ANNEXURE I: E-DELPHI QUESTIONNAIRE (ROUND TWO)

e-Delphi Questionnaire Round Two

Aim 1: Establishing the components of a PT rehabilitation programme

Give your opinion with regard to the inclusion of the following components in the <u>OVERALL</u> rehabilitation programme for PT

1. Rest from activity and monitor the pain

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

2. A patella tendinopathy (PT) rehabilitation program should comprise of eccentric training, core and hip strengthening, lower limb stretching, proprioceptive retraining, plyometric and sport specific skills

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

3. Lower limb stretching with the focus on Quadriceps and Hamstring muscles

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

4. Core strengthening with the focus on deep core muscles (Transverse abdominus)

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

5. Hip strengthening with the focus on Hip abductors (Gluteus medius muscle)

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

6. Proprioception training with the focus on a single leg weight bearing exercise

- Agree
- Partial agree
- Disagree

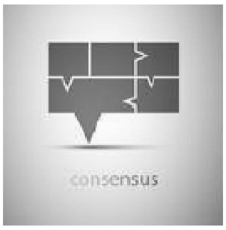
7. Cardiovascular training with the focus on exercises with little knee movement for example swimming or cycling

- Agree
- Partial agree
- Disagree

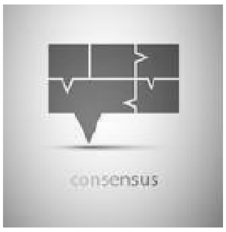
8. Plyometric training with essential focus that the technique is executed correctly

- Agree
- Partial agree
- Disagree

Sport-specific skills training



Return to sport assessment



9. Any other comments or suggestions

Aim 2: Establishing the suggested basis of decision-making on components of a PT rehabilitation programme
(Weeks 1 - 12)
Give your opinion with regards to the decision-making on the inclusion of the following components in the OVERALL rehabilitation programme of PT

10. Inclusion of different components in the rehabilitation of Patella Tendinopathy is mainly based on FUNCTION, with some consideration of TIME post-injury in certain cases

◯ Agree

◯ Partial agree

◯ Disagree

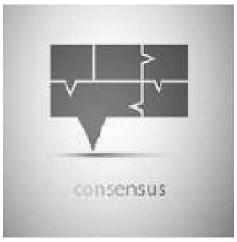
11. Inclusion of different components in the rehabilitation of Patella Tendinopathy is mainly based on FUNCTION, with some consideration of PAIN post-injury in certain cases

◯ Agree

◯ Partial agree

◯ Disagree

Inclusion of different components ARE based on FUNCTIONAL abilities



12. Any other comments or suggestions

Aim 3: Establishing the suggested format of a PT rehabilitation programme (Weeks 1 - 12)
Give your opinion with regard to the decision-making on the inclusion of the following components in the rehabilitation programme of PT should a time-based approach be followed

Rest from activity

13. Some form of knee eccentric training (for example in isolation or combination with other techniques) from week 2

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

Lower limb stretching (week 1-2)

Core strengthening (week 1-2)

Hip strengthening (week 1-2)

Proprioception training (week 2-4)

Cardiovascular training (week 1-2)

Plyometric training (week 8-12)

14. Sport-specific skills training starting in week 4 and progress to week 12 by re-assessing every week if progression is appropriate

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

15. Return to sport after an individual functional assessment between week 8-12

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

16. Any other comments or suggestions

Give your opinion with regard to the decision-making on the inclusion of the following components in the rehabilitation programme of PT should a PAIN-BASED approach be followed

17. Rest from any activity that cause pain but continue with functional activities

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

18. Eccentric training with the focus on functional ability rather than pain

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

19. Lower limb stretching can commence if low levels of pain is experienced

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

20. Core strengthening can commence if low levels of pain is experienced

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

21. Hip strengthening can commence if low levels of pain is experienced

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

22. Proprioceptive training can commence if low levels of pain is experienced during functional proprioceptive training

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

23. Cardiovascular training can commence within low levels of pain

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

24. Plyometric training must be within limits of pain levels and monitored during functional activities

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

Sport-specific skills training (VAS between 1 and 3)

Return to sport assessment (VAS between 1 and 3)

25. Any other comments or suggestions

General questions

26. The rehabilitation is different during the OUT-season and In-season training

- ◯ Agree
- ◯ Partial Agree
- ◯ Disagree

27. Patella tendon strapping is important during the rehabilitation and return to sport

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

28. Progression of the rehabilitation program must be according to response to load

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

29. Athletes specific individual needs must be addressed during rehabilitation

- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

30. The trainer or coach expectations influence the rehabilitation

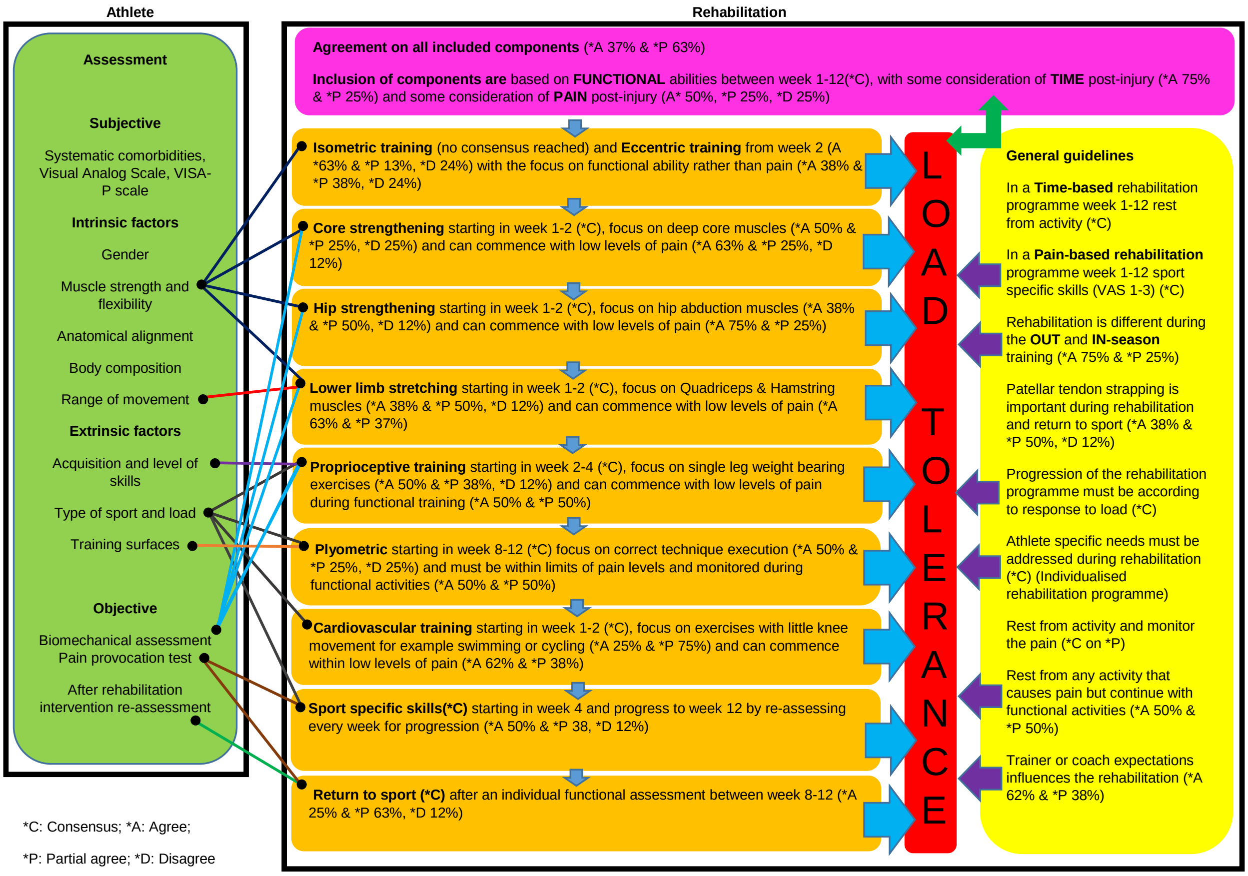
- ◯ Agree
- ◯ Partial agree
- ◯ Disagree

31. According to the consensus statements it reveals that there is a lack of information regarding the modalities utilised between rest, cardiovascular exercises, strengthening, proprioceptive training, plyometric and sport specific exercises. Can you recommend any suggestions?

ANNEXURE J: E-DELPHI MODEL (ROUND THREE)

e-Delphi Model Round Three

Rehabilitation model of Patellar Tendinopathy



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ANNEXURE K: INFORMATION DOCUMENT TO THE RUGBY UNION MEDICAL MANAGER

Information Document to the Rugby Union Medical Manager

Information document regarding the research project rugby to medical manager

I am a qualified physiotherapist with a Master's degree in Sports Physiotherapy and am currently busy completing my Doctoral degree at the University of the Free State. A research project forms part of this Doctoral study, and since my interests lie in sports, the research will also be carried out in this field. This research aims to compile an integrated management model for patellar tendinopathy.

The study will be completed in Pretoria, Gauteng. It involves the collection of information from elite rugby players with patellar tendinopathy. It will be presented in English. The participation of the elite rugby players implies the following:

- A research intervention which will run over 12-weeks. Subjective questionnaires will be completed and objective tests will be performed. This will follow an exercise program for the full duration of the research period to strengthen the patellar tendon.
- Their participation in this research study is completely voluntary.
- They will not receive remuneration for participating in the research study and it will be at no cost to them.
- Confidentiality will be maintained at all times.
- No elite rugby player will be implied in the description of the data.
- The research study was approved by the Ethics Committee of the University of the Free State *(UFS registered project 181/2015).*
- The data compiled from this study could, at the completion of the study, be made available to the involved sports medical personnel.
- The study will be published in a peer-reviewed journal.
- The researcher is covered by insurance if any complaint from the study participants arise. Insurance policy: SASP membership: MOR055

Your permission to include the elite rugby players will be greatly appreciated.

For any queries regarding the study, you may gladly contact me.

Kind regards

Sanell Morgan

Cell: 072 912 1744

Email: duplessis.sanell@gmail.com

ANNEXURE L: INFORMED CONSENT FROM THE RUGBY UNION MEDICAL MANAGER

Informed Consent from the Rugby Union Medical Manager

Informed consent rugby medical manager

The rugby medical manager are cordially informed that elite rugby players will take part in the research project dealing with the integrated management model for patellar tendinopathy.

The rugby medical manager have been verbally informed about the research project by the researcher, as well as by an information sheet regarding the research.

The rugby medical manager may contact the researcher at any time on cellular number +27 72 912 1944 or email duplessis.sanell@gmail.com if they have any concerns or questions.

Additionally, you may contact the Secretary of the Ethics Committee of the Health Science Faculty at the University of the Free State at telephone number +27 51 405 2812 for any concerns or questions about the rights the elite rugby players.

As the rugby medical manager, I understand that all information will be kept confidential at all times. I also understand that the elite rugby players participation is voluntary, and that they can withdraw from the research project at any time without any penalties. Additionally, I am aware that there will be no financial compensation for the elite rugby players to participate in the research study.

Should you agree to this, a copy of this document as well as the information letter regarding the research study will be given to you.

The research project, as well as the above mentioned information, has been verbally explained to me and I understand the involvement of the elite rugby players in this study and I voluntarily give my consent.

____

Signature of rugby medical manager

ANNEXURE M: INFORMATION DOCUMENT TO STUDY PARTICIPANTS

Information Document to Study Participants

Information document with respect to the research project Study Participants

I am a qualified physiotherapist with a Master's degree in Sports Physiotherapy and am currently busy completing my Doctoral degree at the University of the Free State. A research project forms part of this Doctoral study, and since my interests lie in sports, the research will also be carried out in this field. This research aims to compile an integrated management model for patellar tendinopathy.

Patellar tendinopathy refers to pain, swelling and reduced activity in the knee and is a common pathology in elite and amateur sport participants. This affects an athlete involved in repeated explosive knee extension or eccentric flexion of the knee such as hopping and jumping. This type of activity overloads the patellar tendon and leads to micro trauma in the tendon. Patellar tendinopathy is a multi-dimensional pathology caused by various factors such as age, reduced muscle flexibility of hamstrings and quadriceps, obesity, limited muscle strength, anterior patella tilt, excessive pronation or supination of the feet, high exercise volume and frequency as well as the hardness of the ground on which the exercises are carried out. It is a pathology treated commonly by sport physicians and physiotherapists at medical sports centres and remains a challenge. Consequently, this research focuses on expanding the current databases and ultimately contributing to the successful treatment of this condition.

The study will be completed in Pretoria, Gauteng. It involves the collection of information from elite rugby players with patellar tendinopathy. It will be presented in English. Your participation in the research study implies the following:

The research intervention duration will be 12-weeks. Firstly, before the intervention, a meeting between you and the researcher will be arranged at a specific venue. The venue will be the same meeting place for the full intervention. The appointment will last one hour and it will be during the week. You will be verbally informed by the researcher about the research study as well as receiving an information letter regarding the research study. Additionally, a letter of informed consent will be provided to you. You will complete the applicable questionnaires and the EMG test for the Quadriceps muscle activation. Weight and height measurement will also be taken. The exercises will be explained and demonstrated by the researcher herself. During the intervention time phase, you will be followed-up in person by the researcher three times a week for 30 minutes for the full duration of the research period at a suitable time to you. On the last meeting in week 12, questionnaires will be completed and the EMG test will be repeated. After the intervention, you can return to your specific physiotherapist, biokineticist or medical personnel that treated you before the intervention and they can continue with the rehabilitation program.

- Your participation in this research study is completely voluntary.
- You will receive no remuneration and participating in the research study will be at no cost to you.
- Confidentiality will be maintained at all times.
- No study participant will be implied in the description of the data.
- The research study was approved by the Ethics Committee of the University of the Free State *(UFS registered project 181/2015***)**.
- The data compiled from this study could, at the completion of the study, be made available to the involved sports medical personnel.
- The study may possibly be published in a peer-reviewed journal.

Your participation in this research study will be greatly appreciated.

For any queries regarding the study, you may gladly contact me.

Kind regards

Sanell Morgan
Cell: 072 912 1744
Email: duplessis.sanell@gmail.com

ANNEXURE N: INFORMED CONSENT FOR STUDY PARTICIPANTS

Informed Consent for Study Participants

Informed consent of study participants

You are cordially informed to take part in the research project pertaining to the integrated management model for patellar tendinopathy.

You have been verbally informed about the research project by the researcher, as well as by an information sheet regarding the research.

You may contact the research at any time on cellular number +27 72 912 1944 or email duplessis.sanell@gmail.com if you have any concerns or questions.

Additionally, you may contact the Secretary of the Ethics Committee of the Health Science Faculty at the University of the Free State at telephone number +27 51 405 2812 for any concerns or questions regarding your rights as a study participant.

I, as study participant, understand that all information will be kept confidential at all times. I also understand that my participation is voluntary, and that I can withdraw from the research project at any time without any penalties. Additionally, I am aware that no financial compensation will be received for my participation

Should you agree to participate in this research project, a copy of this document as well as the information letter given to you will be provided.

The research project, as well as the above mentioned information, has been verbally explained to me and I understand my involvement in this study and voluntarily give my consent to participate.

____

Signature of study participant

ANNEXURE O: QUESTIONNAIRE TO STUDY PARTICIPANTS

Questionnaire to study participants

For official use only

Participant Number [ ][ ][ ] 1 - 3

Please answer the questions by placing an 'x' in the appropriate block or complete the answer in the space provided

Section 1: Demographic information

1. Age __________ years — [ ][ ] 4 - 5

2. Weight __________ kg — [ ][ ][ ] 6 - 8

3. Length ___________ cm — [ ][ ][ ] 9 - 11

BMI __________% — [ ][ ][ ] 12 - 14

Section 2: Injury pattern of Patellar Tendinopathy

4. Player position in rugby — [ ] 15

Forward player	
Backline player	

5. Does the injury affect your dominant or non-dominant limb? — [ ] 16

Dominant	
Non-dominant	

6. For how long have you been experiencing pain in your patellar tendon? — [ ] 15

1 - 2 weeks	
2- 4 weeks	
4 - 8 weeks	
8 - 12 weeks	
3 months or more	
More than 6 months	

7. Is this a new or reoccurring injury? — [ ] 17

New injury	
Reoccurring injury	

8. Which activities or actions causes the symptoms?

Jumps / hops on one leg		18
Running / Jogging		19
Change of direction activities		20
Intensive training regime		21
Other		22

9. If "other", please specify

____ 23-24

____

____

10. Was the onset of symptoms gradual? 25

Yes	
No	

Section 3: Load tolerance

11. Does an increase in intensity during training aggravate your Patellar Tendinopathy? 26

Yes	
No	

12. Does more frequent training aggravate your Patellar Tendinopathy? 27

Yes	
No	

13. Does an increase in duration of training aggravate your Patellar Tendinopathy? 28

Yes	
No	

Section 4: Sport participation

14. What is your highest level of participation? 29

International	
National	
Provincial	

Thank you for your participation in this study

ANNEXURE P: LETTER OF ACKNOWLEDGEMENT: LANGUAGE EDITING

Letter of Acknowledgement: Language Editing

Acknowledgement of Language Review and Reference Editing

Date: 21 June 2017

To whom it may concern

This serves to confirm that I performed the tasks of *language review and reference editing* for *Sanell Morgan* on her PhD Thesis (Chapters 1 – 2, 6 – 7, entitled: *An Integrated Management Model for Patellar Tendinopathy* for submission *July 2017*. Final documents with comments for correction before submission was provided by me to *Ms Morgan on 21 June 2017.*

I, Elsa Laura Diedericks, obtained a post-graduate honours degree in Linguistics and Literature Science (specialising in Translation, Editing and Interpreting) from the University of Johannesburg during 2004. I am a seasoned Language Practitioner with my own language practice and more than 13 years' experience in the field, with various high-profile tertiary education clients, including the University of Johannesburg and North-West University.

Should any further particulars be required, please do not hesitate to contact me.

Elsa Diedericks

Senior Language Practitioner | Owner at the Language Lab

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28 June 2017

To whom it may concern

This is to testify that the abstract, executive summary, and concept clarification sections of the thesis titled:

“An Integrated Management Model for Patellar Tendinopathy”

by

Sanell Morgan

have been language edited to the best of the language practitioner’s knowledge and ability.

The language practitioner in question is registered at the South African Translators’ Institute (SATI) with membership number 1003382, and thereby fully qualified and authorised to provide said services.

Should there be any queries, please feel free to contact the language practitioner at the number provided below.

Kind regards

Elcke du Plessis

0845480579

ANNEXURE Q: *TURN-IT-IN* SIMILARITY REPORT