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Evaluating applied physiotherapy practice in managing Patellofemoral Pain Syndrome: extending the scope beyond clinical measures and treatment

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EVALUATING APPLIED PHYSIOTHERAPY PRACTICE IN MANAGING PATELLOFEMORAL PAIN SYNDROME:

EXTENDING THE SCOPE BEYOND CLINICAL MEASURES AND TREATMENT

Thesis submitted in fulfilment of the requirements for the Degree of Doctor of Philosophy in Bangor University, July 2016

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DEDICATION

To my family who never stopped believing in me

LIST OF ABBREVIATIONS

ADLS = Activities of Daily Living Scale

AKP = Anterior Knee Pain

AKPS = Anterior Knee Pain Scale

AMSTAR = A Measurement Tool to Assess systematic Reviews

ARMG = Applicability and Recommendations Methods Group

BU = Bangor University

CKC = Closed Chain Exercises

CSP = Chartered Society of Physiotherapy

CP = Chondromalacia Patellae

CPD = Continuing Professional Development

DOH = Department Of Health

DS = Demitris Stasinopoulos

ESP = Extended Scope Physiotherapist

FIQ = Functional Index Questionnaire

GM = Gluteal Muscles

HCPC = Health and Care Professions Council

ICC = Intraclass Correlation

ITB = Iliotibial Band

JJ =Jeremy Jones

Kg = Kilograms

LEFS = Lower Extremity Functional Scale

m = meters

MAKPS = Modified Anterior Knee Pain Scale

MCQ = Multiple Choice Questions

MFIQ = Modified Functional Index Questionnaire

MVC = Maximum Voluntarily Activity

N = Newton

NHS = National Health System

NWW = North West Wales

OA = Osteoarthritis

OKC = Open Kinetic Chain

PFPS = Patellofemoral Pain Syndrome

PNF = Proprioceptive Neuromuscular Facilitation

PRISMA = Preferred Reporting Items of Systematic reviews Meta-Analyses

PROMSs = Patient Reported Outcome Measures

PSS = Patellofemoral Severity Scale

Q angle = Quadriceps angle

QUOROM = Quality Of Reporting Of Meta-analysis

RCT = Randomised Controlled Trial

RoR = Review of Reviews

SEM = Standard Error of Measurement

SF-36 = Short Form-36

SKB = Small Knee Bends

SLR = Straight Leg Raises

TFL = Tensor Fasciae Latae

VAS = Visual Analogue Pain

VAS-LBP = Visual Analogue Scale for Low Back Pain

VAS-U = Visual Analogue Scale for Usual Pain

VAS-WP = Visual Analogue Scale for Worst Pain

VL = Vastus Lateralis

VMO = Vastus Medialis Obliquus

WAG = Welsh Assembly Government

WOMAC = Western Ontario and McMaster Universities Arthritis Index

ABSTRACT

Background

Patellofemoral Pain Syndrome (PFPS) is a well-recognised condition in athletes confounded by multifactorial causes. Literature highlighted that the overall evidence base was primarily centred on athletic/military patients with a lack of substantive guidelines. Furthermore, clinical physiotherapists reported problem areas in managing treatment options and accessing 'best practice', prompting the initiation of this study in 2009. This area has continued to be problematic for applied physiotherapy practice with initial developments only starting to emerge in 2012.

Aims

The thesis focused on the exploration of issues surrounding implementation of evidence in practice, critically appraising the utility of current approaches in assessment, management and treatment of PFPS by physiotherapy practitioners. As a consequence it sought to understand the complex area of applied physiotherapy practice in PFPS in order to identify areas for improvement and remedial strategies for implementing best practice.

Methods

The thesis adopted a mixed methods approach, including the framing of the thesis phases as a series of case studies that explored different dimensions of applied physiotherapy practice in PFPS. The 7 phases included a scoping review of reviews, reporting the current evidence base; an applied PFPS review, reporting the current physiotherapy clinical practice as well as a utility review of measures and metrics in practice, reporting the reliability and criterion validity of the physiotherapy tools in practice. Additional phases involved an evaluation of tools and the usefulness of their outcome measures; practitioner context practitioner role

reporting the effectiveness of the applied physiotherapy treatment and finally modelling across cases leading to the development of an explanatory theoretical framework.

Findings

A systematic review of reviews undertaken highlighted that most of the literature had used athletic/military populations whilst the most prevalent causes of PFPS were weakness and shortening of a variety of muscles. However, there was no evidence whether these findings were applicable to PFPS patients referred to district NHS physiotherapy departments. The overall thesis reported 'poor bridging' between evidence and clinical practice with a lack of evidence being applied in practice. In response, physiotherapists modified their approaches, detaching themselves from evidence and 'surfacing' of knowledge about PFPS focused on athletic patient. The thesis identified the key contexts that influence applied physiotherapy practice and developed an explanatory PFPS model. It consisted of interrelated core elements focused on practitioner, patient, evidence and organisational contexts. Implementation required a context and facilitation orientated approach focused on adopting PARIHS as a framework.

Discussion

The original contribution of the thesis builds upon the empirical development of a PFPS model and highlights the key contexts that influence applied physiotherapy practice in the NHS. This thesis identified the complexity of implementation, requiring facilitation that involves 'bridging' between PFPS applied physiotherapy, the evidence base and guidelines. It is important that new evidence addresses the dissonance apparent in the key contexts that influence PFPS physiotherapy practice and focuses on implementation using frameworks that provide a synthesis between individual, organisational and wider context to support applied physiotherapy practice in PFPS.

STRUCTURE OF THESIS

Organisation of Thesis

The thesis comprises a series of chapters, as follows:

Chapter One: Introduction and background

This chapter introduces the background context and researcher's personal motivations for undertaking this research. It also presents how the research problem was identified via the interaction with the local physiotherapy department. The chapter presents the aims and the research questions formed after the observations at the clinical physiotherapy practice. Finally, in this chapter the reader can find all the introductory information about PFPS and the reasons for considering PFPS a complex rather than a 'simple' intervention in applied physiotherapy practice.

Chapter Two: Overarching Methodology and Methods

This chapter sets the scene for the thesis studies and presented the basis for mapping their findings in the later chapters. The author utilised a case study approach to construct an understanding of the phenomenon, using diverse elements of the case. These elements included a scoping process utilizing a review of reviews; an applied PFPS review identifying the PFPS assessment and treatment in practice; an utility review searching the measures and metrics (including scales) in practice; an overview of practitioner context in the frame of PFPS treatment effectiveness and an evaluation of the role of physiotherapy and applied practice on pain and function.

Chapter Three: Developing the research question: a scoping process utilizing a review o

reviews

This chapter shows the numerous components of PFPS risk factors, outcome measures clinical tests and exercise treatment suggested by the literature and the contradictions betwee the studies whilst it informs the evidence base context which will be used in the synthesis chapter. The results of this study were also used to inform the practitioner context since they defined how updated the local physiotherapists were with regards to their PFPS practice. This chapter also reported the gap (poor bridging) between the patient characteristics displayed by the secondary studies and the patients that physiotherapists claim to see in their clinic.

Chapter Four: Applied PFPS review-assessment and treatment in practice

This chapter documents the completion of a mixed method study consisted of a questionnaire survey and independent interviews and was important in answering the research questions of this study, since it presented the treatment and assessment components of applied PFPS physiotherapy. By reporting the clinical practice and the barriers physiotherapists face when they treat PFPS, this study presented the first steps of the contexts that play an important role in PFPS treatment implementation. The study also enabled the next studies to reveal the usefulness of the clinical tools in the applied physiotherapy practice, but also whether the available literature can be used (and if not why) by the NHS physiotherapists.

Chapter Five: Utility review – measures and metrics in practice

This chapter explores the measures and metrics in the applied physiotherapy practice through the detailed quantitative exploration in patients with PFPS, healthy controls and patients with other conditions of the lower limb. The results validated the difficulty that treatment provide confront when they see patients with PFPS. The multifactorial cause did not allow clinical tests to be very specific for PFPS. This probably explained the reason that physiotherapists modified the way they assessed the syndrome by using the same methods when treating it.

Chapter Six: An evaluation of tools of the Anterior Knee Pain Scale and the Lower Extremity Functional Scale in Patellofemoral Pain Syndrome

This chapter explores further the evaluation of two outcome measures used in the assessment of PFPS. This phase showed problematic evidence base context and a lack of specific outcome measures for patients with PFPS. Perhaps this was already known by the clinical physiotherapists who reported not to use them regularly. This chapter showed the strong need for reliable, valid and meaningful scales in PFPS which will enable researchers and clinicians to assess and measure treatment results. The scales that are used today are not specific for PFPS and can be modified for PFPS patients.

Chapter Seven: An evaluation of applied practice – A six week physiotherapy treatment programme

This chapter explores the effectiveness of the applied PFPS physiotherapy by monitoring a six-week physiotherapy treatment at the local NHS physiotherapy department. The results were not completely in line with what physiotherapists reported in chapter 4 about the aims of their treatment. These results revealed that there were specific barriers in the clinical physiotherapy practice (patient and organisational contexts) that would not allow physiotherapists to achieve what they wanted to achieve.

Chapter Eight: An evaluation of the role of physiotherapy and applied practice on pain and function

This chapter explores physiotherapists' beliefs about the role of physiotherapy and their explanations of the results of the previous study (Chapter 8). This study identified an important part of the research question regarding the transferability of evidence in the clinic. This chapter validated not only the difficulties facing physiotherapists in applied practice in the area of PFPS but also identified potential areas for improvement. It underlined that physiotherapists were modifying their practice to attempt to 'bridge' the problematic evidence-base in the context of their NHS orientated patients. This chapter provided an important platform for drawing together the different phases and seeking to identify ways forward for applied physiotherapy.

Chapter Nine: Synthesis and analysis

This Chapter outlines the final model, generated through the process of discovery that was facilitated by the findings from the mixed method, quantitative and qualitative work. The chapter presented the dynamic interrelationship between PFPS contexts. The overall model highlighted that the implementation of a consistent and appropriate management of PFPS operated on a continuum ranging from 'intra-physiotherapy practice', 'inter–physiotherapy practice' to 'extra physiotherapy–practice'. Finally, the chapter developed further with not only a PFPS model for applied physiotherapy but also a model that identified the opportunities and barriers towards implementation of improvements in the treatment of PFPS by physiotherapists in clinical practice.

Chapter Ten: Discussion and recommendations

This final chapter provides a reflexive account of the utility of the final model and its potentials. The chapter presents the contribution and impact of PFPS as a phenomenon that merited further examination as part of applied physiotherapy practice. Strengths and limitations of each stage are described, whilst results and important novel outcomes were discussed. A series of specific recommendations are provided in relation to policy, practice and research.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

1.1 INTRODUCTION

The author of this thesis elected to study Patellofemoral Pain Syndrome (PFPS) in greater depth during an MSc course in exercise rehabilitation and conducted research on McConnell's Vastus Lateralis inhibition technique in people with PFPS. On successful completion of his MSc course, he applied for a PhD studentship from the Research Capacity Building (RCBC) Wales Collaboration. The priorities of the study were to develop research capability and capacity in allied health professionals, including physiotherapists, and to align research projects with one or more Welsh Assembly Government clinical practice priorities, including: early intervention, long-term conditions management and service delivery and organisation. PFPS fitted these priorities.

Before the initiation of this PhD study several discussions with the extended scope physiotherapists specialising in musculoskeletal medicine at NWW and other physiotherapists took place to obtain an initial understanding of physiotherapy practice relating to PFPS in NWW. The local physiotherapists reported that although they were well informed about the syndrome from PFPS seminars and workshop attendances, the fact that there were no written gold standard guidelines on specific assessment, treatment and measuring outcomes in PFPS, unlike other conditions [e.g. treatment after Anterior Cruciate Ligament (ACL) reconstruction], forced them to follow their own assessment and treatment methods. Therefore, treatment was dependent on individual physiotherapists; also because the available literature did not seem to be useful in the clinical environments of NHS departments and to the non-athletic patients that physiotherapists see in the clinic. Literature did not appear to be relative to the patients they see and to the compliance they get from them. Physiotherapists also discussed their clinical practice with the researcher, reporting that they use many, different methods in the assessment, treatment and measuring outcomes of patients with PFPS. Physiotherapists also reported poor treatment compliance in some patient groups who returned to clinic with ongoing unresolved pain. Lack of evidence to inform intervention and the provision of ineffective service delivery is not desirable in a public service like the National Health Service (NHS).

The above observations broadly set the PhD aims. NHS physiotherapists in NWW used many different methods to assess, treat and measure outcomes however; since there were no gold standard guidelines, it was decided that the first stage of this PhD would consist of an extended systematic review of reviews which aimed to:

a) Identify what literature reports about the characteristics of patients with PFPS and the assessment, treatment and use of outcome measures.

   The literature review took place before and during this research study. During this PhD more questions were raised and added in the literature review.

   Following on from the literature review, the next stage was to identify actual NHS physiotherapy practice by questioning and interviewing all email-available physiotherapists of NWW. The data were analysed in a mixed-method qualitative study which aimed to:

b) Identify how NWW physiotherapists assess, treat and measure outcomes when treating PFPS and what the barriers they have to confront.

   Having determined what physiotherapists do in the clinic, it was recognised that strengthening and stretching of several lower limb muscles were two of the important components of physiotherapy treatment. The next step was set to identify how specific the tests they used were for patients with PFPS. Therefore, the next stage aimed to:

c) Identify how reliable, valid and able to differentiate PFPS from other populations the clinical physiotherapy methods were.

This was investigated using a case control study which compared the physiotherapy clinical tests in PFPS patients and healthy controls. A feasibility study was then carried out which compared the same tests in PFPS patients and patients with other lower limb conditions (after testing the reliability of a portable dynamometer, so, that the tests could be conducted within a clinical setting). Within this stage, the usefulness of the questionnaires relating to PFPS was also examined.

A further study also recorded the feasibility of these outcome measures during physiotherapy practice and aimed to:

d) Identify the effect of physiotherapy treatment on patients with PFPS after a six-week treatment.

e) The findings of this study were unexpected, thus, it was decided to discuss the results with the physiotherapists in focus groups. The aim was to identify what NWW physiotherapists believe about their clinical practice and how this relates to their recorded-treatment findings. What are the implications of their practice to themselves and NHS physiotherapy departments in general?

1.1.1 Research Question

Overall the thesis explores the phenomenon of PFPS as an area that merits further examination as part of applied physiotherapy practice. The study which is documented in the thesis, details the limitations of the current evidence base linked to applied practice and the poor bridging between evidence, clinical contexts and individual practice. It explores not only the issues surrounding implementation of evidence in practice, but focused on the utility of current approaches in assessment, management and treatment of PFPS by physiotherapy practitioners. As a consequence the research question sought to identify key factors that operated in the arena of applied physiotherapy practice that may potentially influence patient outcomes. Furthermore the research question attempted to identify areas for improvement and possible remedial strategies for implementing best practice. This was based on a review of the evidence-base and empirical data, centred on an appropriate implementation-focused model for applied physiotherapy practice in PFPS.

The detailed research question was focused on the following dimensions of PFPS as an area for inquiry to understand PFPS as a complex rather than a 'simple' intervention in applied physiotherapy practice:

- The completion of a scoping review to identify the key strands of evidence that inform the current understanding of PFPS, standard measures and treatment for PFPS in clinical practice, also locating the key professional responsibilities and roles, as well as patient contingencies.
- The examination of contextual factors that mediated, mitigated or facilitated improved utility of treatment and measures in applied physiotherapy practice, focusing particularly on the role of interpretation and implementation of evidence and their use by physiotherapy professionals, operating within particular organisational environments.
- The study sought to understand the position and interaction between the physiotherapist and the administration of treatment for PFPS as an intervention, exploring the role of the individual physiotherapist in acting upon the available evidence. In this way the relationship between physiotherapist, context and evidence was examined in order to identify areas for improved practice and efficacy.
- The study 'unpacked' the research question as part of a review of evidence and empirical data in order to develop recommendations for improved implementation of

PFPS as a complex intervention. The recommendations focus on a context-orientated approach to guide clinical treatment and measures in PFPS.

As such, the research question underpins a thesis that has focused on comprehending the applied context of PFPS in physiotherapy practice and builds on the strengths of current approaches to the implementation of complex interventions that focus on understanding context. Additionally, the thesis develops a model of PFPS as an applied intervention and embeds the results in a wider argument regarding challenges to implementation of best practice in clinical environments where practitioners act within boundaries of autonomous practice, operating within a developing evidence-base.

1.1.2 Original Contribution and Impact

The thesis provides an account that identifies the relevance of the present study within the field of healthcare sciences and particularly physiotherapy practice,

- It evidences and identifies the range of factors that underpin the complexity of PFPS as an area of practice for physiotherapist in the applied context of practice;

- It examines the utility of clinical measures and treatment within the context of applied practice, and generates a greater understanding of the mitigating factors that influence these in the work of physiotherapist with PFPS, suggesting impacts on patient outcomes;
- It develops a model based on a multi-phased study that examines the area of applied practice in PFPS management in physiotherapy that account for PFPS as a complex intervention;
- Based on the overall results the thesis challenges the current understanding of PFPS as an area for innovation and change in physiotherapy practice and suggests the utility of a

revised and context-focused model of implementation for improvements centred on the PARIHS framework.

1.1.3 Defining the field and operational terms

Terminology

Anterior knee Pain (AKP) is one of the most common clinical conditions in patients of either sex, all activity levels and ages (Wojtys et al., 1990). In the past, the term used for AKP was chondromalacia patellae which described pathologic changes in the articular cartilage of the patella, such as, fragmentation erosion and softening. PFPS is frequently confused with chondromalacia patellae; however the latter is a pathologic diagnosis and constitutes a distinc cause of knee pain (Sandow & Goodfellow, 1985). Other common synonymous terms include, lateral facet compression syndrome and retropatellar pain syndrome (Cutbill et al., 1997). There are no specific findings on physical exam that are diagnostic of this PFPS problem (Jackson, 2001). This is why a number of clinicians identify this condition by excluding any other knee problems (e.g. menisci, ligaments) (Thomee et al., 1999).

Prevalence and demographics of PFPS

Research conducted in eight general practices in the United Kingdom has shown that AKP represents 12% of all knee-related consultations and 71% of these cases are diagnosed as Patellofemoral Pain Syndrome (PFPS) (Wood et al., 2011). PFPS is thus the second most common musculoskeletal complaint presented to physiotherapists and the most common knee problem physicians have to confront (Houghton, 2007; Witvrouw et al., 1996).

In 2000 PFPS was also considered as a post-traumatic complaint after ACL knee surgeries. The incidence of PFPS after ACL surgery with bone-patellar tendon-bone autografts was from 4% to 40% (Fu et al., 2000) whilst the incidence was ranged from 6% to 12.5% 2 years post surgery in hamstring grafts (Aune et al., 2001). These assumptions were later challenged by a critical review study which aimed to identify the primary research and the quality of the

PFPS papers along with the amount of patients included in each of them. One of the conclusions was that ACL reconstructions do not lead to PFPS (Selfe, 2004). Today, there is still a controversy regarding this association. Recently, researchers (Culvenor, et al., 2014) reported that Patellofemoral OA is common following ACL reconstructions and is related to AKP. Patellofemoral Osteoarthritis (PFOA) is now considered as a subgroup of knee OA (Witvrouw et al., 2014). Several studies reported radiographic evidence in people with pain on the knee and regardless the methods they used, the prevalence was significant in the lateral patellofemoral compartment (Duncan et al., 2009).

Females are significantly more likely (2.21 times) to develop PFPS than males (Boling et al., 2010). Females are more vulnerable to suffer from PFPS because of anatomic factors such as the increased pelvic width, which results to an excessive lateral thrust on the patella (Boling et al., 2010). In addition, postural and psychosocial factors such as wearing high heels and sitting with the legs adducted when wearing a skirt, can produce the incidence and acuteness of this syndrome in females (Fulkerson and Arendt, 2000). Another population that is affected more is adolescents between 12 and 17 years of age (MacIntyre and Robertson, 1992) This is probably because adolescents are usually more active than adults whilst their biomechanical alignments are still dynamic (MacIntyre and Robertson, 1992). Other evidence regarding the prevalence or incidence particular to other populations shows that the incidence in military men is 3.8% and in women 6.5% annually, whilst the prevalence is 12% in men and 15% in women (Boling et al., 2010). The rate is around 9% in young active adults (Witvrouw et al., 2000). The frequency is 5.4% of the total injuries high as a quarter of the overall knee problems treated in sport rehabilitation clinics (Devereaux and Lachmann, 1984).

PFPS is very common in athletic communities, thus, PFPS is also known as the Runner's Knee (Mensch and Ellis, 1986). Over 2.5 million runners will be diagnosed with PFPS every year and 70-90% of these will have recurrent or chronic pain. In addition, 5 years after rehabilitation, 80% still reported pain and 74% had reduced their activity level (Noehren, Scholz, & Davis (2011). However, the general and sporting populations' true incidence is unknown, and the much cited figure of 25%-40% (Witvrouw et al., 2014) is based on reports from sports clinics which have ascertainment bias because the general population they see is athletes. Thus, there is not enough evidence to confirm the incidence of PFP in non-athletic clinics. (Mølgaard, Rathleff and Simonsen, 2011).

Symptoms and Signs of Patellofemoral pain syndrome

Literature shows no consensus regarding the definition, aetiology, and diagnosis of PFPS (Arroll et al., 1997). Most studies describe symptoms of insidious onset, such as diffuse retropatellar and peripatellar localized pain in one of the two knees or in both (Arroll et al., 1997). The pain is aggravated by walking uphill or downhill, squatting, kneeling, or by prolonged sitting with flexed knees (Arroll et al., 1997). There is reportedly no correlation between the pain intensity and the range of knee extension or flexion, femoral rotation, or quadriceps angle (Galanty et al. 1994). Clinical tests used to assess patients with PFPS have shown to lack reliability and validity (Caylor et al., 1993; Powers et al., 1999) because of the difficult pathophysiology. Radiographic findings are inconclusive in diagnosing PFPS, but they can be used in a differential diagnosis (Haim et al., 2006). People suffering from PFPS are presented with knee pain during or after sports, have difficulty to fully bear their weight on the affected knee, while there is pain after some activities such as squatting and kneeling (Houghton, 2007). Knee effusion is not common but can be presented after heavy activities such as running (Witvrouw et al., 1996).

<u>Risk factors</u>

Only recently the aetiology of PFPS has been separated into different subgroups of risk factors. This first attempt was reported in the first PFPS consensus meeting in Baltimore, Australia (Davies and Powers, 2010). In this meeting, the risk factors were presented as local proximal and distal and are described further below. The last update comes from the consensus statement in Vancouver, Canada, 2013 (Witvrouw, et al., 2014). In that meeting, it was recommended for first time that interventions should be tailored to specific populations of patients (i.e. adolescents, athletes, military, older adults whilst the methods for participant recruitment should be well described to include the site (school, clinic sports) (Witvrouw, et al., 2014. These are two of the intervention components that have been searched in this thesis since 2009.

Local factors

A recent systematic review (Lankhorst et al., 2012) indicates that an increased Quadriceps angle (Q angle) is not a risk factor for PFPS supporting previous doubts on the Q angle's relevance. In addition, structural abnormalities coupled with poor biomechanics may increase the likelihood of PFP; however, the relationship between structure and biomechanics is not yet known because no cohort study has ever looked at both components at the same time (Witvrouw et al., 2014). Recent evidence in local risk factors suggests that abnormal alignment of the patellofemoral joint may lead to focal areas of loading and to cartilage damage (Stefanik et al., 2010). There is insufficient evidence that different local structures may contribute to nociception in PFPS. These may be the infrapatellar fat pad in patellofemoral pain (Dragoo, Johnson and McConnell, 2012), and increased water content in subchondral patellar bone in athletic patients (Ho, et al., 2013). Other local risk factors that have been addressed in a previous consensus statement included the decreased proprioception in patients with PFPS, quadriceps weakness and atrophy and timing especially of the Vastus Medialis Obliquus (VMO) however, evidence to the contrary has also been reported (Witvrouw et al., 2014). Finally evidence showed that there is a maltracking of the patella which moves proximately as the tibiofemoral joint extends. This maltracking may influence the effectiveness of interventions because the proximal movement of the patella gives a disadvantage to quadriceps for contraction (Derasari et al., 2010)

Proximal factors

There is new evidence that proximal mechanics such as excessive hip abduction and internal rotation may be altered in women with PFPS, but, there is still no evidence that the same mechanisms appear to men (Nakagawa et al., 2012). Trunk mechanisms such as contralateral pelvic drop have been identified as risk factors for PFPS however; these mechanisms may differ between men and women because women have different pelvic structure (Noehren et al., 2012). The effect of fatigue in hip muscles remains unclear. One study has shown that alterations in sagittal plane but not in the frontal (Bazett-Jones et al., 2012), plus the onset and progression of the pain make fatigue measurements difficult. In addition, isometric hip extension is also considered to be weaker in patients with PFP, and this weakness can be exacerbated by an exhaustive run (Bazett-Jones et al., 2012). Finally there is also evidence that gluteus medius activation may be delayed and of shorter duration. Barton et al., (2013) reported that delayed and shorter duration of gluteus medius electromyography (EMG) may indicate impaired ability to control frontal and transverse plane hip motion.

Distal factors

The rearfoot eversion has always been identified as a risk factor for PFPS (Witvrouw et al., 2014; Rodrigues, Tenbroek and Hamill, 2013). However, its importance remains unclear (Witvrouw et al., 2014). More of the available rear foot eversion during gait is used by patients with PFPS compared with healthy controls (Rodrigues, Tenbroek and Hamill, 2013). Greater rearfoot eversion may be related to hip adduction in patients with PFPS (Witvrouw et al., 2014). Additionally, greater tibial internal rotation has recently been found in patients with PFPS (Noehren et al., 2012). Therefore, such alterations may provide a link between PFPS and distal factors.

Contemporary management strategies

Since there are many factors that can lead to PFPS, before treatment planning, a detailed examination is needed (Collins et al., 2012). A detailed physical examination allows identification of the unique contribution for each individual (Harvie et al., 2011). This would include strength and flexibility of several muscles, lower limb alignment, patella position, muscle coordination and proprioception (Harvie et al., 2011). Collins et al. (2012) suggested that the rehabilitation programme should be separated in the same subcategories of risk factors, i.e. local, proximal and distal. This would provide clinicians with a simple guide to check all three joint components that might affect the knee. A recent update on rehabilitation of PFPS (Dutton, Khadavi and Fredericson, 2014) suggests the utility of quadriceps strengthening; especially of the VMO, In addition, soft tissue flexibility such as the hamstrings, calves, Iliotibial Band (ITB) /Tensor Fascia Latae (TFL), patellar taping, patellar bracing for patellar maltracking, hip strengthening (especially of the gluteus medius), foot orthotics to decrease foot eversion, gait re-education, and training modification may be required in the treatment of PFPS. However, there are many contradictions between studies with regards to the aforementioned treatment components (Witvrouw et al., 2014). In addition functional tasks such as squats, stationary cycling, static quadriceps, active straight leg raise, leg press, and step-up and down exercises are suitable for patients with patellofemoral pain syndrome (Harvie et al., 2011). More details of contemporary management strategies are explained in the review of reviews of Chapter 3.

1.2 SUMMARY

This chapter aimed to introduce the reader with the background of the researcher and the reasons for selecting PFPS as a PhD research area. After explaining the pre-PhD observations about PFPS clinical practice the aims and the research questions were fully described. This chapter also gave important information about PFPS risk factors, contemporary management and the difficulties physiotherapists have to face when they assess and treat PFPS. Finally, this chapter set the PFPS dimensions and explained why PFPS should be considered a complex rather than a 'simple' intervention in applied physiotherapy practice.

CHAPTER TWO: OVERARCHING METHODOLOGY AND METHODS

"The utility of case research to practitioners and policy makers is in its extension of experience "

(Stake, 2000, page 449)

2.1 INTRODUCTION

The exploration of the research question required an approach that focused on the nature of applied physiotherapy experience as well as the sources of evidence located elsewhere such as in the literature. A key concern of the study (as reported in the thesis) was to understand the complexity of PFPS in the arena of physiotherapy practice, prior to suggesting improved implementation methods. In order to achieve this, the author adopted a case study approach that focused on interpreting different sources of information to comprehend the experience of managing PFPS as a complex intervention. The work of Roberts Stake (2000) was utilised as an overarching framework as it enabled a flexible approach using different strands of PFPS management and treatment as cases-in-practice that could be utilised to draw together insight regarding the overall 'collective case' of PFPS in applied physiotherapy practice. Although primarily qualitative in its approach it also enables a mixed methods approach to the collection of data to understand the phenomenon under investigation. It facilitates a 'collective' case study approach (Stake, 2000) that draws together a range of evidence from different 'cases', represented as phases in the study and reported in the thesis. These cases are defined as areas of evidence underpinning PFPS management as an applied physiotherapy phenomenon.

2.1.1 Case Study as an overall approach and Mixed methods

Case study research provides a flexible approach with mechanism for examining complex research questions, enabling the researcher to include a range of data using qualitative, quantitative or mixed methods to understand the phenomenon (Stake, 1992).

General

Qualitative case study is a perspective to research that facilitates investigation of a phenomenon within its context using a diversity of data sources (Baxter and Jack, 2008). This makes certain that the issue is not examined through one lens, but rather a number of lenses which enables for multiple facets of the phenomenon to be displayed and understood (Baxter and Jack, 2008). There are two key perspectives that guide case study methodology; one proposed by Robert Stake (1995) and the second by Robert Yin (2003). Both try to ensure that the topic of interest is well investigated, and that the essence of the phenomenon is revealed, but the methods that they each employ are quite different.

Yin

Yin (2003) provides methodological guidelines regarding when to use a case study approach. According to Yin (2003), a case study design should be considered when: (a) the focus of the study is to answer "how" and "why" questions; (b) you cannot manipulate the behaviour of those involved in the study; (c) you want to cover contextual conditions because you believe they are relevant to the phenomenon under study; or (d) the boundaries are not clear between the phenomenon and context. Such an example is the current study which aimed to determine the types of decisions made by physiotherapists and the factors that influenced the decision making when treating PFPS. A case study was chosen because the case was the decision making of physiotherapists but the case could not be considered without the context, the NHS physiotherapy settings and patients' characteristics. It was in these settings that the decision making skills were developed and utilized. It would not be possible to have a true picture of physiotherapy decision making without considering the context within which it occurred.

Stake

Stake (1992) finds it useful to identify three types of cases; the intrinsic case study, the instrumental case study, and collective case study. The intrinsic study is the study that is being undertaken because the researcher wants better understanding of the particular case (Stake, 1992). The intrinsic study does not often represent other cases. It is the main focus of the researcher.

The instrumental study is being used to provide insight into an issue or to redraw generalization. This case is of secondary interest and is looked at depth although the understanding of an external interest is what really matters.

The third type is the collective study which does not have an interest in one particular case but usually the researcher studies a number of cases in order to investigate a general condition, a population or a phenomenon (Stake, 1992). The number and the nature of the studies may not be known beforehand by the researcher but they are chosen on the way because it is believed that understanding them will lead to a better understanding of more or other cases (stake, 1992). PFPS matches perfectly in this type of case studies and mirrors the different cases studies in order to investigate the PFPS population and PFPS as a phenomenon and not as an intrinsic study only.

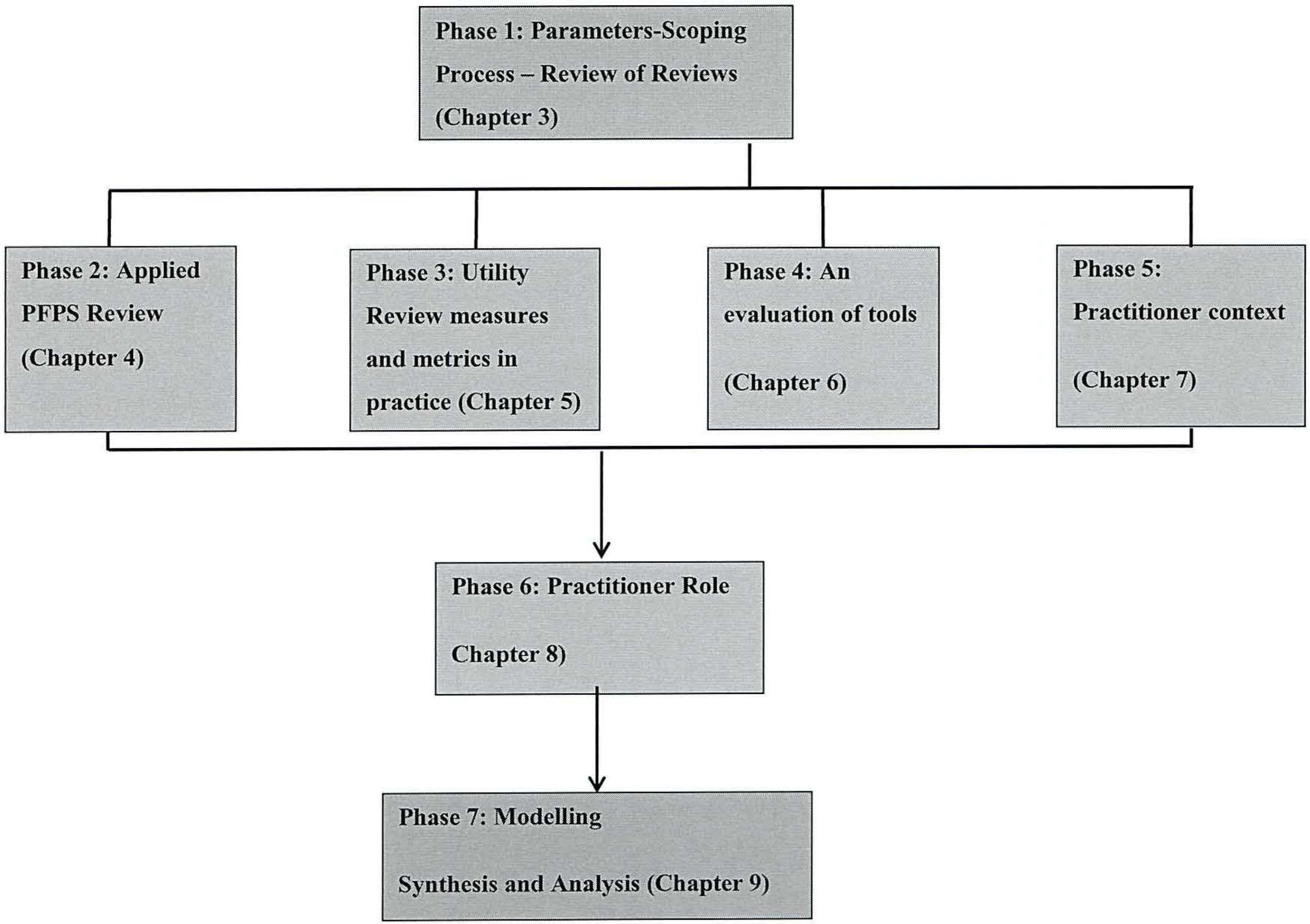
Mixed methods

Mixed methods research has come of age. To include only quantitative and qualitative methods falls short of the major approaches being used today in the social and human sciences (Creswell, 1994). Mixed methods researchers look at different approaches to collecting and analyzing data rather than subscribing to only one way (e.g., quantitative or qualitative) (Murphy, 1990). Therefore in mixed methods research, researchers use both quantitative and qualitative data because they intend to provide the best understanding of a research problem (Cherryholmes, 1992). In particular, three general strategies and several variations within them are usually used: a) sequential procedures, b) Concurrent procedures and c) transformative procedures (Creswell, 1994). Sequential procedures are those where the researcher tries to expand or to elaborate the findings of one method with another; concurrent procedures, in which the researcher mingles quantitative and qualitative data in order to provide a comprehensive analysis of the research problem; and transformative procedures, in which the researcher uses a theoretical lens as an overarching perspective within a design that contains both quantitative and qualitative data (Creswell, 1994). This thesis has used both sequential and concurrent procedures. Since there is no previous research that has analysed physiotherapy practice and behaviours there was an initial need to elaborate and expand clinical practice and physiotherapists' theories behind their PFPS assessment and treatment methods. Additionally, there was a need to converge qualitative and quantitative data to analyse comprehensively the reason for performing this practice and adopting several behaviours. Therefore, the mixed methods were the most appropriate way to be used as a base in this collective case study because it would enlightened PFPS physiotherapy practice with both ways (qualitative and quantitative) but also would provide with problematic situations and reasons for picking up specific assessment and treatment methods.

2.2 STUDY DESIGN

The inquiry was framed within the study as comprising a number of interrelated phases that enabled a number of 'intrinsic' (Stake, 2000) components of the phenomenon to be examined as cases that cumulatively represented a 'collective case study' (Stake, 2000) of PFPS (Figure 1).

Figure 1. Study Design and Integrated Phases of Inquiry



The respective phases are summarised as follows prior to further consideration in each chapter

2.2.1 Phase 1: Developing the research question: a scoping process utilizing a review of reviews (chapter 3)

Aims of the study

The aim of this study was to identify what literature reports about the characteristics of patients with PFPS and the assessment, treatment and use of outcome measures.

Methods

The systematic RoR approach of Smith et al. (2011) was used, with additional data mining to extract specific evidence of interest from the primary studies included in the systematic reviews.

The Smith approach (2011) uses standard systematic review processes to identify and appraise reviews, describe the quality of the evidence base, summarise and compare the review's conclusions and discuss the strength of these conclusions. The Preferred Reporting Items of Systematic reviews Meta-Analyses (PRISMA) guidelines formerly known as QUOROM (Quality Of Reporting Of Meta-analysis) was adopted when conducting this review (Moher et al., 2009). PRISMA consists of a 27-item checklist and a four-phase flow diagram about identification, screening, eligibility and inclusion. PRISMA items which could not be used in this systematic RoR (e.g. question 21 about meta-analysis results) are not presented. All other questions included in the PRISMA checklist were used.

Protocol and registration

The protocol and the questions of the current study were designed beforehand; however the protocol was not published or uploaded on the web.

Eligibility criteria

Inclusion criteria

- Only reviews with a clear search strategy and detailed references (McNeill, Lynn and Alderdice, 2012) which attempted to collate all empirical evidence that fitted pre-specified eligibility criteria in order to answer a specific questions were selected (Oxman 1993).
- Only reviews in English language were obtained.
- No restriction regarding the origin of the systematic reviews (country) was imposed.
- Only reviews with available full text were included.
- Reviews which include the following study design papers: systematic reviews, meta-analyses, randomized controlled trials (RCTs), case-control studies, cohort studies, case series, formal consensus and expert's opinion were included.
- Study population: adults with PFPS. Participant can be either patients of NHS or patients visiting a private clinic or private practice physiotherapists.
- Case definition: PFPS, AKP (Anterior Knee Pain), CP (Chondromalacia Patellae); if the authors intended AKP or CP to be a description for PFPS.

Exclusion criteria

- Study design: Studies with no clear search strategy and detailed reference. Studies that did not report clear methodology.
- Study population: non-humans, or people under the age of 18.
- Case definition: Studies focusing on other named knee pathologies (such as Osgood Schlatter disease, Sinding Larsen-Johansson's disease, tendinitis or bursitis, intra-articular pathologies, plica syndromes and rarely occurring pathologies) were excluded.

Studies eligible for this RoR were those published from 1993 to July 2013. The reason for the 1993 year selection was that according to Lichtenstein et al. (2008) the search needs to cover at least two decades. In addition, the earliest PFPS reviews identified by quick search were published in 1993. In earlier years (1955 to 1980) surgical interventions were more common than non-operative treatment and most of the articles were written from an orthopaedic standpoint (Blazina et al., 1979; Lubinus 1979).

Information sources/search

Databases searched included PubMed, CINAHL, SPORTDiscus, Pedro and the Cochrane Library. Reference lists of highlighted recent reviews were manually searched to identify additional reviews (Booth et al., 2011). Four key areas were searched using the words: PFPS, Anterior Knee Pain (AKP) or Chondromalacia patella (CP), plus a keyword. The keywords for the four research topics were a) risk factors; b) exercise treatment; c) diagnostic clinical tests and d) psychometric outcome measurements. This study aimed to identify reviews only, therefore, the last keyword in every search was the word 'review' (Appendix 1).

Study selection

For the first level of screening, one reviewer KP read the titles of all the available citations obtained from the electronic database search and reference lists and removed all the citations which were not related to PFPS. The second level of screening involved the screening of abstracts, and was conducted by two reviewers KP and DS. Full-text articles were obtained for the reviews which did not clearly meet the eligibility criteria. When, even after analysing the full text, the eligibility of an article remained uncertain, it was planned to ask a third reviewer to undertake a full analysis; However, this contingency was not required (Smith et al., 2011).

Critical appraisal of reviews

In order to assess the quality of a paper, there was a need to consider not only the type of evidence (i.e. randomised trials, pilots, cross-sectionals or others) but also the methodological quality of each review. Therefore, a two-stage evaluation was performed in each review assessment. At first, the level of evidence was graded (Smith et al., 2007) and then the methodological quality of each review was assessed (Shea et al., 2007). In order to assess the level of evidence, systematic reviews with randomized controlled trials were established as first in the hierarchy (gold standard) and then an evidence grade was given to each review based on the Scottish Intercollegiate Guidelines Network (2008). This framework assesses the evidence level from different sources (from 1++ to 4). Only the first 4 categories assess review studies; therefore, the reviews of this study were graded from 1++ to 2++.

According to Clarke, (2008) the methodological conduct of a review plays an important role in the successful interpretation of results from systematic reviews. Therefore, in order to present high methodological evidence, this review used a framework for the assessment of the methodological qualities of systematic reviews. The AMSTAR tool (Shea, 2007) was selected as the most acceptable to critically appraise the methodology of systematic reviews. AMSTAR is used by a number of groups such as the Canadian Agency for Drugs and Technologies in Health and The Cochrane Effective Practice and Organization of Care Group. The tool consists of 11 items and was created to assess the methodological quality of systematic reviews and found to have good inter-rater reliability (Kappa scores >0.8) and good face, content and construct validity (Shea et al., 2009). Each item is given a score of 1 if the specific criterion is met, or a score of 0 if the criterion is not met, is unclear, or is not applicable. According to the total score that each systematic review received the methodological quality of included reviews was assessed and rated as low, medium or high quality. AMSTAR characterises quality at three levels. Levels 0-3 can be considered as low quality, 4-7 as medium quality and 8-11 as high quality (Sharif et al., 2013). In this RoR high, moderate and low quality levels were utilised.

Although PRISMA is not a quality assessment instrument for systematic reviews it can be useful for critical appraisal purposes. Consequently, the study also set out to identify which of the systematic reviews used PRISMA to report their data and how many of the 27 items have been used. This information was considered supplementary and was not used as a criterion to include or exclude any reviews. In case of any disagreement regarding grading of evidence, quality appraisal of reviews or effectiveness of the intervention, consensus was reached by discussion between the main researcher and DS.

Data collection process

Titles and abstracts were screened for eligibility according to the following inclusion and exclusion criteria. When the appropriateness of some reviews was not clear, the full text was obtained.

Data items

The variables for which data were sought included patients with PFPS of all ages except for children, participated in RCT's, case-control or cohort studies. Studies could be funded by an external source or not.

Risk of bias in individual studies

No methods used for assessing risk of bias.

Summary Measures

No statistical analysis was undertaken for the data interpretation.

Additional analyses

The additional analyses included the search for evidence regarding the secondary questions of this review (5-8 from the review questions). All secondary questions that this review was designed to answer were not reported according to statistical significance but according to the categories each of the question could be separated into (e.g. research place=clinic or research centre). Only systematic reviews with clear study report were used in this section.

2.2.2 Phase 2: Applied PFPS review-assessment and treatment in practice (Chapter 4)

Aims of the study

The study aimed to identify how NWW physiotherapists assess, treat and measure outcomes when treating PFPS and what the barriers they have to confront.

Methods

A mixed-method study was designed to interrogate physiotherapists practicing in the National Health Service (NHS) and in private practice in NWW about their clinical practice relating to PFPS. The design incorporated a primarily quantitative questionnaire survey and a secondary 'nested' qualitative interview component with a sample of physiotherapists who responded to the questionnaire (Creswell et al., 2003) The reason for choosing this mixed-method study was to add breath and scope to what clinicians do when they assess and treat PFPS and to reassure convergence between the survey and the individual interviews.

Sampling

Before sending the survey to the physiotherapists, the survey and the interview framework were piloted by 5 physiotherapy students who did their clinical placement at the physiotherapy clinic at Ysbyty Gwynedd. No changes were made after the pilots. The potential participants were physiotherapists with email access in a defined geographical area (NWW). Those working in the NHS were identified through the hospital email system. Those working in private practice or other organisations were identified via the yellow pages telephone directory and via an online search engine.

Questionnaires were sent to a total of 48 Physiotherapists. 30 responded (response rate 62.5%). 21 (70%) of the respondents worked in the NHS, 6 (20%) in private practice, 5 (16.7%) in both NHS and private practice and 2 (6.7%) in other organisations.

11 out of 30 questionnaire respondents (36.6%) were purposively selected and interviewed at their work place. The interview sample was selected to represent proportionally men and women who work for the NHS and in private practice (2 males & 7 females from NHS, 1 male & 1 female from private practice). Further details of the respondents' and interviewees' characteristics are detailed in Table 1.

<u>Questionnaire respondents: 30</u> **Gender**: 7 Males, 23 Females Willing to be interviewed: **26** (86.7%)	**Physiotherapists** — **Number of Patients with PFPS per month** 12 (40%) → 1-2 13 (43.3%) → 3-5 5 (16.7%) → 6-10
Experience in years: **Physiotherapists** — **Years** 3 (10%) → 2 2 (6.7%) → 3 3 (10%) → 4-5 3 (10%) → 6-10 15 (50%) → 11-20 4 (13.3%) → 21+	**Confidence in treating PFPS:** **Physiotherapists** — **Confidence (out of 5)** 10 (33.3%) → 3/5 12 (40.0%) → 4/5 8 (26.7%) → 5/5
<u>Interview respondents: 11</u> **Gender**: 9 Females, 2 Males	**Participants** — **Number of Patients with PFPS per month** 4 (36.4%) → 1-2 5 (45.5%) → 3-5 2 (18.2%) → 6-10
Experience in years: **Physiotherapists** — **Years** 1 (9.1%) → 2 2 (18.2%) → 4-5 1 (9.1%) → 6-10 6 (54.5%) → 11-21 1 (9.1%) → 21+	**Confidence in treating PFPS:** **Physiotherapists** — **Confidence (out of 5)** 3 (27.3%) → 3/5 4 (36.4%) → 4/5 4 (36.4%) → 5/5

Table 1. Characteristics of the physiotherapists who responded to the questionnaire and those who attended the follow

Data Collection

Questionnaire development

The questionnaire (Appendix 2) was developed by a multidisciplinary team consisting of the researcher, who is a registered physiotherapist, an exercise physiologist, a rheumatologist, a methodologist and an Extended Scope Physiotherapist (ESP) specialising in musculoskeletal conditions. An extensive literature review, including Cochrane reviews, was undertaken to identify what outcome measures, treatment methods and functional tasks have been used in previous studies. The findings were converted into questions within a 39 question questionnaire to explore physiotherapists' clinical practice on PFPS.

The first 6 questions were filter/personal questions enquiring about participants' experience i years and type of practice. The next 26 questions were Multiple Choice Questions (MCQ) questions using a Likert type scale, from 1 (never) to 5 (always) separated into two sections. The first section asked about specific techniques the physiotherapists use to treat PFPS, while the second section asked about specific tests and questionnaires they used to assess the syndrome. Respondents could expand on their clinical practice, as the last 7 items were open questions about assessment and treatment.

Questionnaire administration

The questionnaire was uploaded onto online survey software (www.surveymonkey.com) and was available for 4 weeks. The ESP sent an email (Appendix 3) with the survey link requesting that participants complete the questionnaire. The questionnaire took approximatel 20 minutes to complete.

Questionnaire Data Analysis

Data analysis was conducted using the online survey software. Percentiles were calculated fo participant responses on the MCQ questions. The corresponding response was clustered to th appropriate Likert type scale digit (0-5). A total percentage was also calculated for each question by dividing the average rating with the 5 subsections of the scale. Open questions were subjected to a content analysis (Mayring, 2000) by adding the number of similar answers given by physiotherapists. In addition, important quotes were inducted when physiotherapists wanted to describe different ways they use to assess or treat the syndrome.

Interview schedule development

The results of the questionnaire informed development of the interview schedule. A schedule was developed (Appendix 4) consisting of 17 broad questions to explore further the assessment and treatment methods physiotherapists use and their beliefs about the syndrome, what features they use to identify the syndrome and how they keep up to date. Three hypothetical cases were constructed and used as examples to elicit discussion about how physiotherapists treated different patients (Table 2). These 3 cases represented typical clinical presentations according to the ESP and were used to cover the broadest range of PFPS patients. Female examples were chosen because the syndrome is more common in females (Tumia and Maffulli, 2002). Interviewees were encouraged to discuss any issues relative to their rehabilitation practice about of PFPS. Each audio-taped interview took approximately 30-45 minutes. All interviews were performed by the author (principle investigator) who had previously attended a course on how to conduct interviews and what steps to follow in order to maintain objectivity.

PFPS-Case 1	PFPS-Case 2	PFPS-Case 3
Woman	Woman	Young female
26 years old	35 years old	17 years old
Elite runner (200m)	Works 8 hours per day	Overweight
Physically fit	3 children	Inactive
Excellent muscular tone	No time for practicing	College girl
Pain under the knee cap	Pain under the knee cap	Pain under the knee cap

Table 2. The three PFPS cases used as examples in the interviews

Data Analysis

Interview data

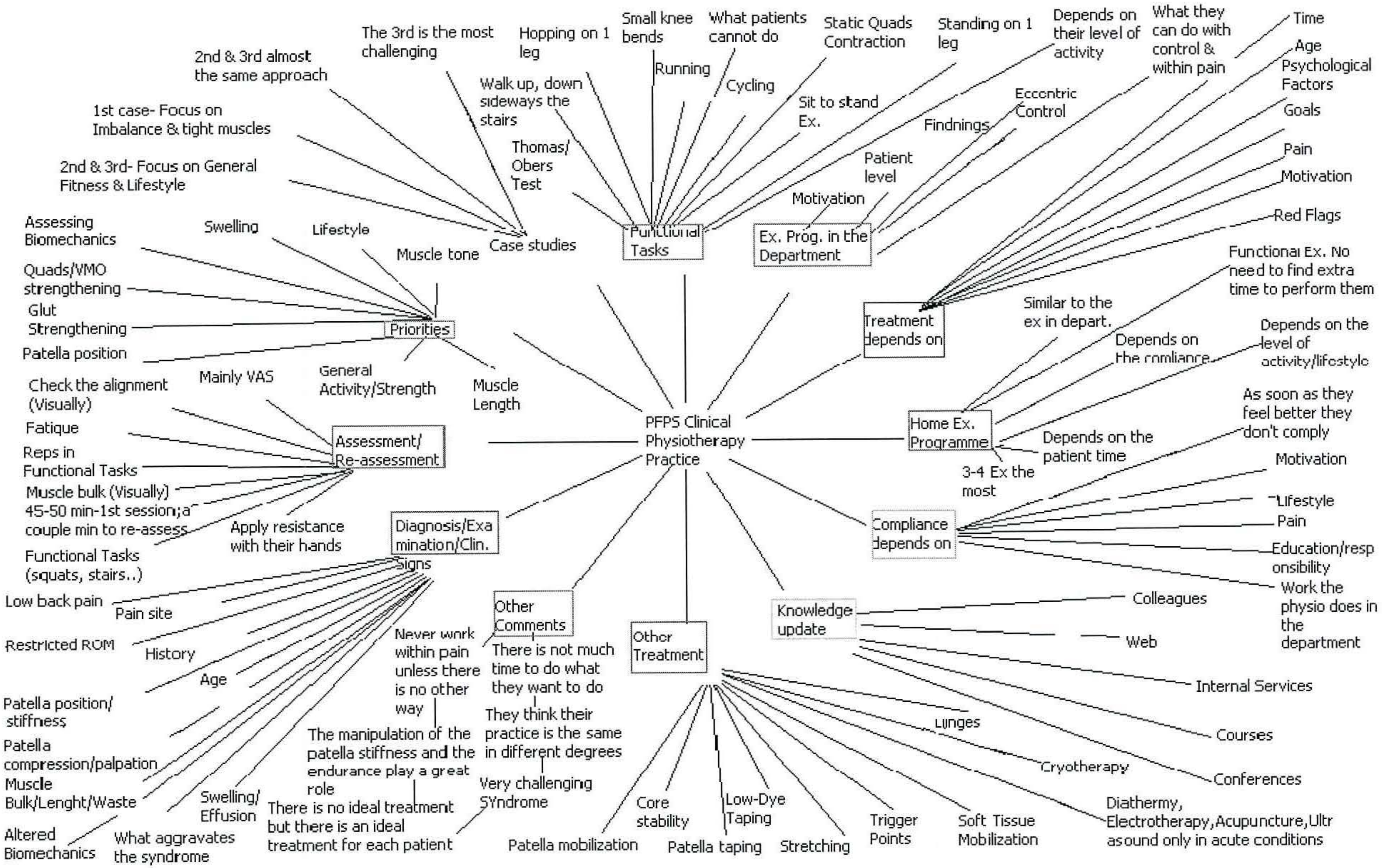
Audio-taped interviews were anonymised, transcribed verbatim and uploaded into the computer software package Atlas. ti, version 6.1.1 (GmbH, Berlin) to organise, analyse and sort data. Data were analysed using principles for analysing interview transcripts (Burnard, 1991). This method was used to code and categorise narrative data. The interviewer undertook the coding. Independent code checking was conducted by the rheumatologist team member.

As the qualitative data were to be triangulated against survey data, higher level themes were not developed. After initial reading and re-reading 12 categories (Figure 2) were generated then collapsed into 6 and refined through open coding which captured all issues of interest in the interviews. Each transcript was then coded according to the list of category headings, and in a further process, initial categories with similar content were collapsed and combined. The presented categorised findings comprise 2nd order constructs, which Noblit and Hare (1988) describe as integration of evidence into categories across transcripts. Each category is illustrated by participant quotes (1st order constructs). Where appropriate, reporting of conten analysis was integrated with categories to indicate magnitude of responses. The process was supported by regular team discussions and cross checking at each stage. As additional triangulation, interview data were subject to content analysis in which the number and frequency of assessment methods, treatment options and outcome measures were counted.

Overarching analysis and synthesis

Following analysis of questionnaire and interview data separately, the findings were merged together to report the results of assessment and outcome measurements, treatment methods of PFPS, treatment priorities and options, home exercise programme, acquiring and maintaining knowledge and skills and finally beliefs about the causes of the syndrome. This was followed by a synthesis and comparison of questionnaire survey and interview data.

Figure 2. The 12 Categories Generated By Interviews



Ethics

Ethical approval was granted by the local NHS research ethics committee (09WNo01/21) and the relevant university ethics committee. No written consent was obtained for the questionnaire survey and following standard practice consent was assumed if the questionnaire was returned. However, signed informed consent was obtained before each interview. Participants' personal details were available only to the researchers.

2.2.3 Phase 3 Utility review – measures and metrics in practice (chapter 5)

Aims of the study

The aims of the study were to identify:

a) Which of the tests commonly proposed by the NWW physiotherapists were reliable and which of the outcome measures were valid.

b) The sensitivity, specificity and predictive values of the clinical tests which could be identified as positive or negative.

c) The ability of the clinical tests to differentiate patients with PFPS from healthy controls with no knee pain and with patients with other lower limb conditions.

Methods

Overview

This study was divided into several smaller studies:

Part A: The test-retest reliability of the common outcome measures

Part B: The criterion validity of the common outcome measures

Part C: The sensitivity, specificity and predictive values of the clinical tests

Part D: The ability of the clinical tests to differentiate patients with PFPS from healthy controls with no knee pain

Part E: The ability of the clinical tests to differentiate patients with PFPS from patients with other lower limb conditions

Part A-D recruited the same Twenty NHS patients referred by their general practitioner or a consultant with a diagnosis of PFPS and 20 healthy controls with no knee problems. Part E recruited a further 26 PFPS patients and 26 patients with other lower limb conditions. All participants performed a series of strength, flexibility and outcome measurements as outlined below.

Setting

Part A-D took place in the physiology laboratories of the School of Sports, Health and Exercise Sciences (SSHES), Bangor University while part E took place in the local NHS physiotherapy department.

Ethics considerations

The study was approved by the School of Sport, Health & Exercise Sciences ethics committee of Bangor University and by the Betsi Cadwaladr University Health Board ethics committee (09/WNo01/29 and 10/WNo01/60).

Participant recruitment

Patients with PFPS were recruited from the local NHS district hospital in NWW. Parts A-D: The recruitment took place between January 2010 and October 2010. An extended scope senior physiotherapist identified the potential patients and sent a participant information sheet at patients' home address. The patients, who decided to take part in the study, contacted the researcher, who arranged an appointment at the physiology labs. The 20 healthy controls were recruited after the identification of the 20 patients with PFPS and were age, sex and weight matched. The upper age limit was decided to be '50'. The reason was that older patients could have other knee conditions such as osteoarthritis. Additionally, people up to this age can still be active enough to produce knee pain. The controls included students and staff members of SSHES and their recruitment was done by word of mouth. Patients and controls signed an informed consent at the day of their first participation.

Part E: twenty six patients with PFPS (17 women and 9 men) and 26 age- and sex-matched patients with other lower limb conditions participated in this study. Testing took place from February 2011 to November 2011.All participants were identified via an extended scope physiotherapist who sent an invitation letter and an information sheet to them. The potential participants were phoned by a rheumatologist and if they were interested the phone was handed to the researcher who arranged to see them after their first physiotherapy appointment. Participants were given at least two days to decide whether they chose to participate or not.

Inclusion/Exclusion criteria

Part A-D: The inclusion criteria for patients with PFPS were:

- The referral by a general practitioner or a consultant
- The age between 18 to 50 years old
- The ability to communicate in English.
- Ability to participate in both sessions (1^{st} and 2^{nd} week)

The exclusion criteria for patients with PFPS were

- The presence of other knee conditions such as knee ligament conditions/menisci conditions, history of trauma, previous knee surgery, history of true locking, history of patellar dislocation, history of arthritis, knee joint effusion, patellar tendinopathy, or the inability to attend all sessions (Crossley, et al., 2002).

The healthy controls were age, sex and weight matched with the PFPS patients whilst they should not have any problems on their knees. They had to agree to attend both sessions and were able to communicate in English.

Part E: The inclusion criteria for both groups were:

- Having been referred to the physiotherapy department of a NWW local hospital from their physician or consultant for assessment and treatment due to PFPS or any other lower limb conditions.

The other lower limb conditions included those of the knee (e.g. patella dislocations, ligament and menisci tears and syndromes of the knee different from PFPS), or the hip (e.g. unspecific hip pain, trochanteric bursitis) or the ankle (e.g. sprains, Achilles tendon problems, plantar fasciitis) or muscle tightness in the lower limb. The above conditions were all reported in patients' referrals and no further assessment was done by the research team during recruitment.

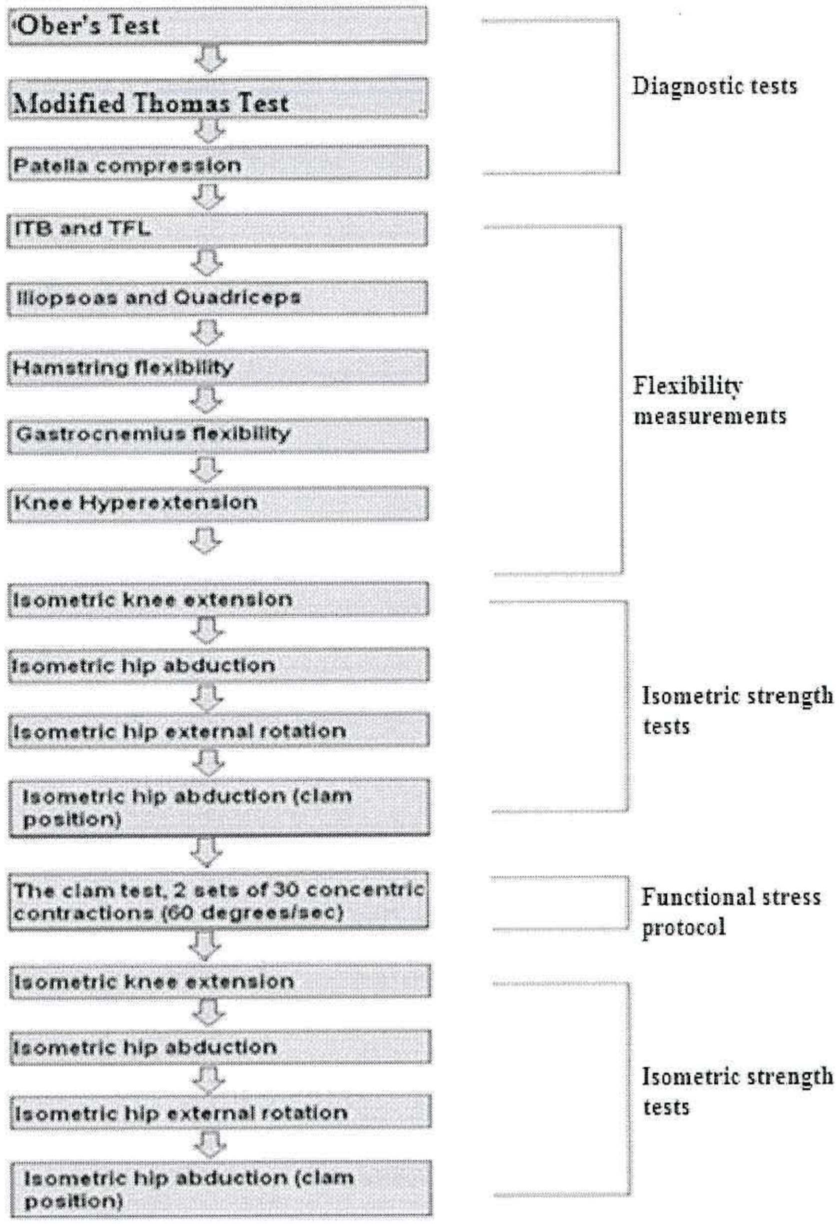
The exclusion criteria involved any open operation of the hip, knee or ankle, history of arthritis, neurological conditions, low back pain or sciatic pain, open wounds, fractures or the patient being unable to undertake both sessions.

<u>Test schedules</u>

Part A-D: Both the PFPS and control groups performed the same protocol twice with at least one week break between sessions (week 1 and week 2: Part A). Only data of week 2 were used for the identification of the clinical tests which could differentiate PFPS patients from healthy controls (Part D). Data from week 1 were only used along with the data of week 2 to check the reliability and criterion validity of the tests (Part A and B). The tests were performed by the author who has clinical experience in musculoskeletal disorders of the knee.

In Parts A-D three "diagnostic" tests for PFPS (Ober's, modified Thomas, patellar compression test) (Part C); five flexibility measurement tests (Ober's, modified Thomas, hamstring, gastrocnemius, knee extension); the patellar position test; and four isometric strength tests (knee extension, hip abduction, hip external rotation and abduction from the 'clam' position) were selected as the most common outcome measurements. The isometric strength tests were repeated after a functional stress protocol which intended to show whether patients with PFPS also have less muscle endurance. The repeatability of the tests was ensured by using the exact same methods in all sessions. When measuring the lower limb strength, belts were put on the pelvis and on the non-tested leg to ensure that there was no additional movement which could interfere with the results. Since physiotherapists reported that they strengthen gluteal muscles when treating PFPS patients (Chapter 4) the 'clam' test was also used to identify the endurance of those muscles. The order of the tests is shown in the flowchart (Figure 3) and their methods are described below. Fewer tests were used in Part E after several tests were deemed not to be as useful (less reliable, valid and unable to differentiate PFPS from healthy controls).

Figure 3. Flow chart to demonstrate testing protocol.



Abbreviations: ITB= Iliotibial Band, TFL= Tensor Fasciae Latae

“Diagnostic” tests methods

The Ober’s and the modified Thomas tests were used to report muscle tightness. In the current studies these two tests along with the patella compression test were also used as diagnostic tests.

Ober’s test

The Ober’s test is designed to show tightness of the ITB and TFL). The participant was placed in the side-lying position with the non-tested leg against the table and the knee and hip flexed to 90^0. The examiner abducted and extended the upper leg (tested leg), Then, the examiner allowed the gravity to adduct the hip. The tightness of ITB and TFL was measured in degrees with a goniometer (Absolute Axis, Baseline, New York, USA). The goniometer was placed at the ipsilateral anterior superior iliac spine with the steady arm parallel to the support surface and the moving arm aligned with the abducted thigh whilst. The measurement was taken when the gravity could not adduct the thigh any further (Reid et al., 1987).

Modified Thomas Test

This test is designed to demonstrate tightness of iliopsoas and quadriceps. To measure iliopsoas tightness, the axis of the goniometer (Absolute Axis, Baseline, New York, USA) was positioned on top of the greater trochanter, with one arm placed parallel to the longitudinal axis of femur and the other arm parallel to the mid-axillary line of the trunk. To measure quadriceps tightness, the axis of the goniometer was placed on the head of the fibula on the examined leg, with one arm being parallel to the longitudinal axis of the tibia pointing toward the lateral malleolus and the other parallel to the longitudinal axis of femur pointing towards the greater trochanter. The non-examined leg was fully flexed and held by the participant’s hands while the tested leg was extended by gravity. The maximal hip extension and knee flexion range of motion values were recorded when the gravity could not further extend the hip and flex the knee. No additional passive movement was performed by the researcher's hands in either hip extension or knee flexion (Harvey, 1998). A more positive hip angle value represents more severe tightness of iliopsoas whereas a more positive knee extension angle represents more severe tightness of quadriceps.

Patella compression test

In a supine position with the tested knee flexed to 20^0 the patella was compressed against the femoral groove. When participants reported this as painful , the test was recorded as positive (Niskanen, 2001).

Flexibility measurement tests

The following flexibility tests were performed with a goniometer (Absolute Axis, Baseline, New York, USA).

ITB and TFL

Measured by the Ober's Test and described in the diagnostic tests session (Vicente, 2006).

Iliopsoas and quadriceps

Measured by the Modified Thomas Test and described in the diagnostic tests session (Harvey 1998).

Hamstring flexibility

This test measures the flexibility of the hamstrings. Participants were in supine position. Two straps were placed, one on the non-examined leg; across the thigh and a second over the anterior superior spines of the ilia to stabilize the pelvis. A line was drawn between the fibula head and lateral malleolus of the leg. This line represented the longitudinal axis of the leg and was a reference of accurate placement of the goniometer. The examiner placed the hip to 90 degrees (confirmed by a goniometer) whilst participants held their knee flexed and the foot in plantar flexion. Then, with the hip stabilized at 90 degrees, participants actively extended the knee until they reached initial mild resistance. The angle of the knee was then recorded by the goniometer as the flexibility of the hamstring muscles (Gajdosik and Lusin, 1983).

Gastrocnemius flexibility

Participants were in supine position with the leg in an anatomical neutral position with the knee in full extension (0 degrees). The researcher stabilized the lower leg and the foot was left to take a neutral position. A measurement was taken in this position by a goniometer and then the foot was moved to ankle dorsiflexion (i.e. the gastrocnemius was stretched). The goniometer had the stationary arm on longitudinal axis of the fibula, whilst, the moving arm was placed parallel to the heel sole. A second measurement was taken when the researcher reached initial mild resistance (Clarkson, 2000)

Knee hyperextension

In supine position with the knee extended (0 degrees), the researcher put one hand above the tested knee, pushing the leg towards the bed whilst the other hand was passively raising the leg from under the foot. The goniometer was placed on the knee parallel to the thigh and tibia to measure the knee hyperextension (Clarkson, 2000).

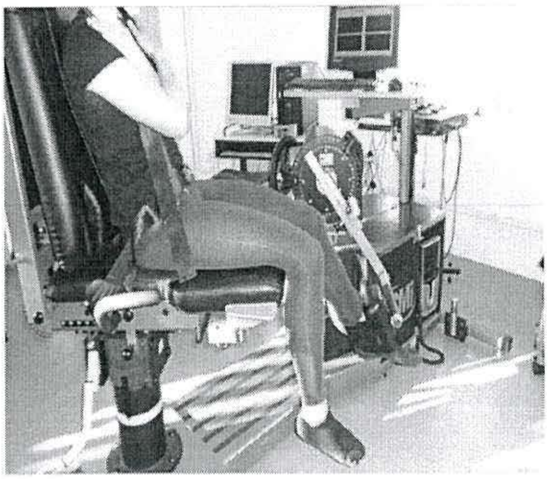
<u>Isometric strength tests</u>

The isometric contractions were performed on an isokinetic dynamometer, (Humac Norm type 770, CSMI), In each of the following tests, 3 isometric warm up tests approximately at 25%, 50%, and 75% of maximal strength were followed by four maximal voluntary contractions (MVCs). Only the strongest MVC was recorded. There was a 30 seconds rest between contractions and a two-minute rest between tests. The researcher encouraged the participants verbally.

Isometric knee extension test

This test measures the strength of the quadriceps muscles. Participants were placed in a sitting position with the knee extended at 60 degrees of full length extension and asked to forcibly extend their knee against the dynamometer. The hip was flexed at 90 degrees whilst the trunk, pelvis and foot were strapped tight with belts (Welsh et al., 1998), (Figure 4).

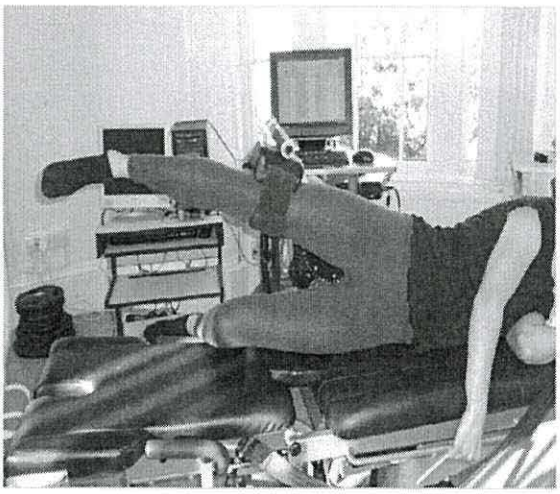
Figure 4. The isometric knee extension test



Isometric hip abduction test

The participant was placed in the side-lying position on the isokinetic dynamometer with th tested leg uppermost and the other knee flexed at 90 degrees. The spine and pelvis were then placed in neutral alignment and stabilised by the researcher's hands whilst the tested leg was strapped with the isokinetic dynamometer lever arm at 30 degrees of abduction. Participants put one hand under the cushion where they put their head and the other hand held the handle which was positioned under the bed. Then, they forcibly abducted their leg against the resistance of the dynamometer (Distefano et al., 2009); (Figure 5).

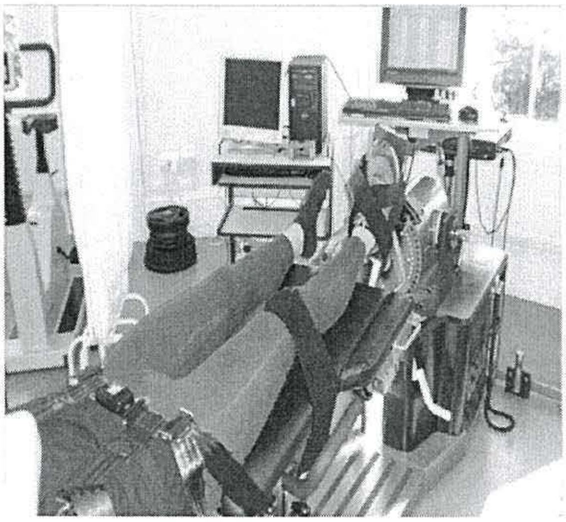
Figure 5. The isometric hip abduction test.



Isometric hip external rotation test

In supine position with both knees fully extended and the tested leg externally rotated to 5 degrees, participants were asked to rotate the foot externally against the resistance of the dynamometer. The pelvis and the tested knee were strapped with belts as no pelvic movement or knee flexion were allowed (Willson et al., 2008); (Figure 6).

Figure 6. The Isometric hip external rotation test



Isometric hip abduction from 'clam' test position

The 'clam' position was performed in a side lying position with the knees flexed at 90 degrees, the hips flexed at 60 degrees and the feet tied together with a belt. The tested leg was then abducted to 30 degrees and the participant was asked to push against the resistance of the dynamometer. The feet were strapped together with a belt; the belt kept the feet together but it did not put any resistance to the contraction. The researcher stabilised the pelvis whilst the participant held a handle with one hand which was positioned under the isokinetic dynamometer bed (Distefano et al., 2009); (Figure 7).

Figure 7. The isometric hip abduction from 'clam' test position

Functional stress protocol

A functional stress protocol was included because muscle dysfunction in PFPS sometimes only becomes evident when a muscle is stressed (Brooks et al., 1996).

The 'clam' stress test

The set up for the 'clam' test was the same as the isometric hip abduction from 'clam' test position (Figure 7). All participants were asked to perform 2 sets of 30 concentric hip abduction repetitions (60 degrees/sec) against the resistance of the isometric dynamometer. The range of motion was from 0 to 30 degrees. The mean score of the 30 repetitions was calculated (N x m/weight). There was a 2-minute break between sets.

The same isometric strength tests on the isokinetic dynamometer were repeated 5 minutes after the stress 'clam' test.

Pain Scales

All participants were asked to complete six pain scales.

- AKPS [(Kujala et al.,1993) (Appendix 5)]
- LEFS [(Binkley et al.,1999) (Appendix 6)]
- Visual analogue scale (VAS) for usual pain VAS-U [(Crossley et al., 2004b) (Appendix 7)]
- VAS-WP (worst pain in the previous week) (Crossley et al., 2004b)
- VAS-LBP (low back pain) (physiotherapists reported they ask PFPS patients for any LBP)
- VAS-'clam' (pain during the functional stress 'clam' test)

Statistical analysis

In order to assess intra-rater reliability the measurements were taken by the same practitioner, whilst, to assess test-retest reliability all the participants visited the laboratory twice and performed the same tests. Scales were tested for criterion validity (Bent et al., 2009).

Part A: Intra-class correlation coefficient (ICC) along with Bland and Altman plots scales (check appendix 8) was performed to assess intra-rater and test-retest reliability (Kottner et al., 2010).

Part B: To establish criterion validity five scales (VAS-W, VAS-clam, VAS-LBP, AKPS and LEFS) were checked against the VAS-U which is a valid measure and has been used in previous studies to assess PFPS condition (Crossley et al., 2004b). Additionally, it was the only one outcome measurement that physiotherapists reported they would use in the clinic.

The three VASs were multiplied by ten so that the final score would be out of 100 whereas the LEFS, which has 80 as final score, was divided by 80 and then multiplied by 100. Finally AKPS score is out of 100 hence, the final score was correlated with VAS-U. Intraclass correlation was then measured between each scale with the VAS-U. The strength of the correlation was determined by Cohen (1988) whilst the statistical significance indicated how much confidence should be obtained by the results (Kottner et al., 2010). According to Cohen (1988) a correlation can be defined as large when measurements are above 0.50. However, different authors suggest different interpretations (Pallant, 2007); Bent et al. (2009) reported that a correlation above 0.70 can be considered acceptable. In order to be firm with measurements, 0.70 correlation was decided to be the criterion to define whether the measurements should be considered acceptable or not. Between 0.50 and 0.69 the measurement was moderate whilst, below 0.50 the measurement was considered small. Additionally, Bland and Altman plots were also performed to determine the correlation of VAS-UP with the rest of the scales (check appendix 8).

Part C: To test the predictive values of the tests defined as positive or negative (Ober's test, Modified Thomas test, patella compression) the proportion of true positive measurements (sensitivity) and the proportion of true negative measurements (specificity) were identified. In addition, the predictive values of positive and negative tests were also calculated (Marshall & Bangert, 2008).

Part D: Independent t-Tests were conducted to identify anthropometric differences between the PFPS and the control group. The same analysis was used to identify differences in terms of strength and flexibility between groups. The greater of the two maximum contractions was only used for analysis. The isometric strength results were also normalised by participant's body weight to mitigate the tendency of heavier participants to show greater strength. In addition, a mixed method ANOVA was conducted to identify the effect of task on participant isometric activity. Finally, the performance in the first and the last five repetitions of each set of the functional stress 'clam' was analysed using independent t-tests between the PFPS and control group and paired t-Tests between the first and the last five repetitions to demonstrate the rate of activity reductions in 'clam' position.

Part E: Sample size calculation: The sample size of this study was calculated by an online calculator for observational, cohort and clinical trial studies (www.sph-emory.edu/). The two-sided significance level was set at 0.05; the power (1-β, chance of detecting) was set at 80%; the ratio of sample size, non-exposed/exposed was set at 1.00 and the risk/prevalence difference was set at 0.30). The two groups were calculated to include 26 participants each.

The characteristics (height, weight, age,) of the two groups (PFPS and other lower limb problems) were compared using the independent t-tests or Chi-square tests, depending on the level of data. Paired t-Tests were used to compare the pre-and post-functional stress 'clam' protocol. The same analysis was also conducted for the pain experienced between before (VAS on the day) and after the stress 'clam' protocol (VAS after the functional stress 'clam'). The value for significant difference was set at 0.05. SPSS 17v (IBM, New York, USA) was used for all statistical analysis. Finally, for the Modified Thomas test & patella compression test, the proportion of true positive measurements (sensitivity) and the proportion of true negative measurements (specificity) were identified. In addition, the predictive values of positive and negative tests were also calculated (Marshall and Bangert, 2008). Using the suggested cut-off point of previous authors, (Marshall and Bangert, 2008) the cut-off point for sensitivity, specificity and predictive values for this study was chosen to be 90%.

SPSS version 17 was used for all the analysis. The threshold for statistical significance was set at $p=0.05$. Data are shown as mean ± SD.

2.2.4 Phase 4: Review of applied programme – scale as case focus (chapter 6)

Aims of the study

This study aimed to identify the reliability and usefulness of two common questionnaires relating to PFPS

Methods

The same twenty PFPS participants as per Chapter 5 were used for this study. As part of this study they completed the AKPS and the LEFS on the two different occasions. The time lapse between outcome completions was maximum two weeks. This practice does not allow patients remember the answers they gave in the previous occasion. In addition, the two weeks period was short compared to the time they had to wait before they started having physiotherapy. This, along with the suggestion to keep their activities in similar levels during this time lapse kept the likelihood for any condition change to the minimum. The patients, who had been in pain for 62.20 ± 61.90 (mean ± SD) months, completed both questionnaires by following the instructions without any assistance.

The study was covered by the ethical approval described in Chapter 5 (09/WNo01/29).

Statistical methods

Test-retest reliability of the scales was performed by Intra-Class Correlation (ICC). The overall scores of the scales that participants completed in the first session were correlated wit the overall scores of those in the second session. To identify how reliable each of the questions was, the internal consistency of each scale was reported along with how this would change if each of the questions was deleted. This was performed by reporting the Cronbach's alpha on SPSS (IBM New York, USA, v.20). Cronbach's alpha determines the internal consistency or average correlation of any items within a questionnaire or scale to gauge their reliability (Reynaldo and Santos, 1999). If the reliability of the scale becomes larger when an item is deleted, this means that that question lowers the overall reliability. In addition to this, test-retest reliability was also measured for each single question between the first and the second session. This would reveal whether each question can report the same value at two different times (Reynaldo and Santos, 1999). A value of 0.70 was set as cut-off point. In addition to the ICC, the standard error of measurement was also calculated for each single question to assess how confident we can be with the 'true' score of each question (Mollenkopf, 1949).

To find which of the questions were less meaningful, the questions within the two scales that were answered as 'no problem' in both sessions were identified. Such questions cannot change the overall score of the scales; therefore, they have no clinical value and should be excluded from a scale which measures PFPS conditions. According to the answers received it was decided that the cut-off point for a question to be considered as meaningful would be when at least 10 out of 20 participants reported a question as 'no problem' in both sessions.

2.2.5 Phase 5: Practitioner as context (Chapter 7)

Aims of the study

This study aimed to identify the effect of physiotherapy treatment on patients with PFPS after a six-week treatment.

Methods

Recruitment method

All potential participants were identified by an extended scope physiotherapist who searched the NHS physiotherapy referrals. An invitation letter and an information sheet were then sent to them. Potential participants were phoned by the rheumatologist (JJ) and if they were interested the phone was passed to the researcher who arranged a meeting after the first physiotherapy appointment. Participants were given at least two days to decide whether to participate. The first assessment took place directly after the first treatment session with the physiotherapist; the second assessment took place directly after the last physiotherapy visit which was approximately after 5-8 weeks. In this study there was only an experimental group whilst, no control group was involved.

Ethical approval was granted by the local NHS research ethics committee (10/WNo01/60). Informed consent was obtained from all participants before data collection was initiated.

Participant inclusion/exclusion criteria.

PFPS participants were referred to the physiotherapy department by their general practitioner or hospital consultant for assessment and treatment of PFPS.

The inclusion criteria for the PFPS group included the diagnosis of PFPS by a general practitioner or hospital consultant and their referral to the physiotherapy department.

The exclusion criteria for the PFPS group included the presence of other knee conditions such as knee ligament conditions/menisci conditions, history of trauma, previous knee surgery, history of true locking, history of patellar dislocation, history of arthritis, knee joint effusion, patellar tendinopathy, or the inability to attend all sessions (Crossley et al., 2002).

Procedure

After participants had received their first session of physiotherapy they met the researcher who was blinded to the patients' diagnoses and asked them to complete a consent form. Details of the participants' weight, height and age were recorded. Participants were then aske[d] to complete a series of questionnaires and scales. Only the clinical tests which were found to be reliable valid and able to differentiate PFPS patients from healthy controls were used to identify the effect of treatment. Following this, a number of physical tests were performed (see below).

After they had received their final treatment and were ready to get discharged, participants filled in the questionnaires and scales again and repeated the clinical tests.

Diagnostic tests

Two tests were performed:

- The Modified Thomas test
- The patella compression test; in which participants report whether compression of the patella caused pain

For both tests sensitivity, specificity and positive and negative predictive values were calculated.

(For more details about the tests see Chapter 5).

Flexibility tests

Two tests were performed:

- The Modified Thomas test measuring hip and knee flexion.
- The hamstrings flexibility test

(For more details about the tests see Chapter 5)

Strength tests

Participants were then asked to complete a series of strength tests on the portable dynamometer (described in Chapter 5 and Appendix 9). Seven contractions (each of them lasting for five seconds) were completed for each test. The first 3 were a warm up of 25%, 50% and 75% of their maximum strength while the last 4 100% MVCs. There was a two-minute break between the contractions.

The tests involved:

- Isometric knee extensions from sitting position with the knee extended to 60^0
- Isometric hip external rotation from supine position with the tested leg rotated externally to 5 degrees
- Isometric hip abduction from 'clam' position

(See Chapter 5 and Appendix 9 for details)

Functional stress protocol

Participants then performed a functional stress protocol involving two sets of 30 repetitions from a 'clam' position to 30 degrees of hip abduction with a red thera-band® (The Hygenic corporation, Akron Ohio, USA) around both of their knees. The red thera-band® (4 pounds force in 100% elongation) is an elastic band physiotherapists use in the clinic when they prescribe resistance exercises to their participants. The band was tied tightly around the knees During the protocol the researcher held a t-shape standing measure which was adjusted to show each participant the position of 30 degrees of hip abduction. The knee had to touch the t-shape tool on each repetition of the protocol. There was a two-minute break between the two sets.

As soon as the functional stress protocol was completed, two more maximum isometric contractions from 'clam' test position were immediately performed using the portable dynamometer. The first contractions was used to identify how much the functional stress protocol had reduced the participant's activity and the second, which took place two minutes later, was used to assess the ability to recover.

Questionnaires and Scales

Although the AKPS and the LEFS were found to have questions not specific for PFPS (Chapter 6), their reliability and validity total scores were found to be significant (Chapter 5).

In addition, the MAKPS has not been validated; thus, it should not be used in isolation. Therefore, all three scales (MAKPS, AKPS & LEFS) were used in this study.

Along with the three scales and the two VASs adopted by the MAKPS, (a VAS for usual pain and a VAS for pain on day of the assessment) participants also completed one more VAS for pain after the functional stress 'clam' test. The VAS for pain after the functional 'clam' was found to have moderate validity when compared to VAS for usual pain (Chapter 5). However, it was used in this study to show whether the stress 'clam' increased the pain PFPS patients experienced on the knee. Participants were asked to pencil vertically on a 10-cm line (from 'no pain' to 'pain as bad as it could possibly be') according to the pain they experienced after they performed the 'clam' test. The proportion of pain decrease or increase after the stressing 'clam' performance was measured by comparing the results of VAS 'clam' and the pain they had on the day they visited the physiotherapy department (VAS included in the MAKPS) and not to the VAS for usual pain. The questionnaires and the VASs were completed at both sessions. After the follow-up session all participants received £10 in high street vouchers. Participants completed a form confirming they had received the vouchers.

Data and statistical analysis

A goniometer (Absolute Axis, Baseline, New York, USA) was used to measure all flexibility tests in degrees, while for the strength tests a peak value was measured using chart 5® software for windows. Only the highest out of the 4 MVCs was used for analysis. The strength produced was normalised by participant weight.

Paired t-tests were used to identify the effect of physiotherapy treatment in patients with PFPS after a six-week physiotherapy treatment. The effect size 'r' was also measured by using the Cohen's d given by the equation: '$d = \frac{\chi pre - \chi post}{SD}$,' where χpre was the average mean of pre-treatment, χpost was the average mean of post-treatment and SD was the Standard Deviation

(Thalheimer & Cook, 2002). When using this equation the effect sizes 'r' of .20 are small, .50 are medium, and .80 are large. Chi-square tests for the diagnostic tests before and after treatment were also performed whilst paired t-tests were performed to identify difference between pre and post 'clam' activity; before and after treatment.

Ethical approval

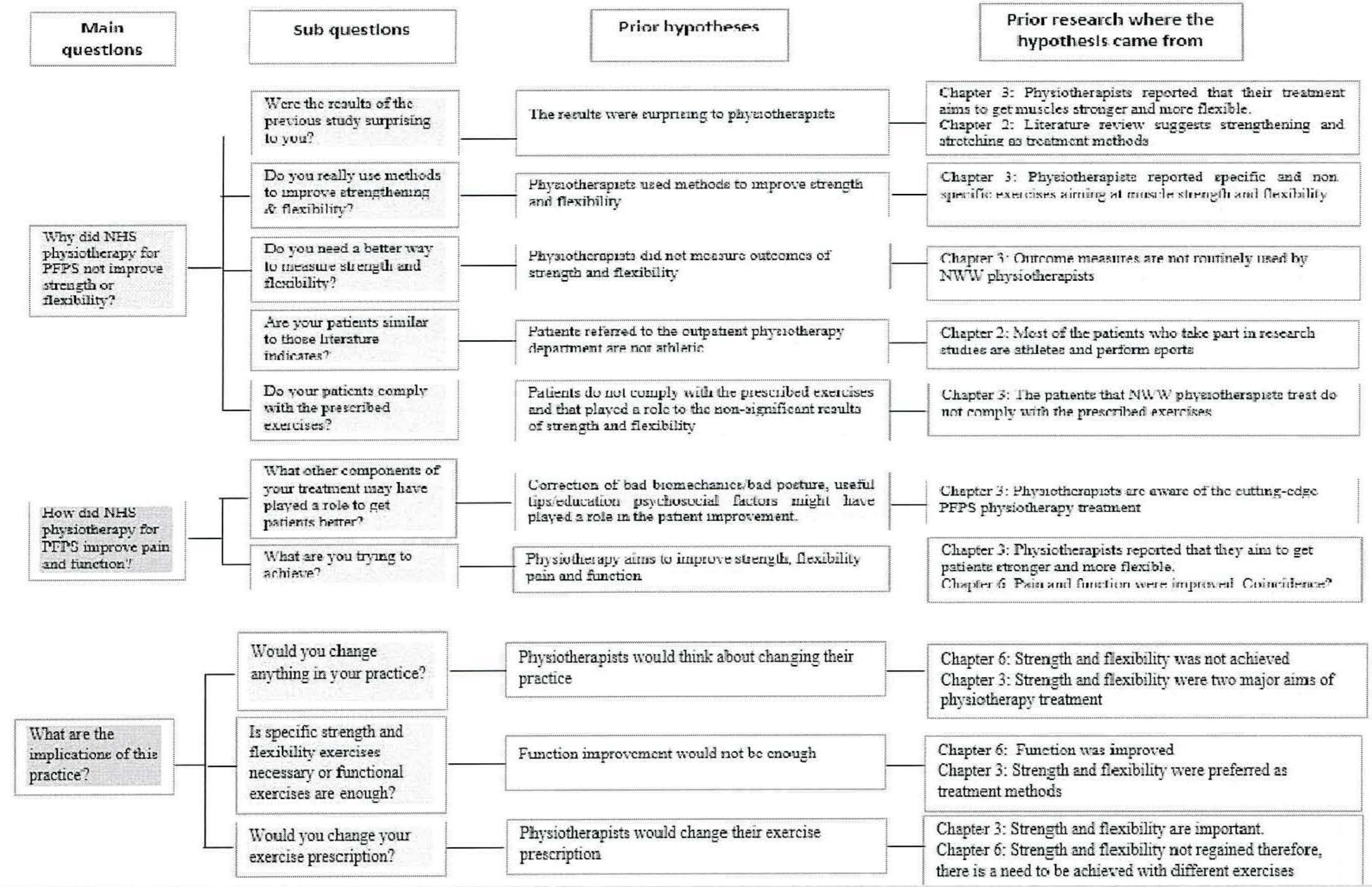
The study was approved by the ethics committee of the School of Sport Health and Exercise Sciences and the Betsi Cadwaladr University Health Board (10/WNo01/60).

2.2.6 Phase 7: An evaluation of the role of physiotherapy and applied practice on pain and function (chapter 8)

Aims of the study

The aim of this study was to establish NWW physiotherapy treatment of PFPS and report the barriers that stopped physiotherapists from increasing strength and flexibility and the contradictions of physiotherapists' beliefs regarding their PFPS practice. The investigation was based on specific and priori designed questions. The questions, sub questions, prior hypotheses where the source of evidence for each hypothesis came from, are presented in the figure below (Figure 8)

Figure 8. The 'A priori framework'



Methods

Britten's methodology was used for this focus group study (Britten, 1995). This study reports three types of interviews; structured, semi structured and depth. In this study, the semi structured type was used which consists of loose structure including open ended questions that define the area to be explored. The interviewer and the interviewee may diverge from this area hence; they can pursue an idea in more detail (Britten, 1995). The applicability of the semi structured type of focus groups in this study lies in the fact that there were specific questions that the interviewees had to answer; however there was an initial diverge from what physiotherapists and the researcher beliefs about the effect of physiotherapy practice in PFPS patients.

Focus groups have several disadvantages; e.g. they tend to become influenced by one or two dominant people in the session, thus, making the output biased (Creswell, 1998). The moderator plays an important role in handling the situation of the whole discussion to be dominated by a few people. Additionally, focus groups are not as effective as individual interviews when dealing with sensitive topics. In such a case participants do not share their real feelings towards some sensitive topics publicly. This can in turn influence the output data. Moreover, focus group output is not projectable. If lots of consistency in the results from a series of focus groups have been reported then it is very likely that the results from these sessions probably can represent a larger number of people. However, it is not expected focus groups to be projectable in the same way as quantitative study findings can be (Krueger & Casey, 2000). In addition, focus groups are very artificial environment which can influence the responses that are generated. This is frequently the argument that ethnographers will use when recommending their methodology versus focus groups. Because researchers using the ethnographic technique will situate themselves in the real environment, that is unreachable for focus groups. In focus groups people are collected in a meeting room thus they might behave differently from how they behave when they are not watched and it will affect the quality of research results (Fern, 2001).

However, focus groups also have important advantages compared to individual interviews. Focus groups encourage participation from those who are reluctant to be interviewed on their own and that they allow comparison of individual opinions after interactive discussion. In focus groups natural conversation will be produced because individuals are allowed to laugh, tell personal stories, revisit earlier questions, and disagree with other research (Kitzinger, 1995). Additionally, in focus groups every participant is under observation by the moderator and assistant moderator, thus, it is easy to make participants fully engage even during non-discussion time. The reason for choosing focus groups in this study was because it was hoped that it would be possible to come to a consensus regarding PFPS physiotherapy practice and this could only come about if those who deliver physiotherapy practice participated in the study. Consensus was achieved by using Onwuegbuzie's principles (Onwuegbuzie et al., 2009) who recommended that the assistant moderator must use template sheets with the focus group questions and the answer that every member gives during the sessions. This would not be feasible if individual interviews were used.

The Ritchie and Spencer (1994) method of qualitative data analysis was selected because this framework was developed explicitly for more applied qualitative research and it has an appeal to all those working in public health and related fields. This framework analysis is particularly appropriate when a study has clear aims at the outset.

In the present focus group study, the findings of previous studies were taken and their application and 'truth value' were explored with NHS physiotherapists who treated PFPS. In addition, this framework analysis could usefully be mapped to a Priori hypothesis that had some initial development ahead of the focus groups.

Ethical approval

Ethical approval was sought from the Ethics Committee of the School of Sports Health and Exercise Sciences, Bangor University, whilst, research and development (R&D) approval wa obtained by the Betsi Cadwaladr University Health Board. Written participant information sheets were given to all physiotherapists at least 24 hours before they decided whether to take part in this study or not. Consent forms were signed by physiotherapists on the day of their participation. All information collected about participants was kept strictly confidential. Any information about the participants had their name removed and were identified by a number so they could not be recognised from it. Participants' personal details were available only to the researcher. The participants received a five pound High Street voucher after the focus group study was completed.

Recruitment/participants

Physiotherapists at the local hospital who treated patients with PFPS were asked to participat in this study. The researcher did not approach any of the physiotherapists. An Extended Scop (ES) physiotherapist (MB) did the recruitment by informing her colleagues about the study and by giving them the participant information sheet. A few dates were proposed as the most feasible for the focus groups. The physiotherapists informed the ES physiotherapist about which of the proposed dates suited them better. The dates with the most available physiotherapists were set as focus group days.

Data collection

Ideally, focus groups should have between 4 and 8 participants in order to facilitate interaction and discussion between participants to explore specific issues or topic of interest (Johnson & Christensen, 2004). Two separate focus groups were planned in the physiotherapy department. The first focus group was performed at 9 am UK time and included five physiotherapists. The second was performed at 1 pm (same day with the first focus group and same time zone) and included seven physiotherapists. The first group had more years of physiotherapy practice (13.80±8.80 years) than the second group (8.20±4.30 years). Table 3 shows the characteristics of the physiotherapists who took part in this study.

Focus group 1	**Sex**	**Years of practice**
P1	Female	20 years
P2	Female	20 years
P3	Male	8 years
P4	Female	1 years
P5	Female	20 years
Focus group 2	**Sex**	**Years of practice**
P1	Female	10 years
P2	Female	5 years
P3	Female	6 years
P4	Male	10 years
P5	Male	10 years
P6	Female	2 years
P7	Female	15 years

Table 3. Physiotherapists' characteristics of the two focus groups

The duration of the focus groups was between 45 and 70 minutes long. In order to get the most of the interviews and to achieve a good quality of sound a quiet room was chosen. Participants were asked to sit in a circle. A table and water were available. Both focus groups were conducted by the main investigator (author of this thesis) who got trained by experienced focus group researcher of the school of Healthcare Sciences, Bangor University, UK. The main investigator read the pre-scheduled questions, handed out the figures of the results of the previous study and encouraged participants to discuss and interact. Since one of the aims of the focus group study was to reach a consensus on specific questions an assistant moderator who was another PhD student with previous experience in qualitative interviews was participated in both sessions. According to Krueger (1994) it is ideal for the focus group to have an assistant moderator. The assistant moderator was responsible for facilitating the discussion, prompting members to speak, requesting overly talkative members to let others talk and encouraging all members to participate. This happened in a non-directive and unbiased way. The assistant moderator was also used as a scribe who wrote down the participants' reaction to their colleagues' responses on a large sheet of paper. The 'assistant moderator' was given prompt questions (questions and sub questions) that the researcher was planning to use beforehand. For each question, the assistant moderator reported a positive or negative expression for all participants according to what they said or their body language (nods or shakes of the head for 'no' or other small verbal or facial expressions) (Morrison-Beedy et al., 2001). The main reason for having an assistant moderator to facilitate this study was to measure the level of consensus in the answers physiotherapists gave. This was a very important element not only for the present study but for the whole thesis which aimed to establish the current PFPS physiotherapy practice.

Before interaction between physiotherapists got started, participants were provided with two supplemental documents which included one figure and three tables (Appendix 11 and 12). These documents reported the major results of the effect of treatment study. The tables and the figure were used to explain the findings of the study to the participants. After this, the participants were asked to discuss the major questions and sub questions of the a priori framework.

Data analysis

Audio-taped interviews were anonymised, transcribed verbatim and uploaded into the computer software package *Atlas. ti,* version 6.1.1 (GmbH, Berlin) to organise, analyse and sort data. Data were analysed independently by two researchers. The analysis was subjected to the framework analysis of Ritchie and Spencer (1994).

Ritchie and Spencer (1994) described five stages in framework analysis. The first step was *familiarisation.* As the focus group study was designed to bring together findings from previous studies in the thesis, the process of familiarisation involved making explicit previous study and the review of reviews findings that warranted further explanation and drawing out a set of questions and hypotheses to be explored and tested in focus groups with physiotherapists. The second step was *identifying a priori framework of questions, sub questions and hypotheses to guide interpretation* of focus group evidence (see Figure 8). The third step was *indexing*. In this stage the a priori framework was applied to the whole focus group data set. To enhance scientific rigour, three review authors (KP, JT and JJ) read and re-read the transcripts and applied the priori framework moving back and forth between the data and the framework and searching for evidence linking with each hypothesis (Carr et al., 2003), which was then discussed with all review team members. The boundaries of the emerging explanations and complexity between the explanations were discussed among the authors. The fourth stage was *charting*. In this stage, data were rearranged in charts to align related evidence with specific hypotheses. Finally, the fifth stage was *Mapping and interpretation.* Evidence was mapped against specific hypotheses and used to support or refute and where appropriate seek out varying explanations.

The assistant moderator was asked to keep notes according to the responses to the prompt questions. Consensus was considered as high when 11 or 12 (all), moderate when 8-10, and low when 1-8 physiotherapists expressed the same opinion. Additionally, factors including frequency, emotional expression and extensiveness of the comments were also considered during the process (Patton, 2002; Krueger and Casey, 2000). The assistant moderator was also asked to add any other issues discussed during the interviews and the way physiotherapists responded to them (Heidegger, 1962). This helped in identifying explanations and ideas discussed during the interviews relevant to the issue of why physiotherapists did not increase strength and flexibility while they improved function and pain.

Finally, with evidence from other studies of this thesis, focus group evidence was used in an overarching synthesis to bring together findings to show the unique contribution of the thesis and draw conclusions for future research, education and practice (see thesis conclusions).

2.2.7 Phase 7: Modelling

The work of Stake (2000) centred on comparison and directed the modelling phase focused on 'storyline' development across the cases. The case reports from each phase were subject to a comparative analytical process in order to draw out the particular and commonality across cases.

Approach to synthesis and analysis

The theory-building properties of grounded theory (Glaser and Strauss, 1967; Glaser 1978; Charmaz, 2006) were utilised to provide additional rigour to the reflective process of the across-case analysis within the synthesis of findings from the collective case study approach. Glaser (1978) argues grounded theory provides an approach to analysis that may be used in a variety of data contexts, defined as a dynamic and creative process that develops categories to concepts to theories through a process of sorting out what is 'core' to the theoretical story. Once such a theoretical story is developed, it identifies the processes that underpin the phenomenon, which in this study focused on the nature of applied physiotherapy practice regarding PFPS and strategies for improvement. In this way, theory is allowed to emerge from the data using the techniques of Constant Comparative Analysis (Glaser and Strauss, 1967; Glaser, 1978) as the technique for achieving the 'comparisons' and 'Triangulation' stages of Stake's (2000) method in case study analysis. This allowed the researcher to identify the categories operating across the phases of the thesis as distinct cases and seek out the 'theoretical story'. Also using the grounded theory form of analysis enabled the researcher to structure his reflections as part of the iterative process of 'reflection' required by Stake being precise to process, meaning and inter-case comparison whilst seeking the overall 'storytelling' (2000). As Stake (2000) argues the researcher should 'place your best intellect into the thick of what is going on. The brain work ostensibly is observational, but more basically it is reflective' (page 445). As a consequence the researcher conducted a further sequence of analysis across the individual cases represented by the respective phases during 2014-15 and re-engaged in the primary data, particularly exploring the explanatory 'storytelling' of PFPS applied practice generated from the mixed-methods dataset developed during the study. As a consequence the analysis constructed a synthesis of the overall findings that secured further insight into the applied social world of the physiotherapist in clinical practice and identified opportunities for further innovation.

2.3 SUMMARY

The chapter has provided an overview of the approach utilised to guide the study. The author utilised a case study approach to construct an understanding of the phenomenon, using diverse elements of the case. These elements included a scoping process utilizing a review of reviews; an applied PFPS review identifying the PFPS assessment and treatment in practice; an utility review searching the measures and metrics (including scales) in practice; an overview of practitioner context in the frame of PFPS treatment effectiveness and an evaluation of the role of physiotherapy and applied practice on pain and function.

CHAPTER THREE: PHASE 1 - DEVELOPING THE RESEARCH QUESTION: A SCOPING PROCESS UTILISING A REVIEW OF REVIEWS

3.1 INTRODUCTION

The literature shows a growing number of published studies on healthcare interventions every year (Ghersi & Pang, 2009). One category of healthcare intervention that contains nebulous pathophysiology is Patellofemoral Pain Syndrome (PFPS) (Cook et al., 2010). This review was conducted to provide background information for exploring the research question integrating evidence from 1993 to 2013. Back in 2008 at the design of the PhD the initial part of the review of the literature revealed that there was limited evidence on how NHS physiotherapists assess, treat, and measure outcomes when they deal with PFPS patients. Therefore, the review was designed to report on literature regarding PFPS assessment, treatment and outcome measures.

3.1.1 Strategies and approaches

A quick database search shows that in 2012 there are more than 70 published studies on PFPS, while there were less than 50 in 2008. This rapidly growing evidence base makes it hard for people involved in providing care to choose from the best quality studies when making decisions (Smith et al., 2011). Researchers have identified this problem and started gathering these studies in systematic reviews in order to appraise and summarise evidence (Smith et al., 2011). Recently, a need for 'rapid reviews' to provide decision-makers with evidence has become apparent, however; these reviews can be sometimes problematic (in terms of their quality) compared to full systematic reviews (Gannan et al., 2010). As the number of reviews began to grow, so have the number of protocols for the conduct of systematic reviews. One such an example is the Cochrane Collaboration where only one review was available by 2008 while since then; eight more reviews have been published (The Cochrane Collaborations).

Lately, researchers and decision makers have started to confront an overflow of reviews (Bastian et al., 2010; Moher et al., 2007). From July 2012 to March 2013 the British Journal of Sport Medicine alone has published 4 systematic reviews on PFPS (Oliveira & Henschke, 2012; Collins et al., 2013; Lankhorst et al., 2013; Barton et al., 2013). Because there are several reviews on similar topics and because it is likely for reviews to be of varied scope and quality, a growing interest of systematic review of reviews (RoR) has been called for (Smith et al., 2011). For example, there are several reviews on PFPS conservative/non-operative treatment (Collins et al., 2012; Bolgla & Boling, 2011), suggested exercises for PFPS treatment (Frye et al., 2012; Harvie et al., 2011), clinical tests for PFPS diagnosis (Nunes et al., 2013; Cook et al., 2012), and factors associated with PFPS (Pappas & Wong-Tom, 2012; Lankhorst et al., 2013). Only one previous RoR on PFPS has been published to date and that was about the quality of the systematic reviews on nonpharmacological conservative treatment for patellofemoral pain syndrome (Barton et al., 2008).

3.1.2 Objectives

The overarching aim to conduct the review was to identify all published systematic reviews, reporting evidence on PFPS risk factors, diagnostic clinical tests, the clinometric properties of outcome measures and treatment, representing a review of reviews (RoR). The secondary aim was to determine the context and characteristics of participants in included studies to see how they compare with routine NHS PFPS patients referred to the physiotherapy department in a district general hospital in NWW.

Following the Smith et al. (2011) approach for conducting a review of systematic reviews in healthcare interventions, the PICOS (participants, interventions, comparisons, outcomes and study design) structure was used to frame the scoping process:

3.1.3 Review Objectives

1. To determine the risk factors for patients with PFPS reported in randomised control trials (RCTs), case control, cohort, cases studies, case series, expert's opinion and formal consensus studies.
2. To identify the clinical tests used for the diagnosis of PFPS reported in RCTs, case control, cohort, cases studies, case series, expert's opinion and formal consensus studies.
3. To identify the outcome measurements used in PFPS, and their clinometric properties reported in RCTs, case control, cohort, cases studies, case series, expert's opinion and formal consensus.
4. To determine the effectiveness of exercise-based interventions for PFPS reported in RCTs, case control, cohort, cases studies, case series, expert's opinion and formal consensus studies.
5. To determine the characteristics of included study participants (adults) and the individual included study context.

3.1.4 Review questions

1. 'What are the risk factors for adult patients with PFPS across study types and patient groups'?
2. 'What diagnostic clinical tests are used for adult patients with PFPS'?
3. 'What outcome measures are used in adult patients with PFPS' across study types and patient groups'?
4. 'What exercises are effective for adult patients with PFPS'?

5. 'What are the types/characteristics/demographics of patients that studies recruit?'

6. 'In what settings and in which countries were the studies conducted'?

7. 'What was the sample size in each included study'?

8. 'Was a dynamometer used to measure strength, and if so, what type and setting was it used'?

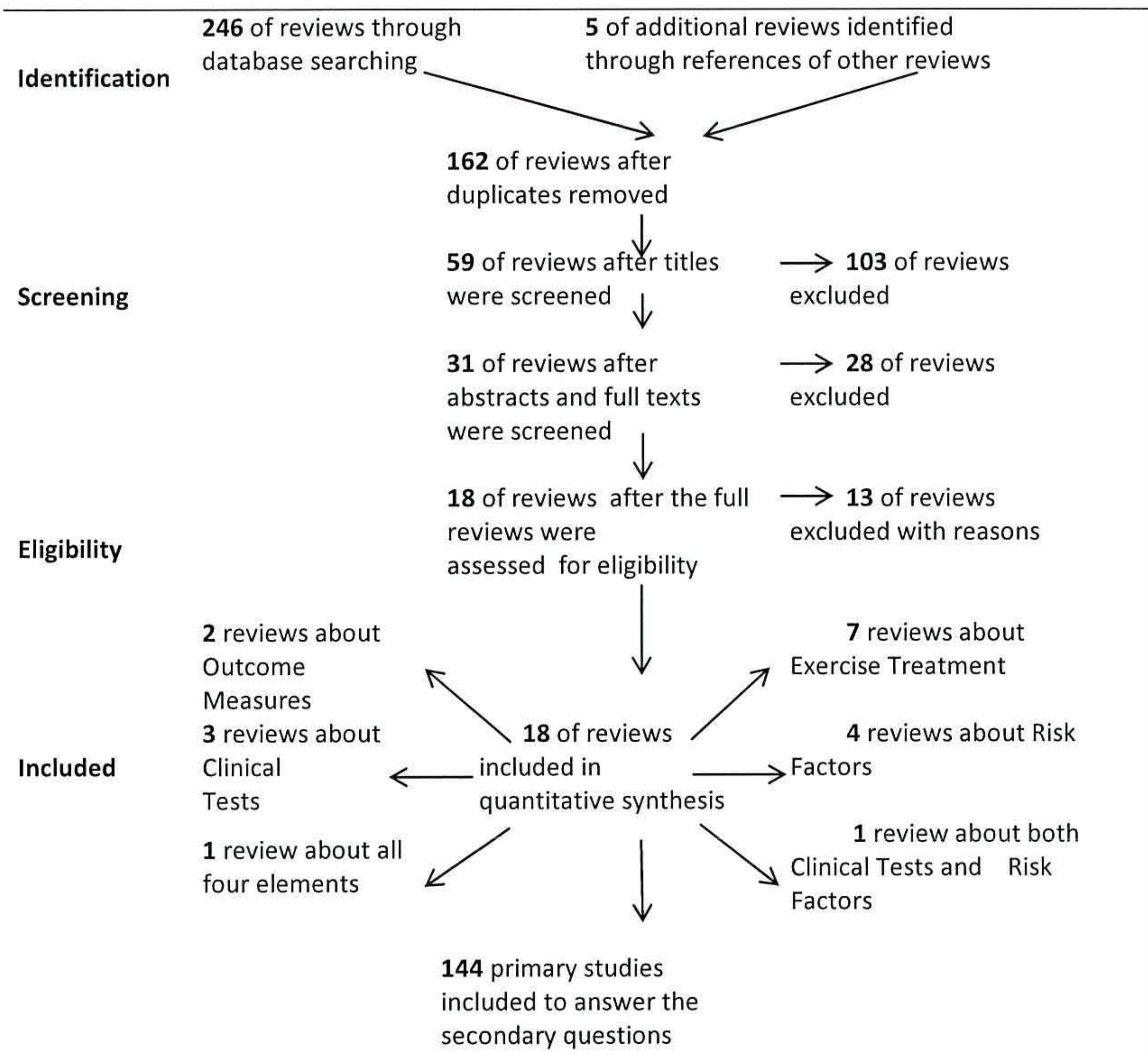
3.2 RESULTS

3.2.1 Study selection

The comprehensive search strategy identified 246 reviews; 86 on exercise treatment, 95 on outcome measures, 48 on risk factors and 17 on clinical tests. Five more reviews were identified through references of other reviews. After the titles of the reviews were screened only 59 of them met the inclusion criteria.

After screening titles and abstracts 31 reviews remained. Full text screening revealed that only 18 reviews were eligible for use; 2 regarding outcome measures, 3 about clinical tests, 7 about exercise treatment, 4 about risk factors, 1 about clinical tests and risk factors and 1 regarding all 4 components of this study. The flow diagram in Figure 9 shows the procedure from identification to inclusion.

Figure 9: Flow diagram of RoR study selection



3.2.2 Study characteristics

From the 13 excluded reviews, 11 revealed no clear methodology regarding how the included studies were gathered; one review reported combined exercise treatment and other treatment not suitable for this review, and the other review reported combined exercise and drug treatment. From the 18 included studies, 7 were entitled as systematic reviews, another 7 as systematic review with meta-analysis, one as a critical review, one as an invited review and the other two as narrative reviews. Since the inclusion criteria of this study determined that reviews with a clear search strategy and detailed references (page 35) could be added in the list, whilst, studies that did not report clear methodology should be excluded (exclusion criteria, page 35), four more reviews which were not entitled as systematic (Malanga, et al., 2003; Fredericson & Yoon, 2006; Bolgla & Malone, 2005; Selfe, 2004) but had clear methodology regarding how they gathered the studies, were also included. However, their purpose was not to answer a single question, therefore in some cases the subject matter related to more than one of the research questions of the present review. Appendix 13 shows all 31 full-text assessed reviews, their topic, design and which reviews were included and which not.

3.2.3 Critical appraisal

The level of evidence for the selected reviews is presented in Table 4. No level of evidence was reported for the four reviews which were not systematic or meta-analysis. The results showed two clinical test reviews of high quality systematic reviews of case control or cohort studies (Nunes et al., 2013; Cook, et al., 2012), one high quality meta-analysis of RCT's (Lankhorst et al., 2012) and three high quality systematic reviews of case control or cohort studies on risk factors (Waryasz & McDermott, 2008; Pappas & Wong-Tom, 2012; Lankhorst et al., 2013), three high quality meta-analyses or systematic reviews of RCT's (Heintjes et al., 2009; Harvie et al., 2011; Collins, et al., 2012) and three high quality systematic reviews of case control or cohort studies on exercise treatment (Fagan & Delahunt, 2008; Bolgla &

Boling, 2011; Frye, et al., 2012) and two high quality systematic reviews of case control or cohort studies on outcome measures (Howe, et al., 2012; Esculier et al., 2013).

Amstar question	Q1 1. Was an 'a priori' design provided?	Q2 Was there duplicate study selection and data extraction?	Q3 Was a comprehensive literature searc performed?	Q4 Was the status of publication (i.e. gre literature) used as an inclusion criterion?	Q5 Was a list of studies (included and excluded) provided?	Q6 Were the characteristics of the included studies provided?	Q7 Vas the scientific quality of the include studies assessed and documented?	Q8 Vas the scientific quality of the include tudies used appropriately in formulatin conclusions?	Q9 Were the methods used to combine the findings of studies appropriate?	Q10 Was the likelihood of publication bias assessed?	Q11 Was the conflict of interest included?	**Amstar**	**Prisma**	**SIGN**
Reviews														
Malanga et al., 2003	CA	CA	Y	CA	N	Y	N	N	Y	N	CA	**3/11**	**5/27**	**N/A**
Nunes et al., 2013	CA	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	**9/11**	**15/27**	**2++**
Cook et al., 2012	CA	Y	Y	Y	N	Y	Y	Y	Y	N	Y	**8/11**	**15/27**	**2++**
Fredericson & Yoon, 2006	CA	CA	Y	CA	N	Y	N	N	N	N	CA	**3/11**	**4/27**	**N/A**
Waryasz & McDermott, 2008	CA	CA	Y	Y	N	N	N	N	CA	N	Y	**3/11**	**6/27**	**2++**
Pappas & and Wong-Tom, 2012	CA	Y	Y	CA	Y	Y	Y	N	Y	N	CA	**8/11**	**17/27**	**2++**
Lankhorst et al., 2013	CA	Y	Y	Y	Y	Y	Y	N	Y	Y	Y	**9/11**	**24/27**	**2++**
Lankhorst et al., 2012	CA	Y	Y	Y	Y	Y	Y	N	Y	Y	CA	**8/11**	**24/27**	**1++**
Heintjes et al., 2009	CA	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	**9/11**	**24/27**	**1++**

Collins et al., 2012	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	Y	**10/11**	**26/27**	1++
Bolgla & Malone, 2005	CA	CA	CA	CA	N	Y	N	N	CA	N	N	**1/11**	**4/27**	**N/A**
Fagan & Delahunt, 2008	CA	CA	Y	Y	N	Y	Y	Y	N	N	Y	**6/11**	**8/27**	2++
Bolgla and Boling, 2011	CA	Y	Y	Y	N	Y	Y	N	Y	N	N	**6/11**	**13/27**	2++
Harvie et al., 2011	CA	Y	Y	Y	Y	Y	Y	N	Y	N	Y	**8/11**	**14/27**	1++
Frye et al., 2012	CA	CA	Y	Y	Y	N	Y	N	Y	N	N	**5/11**	**10/27**	2++
Howe et al., 2012	CA	Y	Y	CA	Y	Y	N	N	Y	N	CA	**5/11**	**10/27**	2++
Esculier, 2013	CA	Y	Y	Y	Y	Y	Y	N	Y	N	Y	**8/11**	**17/27**	2++
Selfe, 2004	CA	CA	Y	CA	N	N	N	N	N	N	N	**1/11**	**4/27**	**N/A**

Table 4. Methodological quality of the included reviews. The AMSTAR questions and the number of the PRISMA items reported in the reviews.

N/A: Reviews which could not be appraised by the SIGN tool because they were neither systematic nor meta-analysis of RCT's.
Abbreviations: Y= yes, N=no, CA=could not answer, NA=not applicable

The methodological quality of the selected reviews showed no study that answered all 11 questions of the AMSTAR tool or reported all 27 items of the PRISMA checklist. The only review which stood out from the rest was the review from Collins et al. (2012) and that because the authors reported that there was a priori design of their study (AMSTAR question-1, PRISMA checklist item-5). On the opposite side, the two studies from Lankhorst et al. (2012; 2013) were the only studies which assessed the likelihood of publication bias (AMSTAR Question-10, PRISMA checklist item-15). All studies performed a comprehensive literature search (question 3 AMSTAR) which was anticipated because this criterion was one of the inclusion criteria for the current review. In addition, most of the studies only reported the included studies and not those which were excluded (AMSTAR question-5). Overall, the AMSTAR tool revealed five studies with low (0-3) four studies with moderate (4-7) and 9 with high (8-11) methodological quality (Table 4).

3.2.4 Clinical tests

Three non-systematic reviews of low level of evidence and two high quality systematic reviews of case reports or cohort studies were found (Appendix 14). None of the non-systematic reviews could be appraised by the SIGN tool, their methodological quality was found to be low (less than 3/11 in the AMSTAR tool) whilst, all three reviews only reported a few items from the PRISMA checklist (less than 5). One of the two systematic reviews also reported meta-analysis on one clinical test (Nunes, et al., 2013). Both systematic reviews were also graded with high methodological quality (more than 8) and with 15 out of 27 items of the PRISMA checklist. The non-systematic reviews, reported different clinical tests for PFPS. The most common were the q-angle, tilting and patellar compression. The q-angle and tilting tests were reported by Fredericson and Yoon (2006) and Selfe (2004) and were found to have low reliability. Patellar compression was reported by Fredericson and Yoon (2006) and Malanga et al. (2003). The first authors reported low sensitivity and specificity. The latter suggested this test without evidence provided. It is important to mention that the Malanga et al. (2003) study aimed to identify several clinical test of the knee; and some of them were for PFPS. Only Fredericson and Yoon (2006) reported functional tests which were found to be highly reliable. Generally, the non-systematic reviews concluded that there is no evidence to support which is the best clinical test for PFPS and the reliability or sensitivity of the tests was low or untested.

The two recent systematic reviews examined a series of clinical tests (24 and 22) some of which were similar, i.e. squatting, active instability. Nunes et al. (2013) reported than none of the tests were good enough for diagnostic purposes because of the lack of homogeneity and test standardisation. Cook et al. (2012) suggested the active instability test, pain during stair climbing, Clarke's test, pain during prolonged sitting, patellar inferior pole tilt and pain during squatting as the best tests. However, they also found important disadvantages across the studies i.e. blinding and different reference standards, therefore, they proposed that PFPS should be a diagnosis of exclusion.

3.2.5 Risk Factors

Six reviews were identified in this section (Appendix 15). Two of them (Fredericson & Yoon 2006; Selfe, 2004) could not be identified as systematic, therefore, their level of evidence and methodological quality were low (AMSTAR 3 out of 11). Larger q-angle, muscle strength deficits, muscle tightness and joint and patella laxity were the components that the two studie had in common. Most of the risk factors showed contradictory results and totally different methodology across the primary studies. This explains why in these two studies comparison across the included studies was difficult if not impossible. Selfe (2004) also reported anthropometric risk factors such as body weight, age and sex, however the evidence was limited and in some cases absent.

One review was entitled as systematic with no meta-analysis (Waryasz & McDermott) 2008). Although this systematic review was identified as high quality systematic review of case control and cohort studies, the methodological quality was low (AMSTAR 3 out of 11) while only 6 out of 27 PRISMA items were reported.

Waryasz and McDermott (2008) reported contradictory results in all reported risk factors except for quadriceps tightness, EMG neuro-motor dysfunction and functional testing. Fredericson and Yoon (2006) reported significant results for Iliotibial Band (ITB) tightness, mediolateral patellar mobility, tight quadriceps, hip abductor weakness and functional performance. Therefore, the only risk factors that both studies agreed on were quadriceps tightness and reduced functional performance of patients with PFPS.

The other three studies were systematic reviews with meta-analysis. Two of them (Lankhorst et al., 2013; Pappas & Wong-Tom, 2012) were high quality systematic reviews of case control and cohort studies whilst Lankhorst et al. (2012) also published a systematic review with meta-analysis of RCTs. Therefore, the level of evidence of the last review was the highest and should be taken into more consideration. In addition, all three studies were graded as studies with high methodology (8-11 in AMSTAR tool). The systematic review of RCT's had one point less in the AMSTAR tool than the non RCT review as there was no declaration of conflicting interests. However, only the two studies from Lankhorst et al. (2013; 2012) reported most of the PRISMA items (24/27 for both reviews) whilst the study from Pappas & Wong-Tom (2012) only reported 17 out of 27. This study concluded that because PFPS is multifactorial, clinicians should evaluate strength flexibility and dynamic alignment of the lower limb. Limited flexibility of quadriceps and gastrocnemius and knee extension weakness could detect a PFPS case, however, these components could not work for non-athletic population as these tests have not been tested in civilians but only in military people who are generally supposed to be more athletic than non-active populations. The other review of case control and cohort studies (Lankhorst et al., 2013) reported that a larger Q-angle, larger sulcus angle, larger patellar tilt angle, less hip abduction and knee extension strength are associated as risk factors in PFPS. However no flexibility tests were reported as risk factors and they called for more research in high-risk groups such as athletes and military populations. Finally, the review of RCTs (Lankhorst, et al., 2012) reported that only knee extension deficits can be considered as risk factors whilst there is not enough evidence for flexibility deficits components. They also reported that clinicians should focus on dynamic lower limb malalignment because all studies in the review reported biomechanical and neuromuscular risk factors and not structural (static) risk factors.

3.2.6 Exercise treatment

Eight reviews met the inclusion criteria of exercise treatment in PFPS (Appendix 16). Two of the reviews were not systematic; the one was narrative (Bolgla & Malone, 2005) and the other was a critical review (Selfe, 2004), respectfully. The other 5 reviews were identified as systematic reviews and three of them included meta-analysis (Bolgla & Boling, 2011; Collins, et al., 2012; Heintjes, et al., 2009). Additionally, three reviews were identified as high quality meta-analysis or systematic reviews of RCTs Collins, et al., 2012; Heintjes, et al., 2009; Harvie, et al., 2011) whilst the other two (Bolgla & Boling, 2011; Frye, et al., 2012) as high quality systematic reviews of case control or cohort studies. Therefore, the level of the first three reviews was found to have high methodological level (8-11) in the AMSTAR tool whils the two reviews of case control or cohort studies had moderate methodological level (4-7 in the AMSTAR tool). Only the reviews from Heintjes et al. (2009) and Collins et al. (2012) reported more than 20 items from the PRISMA checklist (24 and 26 out of 27 correspondingly) whilst the other three reported 14 or less. Both reviews from Fagan and Delahunt (2008) and Bolgla and Malone (2005) were found to have moderate methodological evidence (6/11 AMSTAR tool for both reviews). However the Bolgla and Malone, (2011) review reported more PRISMA items (13/27) than the systematic review from Fagan and Delahunt (2008). As mentioned before the review from Selfe (2004) was identified to have low level of evidence and had only one out of 27 items from the PRISMA checklist.

The main finding from these three reviews was that open kinetic chain (OKC) exercises are as beneficial as the closed kinetic chain (CKC) exercises; however, Collins et al. (2011) suggested that CKC exercises may be preferable for short-time periods. Selfe (2004) finally concluded that since both OKC and CKC exercises are good for PFPS then functional exercises which combines both OKC and CKC is probably important in the rehabilitation of PFPS.

Additionally, all eight reviews showed the importance of quadriceps strengthening. The inclusion of hip abductor strengthening in a rehabilitation programme was supported by Frye et al. (2012), Bolgla and Boling (2011) and Harvie et al. 2011)] but not from Collins et al. (2012), Fagan and Delahunt (2008) and Bolgla and Malone (2005) who reported that adding hip strengthening on quadriceps-based programme did not change the outcomes measures. However, all reviews suggested hip strengthening as a part of a rehabilitation programme and not as the main treatment. Bolgla and Malone (2005) agreed with Selfe (2004) on the evidence that isometric exercises of the quadriceps [Straight leg raises (SLRs)] along with eccentric and isokinetic exercises can be beneficial for PFPS patients.

The review from Heintjes et al. (2009) was the only one which concluded that there is not enough evidence to support that exercise is better in terms of pain and function than no exercise. In contrast, Collins et al. (2012) concluded that the RCTs included in their review support the use of exercise whilst Frye et al. (2012) found one study which showed no improvement after an exercise programme. Contrasting results were reported between Frye et al. (2012) and Collins et al. (2012) regarding whether exercise should be supervised or not. The former reported significant results between supervised and not supervised exercise prescription whilst the latter concluded that there was no significant difference. Only two of the reviews Frye, et al., 2012; Harvie, et al., 2011) included information about whether stretching is beneficial and which structures clinicians should aim for greater flexibility. They both agree that the Iliotibial band is one of these components. Additionally, Harvie, et al. (2011) included even more structures to stretch (hamstrings, quadriceps, gastrocnemius and anterior hip).

3.2.7 Outcome measures

Three studies were identified in this section (Appendix 17). The earliest one was the review from Selfe (2004) which did not focus on outcome measures only. As mentioned previously the study was a critical review with low methodological evidence (1/11). The author reported his surprise that he only found 3 articles investigating outcome measures. Among several outcome measures [Anterior Knee Pain Scale (AKPS), Visual Analogue Scale (VAS), Function Index Questionnaire (FIQ), Modified FIQ (MFIQ), Flandry questionnaire and Pierrynowski] the FIQ was reported as the easiest to complete, the Flandry questionnaire as the most accurate for depicting symptoms and the MFIQ was recommended for clinical use.

The other two studies were identified as high systematic reviews of case controls or cohort studies. Their methodological evidence was moderate for Howe et al. (2012) with 5 out of 11 and high for Esculier et al. (2013) with 8 out of 11 in the AMSTAR tool, respectfully. In addition the reviews included 10 and 17 items of the PRISMA checklist. The review from Howe et al. (2012) evaluated several outcome measures for different knee conditions and not just for PFPS. Among different outcome measures such as the Lower Extremity Functional Scale (LEFS), Patellofemoral Severity Scale (PSS), Patient Specific Functional Scale (PSFS), Visual Analogue Scale (VAS), Lysholm, FIQ and Activities of Day Living Scale (ADLS) only the AKPS was found to be designed for PFPS. Esculier et al. (2013) identified the five most used outcome measures in PFPS and concluded that the ADLS was the most appropriate for PFPS patients because of its reliability, validity and responsiveness. AKPS and FIQ could be also recommended but they still need to be tested in larger populations. The scope of the two reviews was slightly different. Howe et al. (2012) investigated which outcome measure was best for which knee symptom, whilst Esculier et al. (2013) aimed to identify which of the PFPS was best for clinical use in PFPS patients.

3.3 SYNTESIS OF RESULTS

Statistical pooling was not possible because the trials did not often present sufficient data and more importantly, there was not a common set of outcomes across the reviews.

3.3.1 Additional analysis

To answer the secondary questions of this review only the systematic reviews with clear study report were included (Appendix 18). Therefore, the four studies which were excluded from this section were the following: Malanga et al. (2003); Fredericson & Yoon (2006); Bolgla & Malone (2005); Selfe (2004). The reason for not including the primary studies of these four reviews to answer the secondary questions was that their identification was impossible. These studies were mostly narrative and the included primary studies were neither explained nor gathered by the authors. These studies were of general scope and the identification of whether the included references were a material of the research questions investigating by this review was difficult to be reported. Additionally, the primary studies of the included reviews which were the material of different research questions, other than those this review was investigating were also excluded. For example Howe et al. (2012) reported several outcome measures for different conditions of the knee. Therefore, only the primary studies which reported outcomes for PFPS were used in this backtracking search. The 14 systematic reviews included 213 studies; 69 duplicated were identified and 144 primary studies were screened to answer the secondary questions of this RoR. This backtracking search revealed 43 studies which included dynamometers for muscle strength. Most of them (29) used non-portable isokinetic dynamometers rather than hand-held ones. Only 24 studies were identified as randomised controlled trials, whilst there was a wide distribution in the countries were the studies took place. Most of them were conducted in Europe, USA, Canada, Australia and Brazil. In terms of the research setting, there were 21 studies which did not report where the research was conducted; however, most of the studies (67) took place at university laboratories and not in clinical environments. The rest were conducted either in military bases, research centres and university hospitals.

The population that most of the studies used was not specified. Most of the studies did not mention patients' general activity levels. Therefore, in most cases the patient characteristics was unclear. However, there were 40 studies which reported that their patients were active or participated in sports such as running and dancing. In addition to those 40 studies, 14 studies included military populations that could be also considered as active.. Only 8 studies reported that they used outpatient participants or general populations. Therefore, there was a clear tendency from researchers to use active rather than sedentary patients. The 144 studies included 4141 PFPS patients (28 patient per study approximately). The average study participant number becomes even smaller if it is considered that most of the patients were from military studies where large numbers of participants were recruited. Additionally, the gender of participants was not identified in 30 studies; however, the rest 114 studies recruited 1888 women and 1507 men..

3.4 DISCUSSION

3.4.1 Summary of evidence

The purpose of this systematic RoR was to identify the literature evidence on clinical tests, risk factors, exercise treatment and outcome measures for PFPS for two time-periods. Additionally, the search of the primary studies, included in the systematic reviews, brought answers to the secondary questions. These questions were about the number of participants, the systematic reviews used, the gender and the participants' attitude towards sports (athletes or sedentary people), whilst the country, the clinical or laboratory setting and the use of dynamometer was also searched. Generally, this review showed that in the last few years the level of evidence and methodological quality of the reviews has been positively improved. An analytical discussion of all components of this systematic RoR is provided below.

3.4.2 Clinical tests

The results mostly reported the use of q-angle, patellar compression and apprehension test as the best clinical tests for the assessment of PFPS. However, some authors (Fredericson & Yoon, 2006) call for further research because of the low or untested reliability of the tests until a gold standard clinical test to be identified. Five years later the idea of finding the best clinical test seems to be abandoned. There is a clear tendency to functional assessment using specific tasks, such as the squat, or measuring pain during climbing and sitting with the legs flexed. More clinical tests are also reported but because of the non-consistent definition of PFPS, the nebulous pathophysiology and the different methodology among the studies, clinical tests cannot be compared between studies (Cook et al., 2012). This is probably the reason that functional tests are preferred for the assessment rather than specific tests of the patella. For the same reason it is not surprising that newer reviews suggest that PFPS may be a diagnosis of exclusion (Cook et al., 2012; Nunes et al., 2013).

3.4.3 Risk factors

Some of the tests used for assessment (large q-angle, pain on patellar compression) were also suggested as risk factors. However, there were a large number of studies which assessed strength and flexibility differences between PFPS populations and healthy controls. The result revealed many contradictions on specific muscle groups (e.g. hip muscle strength, gastrocnemius, ITB and hamstring flexibility) and the only risk factor that they agreed on was the quadriceps strength deficit and the low functional ability in PFPS. All three reviews were systematic reviews with meta-analysis; with stronger evidence from Lankhorst et al. (2012) who reported the conclusions of RCTs only. Whilst the other two systematic reviews (Pappas and Wong-Tom, 2012; Lankhorst et al., 2013) revealed contradictions on strength and flexibility risk factors, the strong evidence from the review of RCTs only reported that less quadriceps strength should be considered as risk factor whilst there was no evidence on flexibility deficits in PFPS population. Additionally, clinicians should focus on dynamic, rather than static, malalignment of lower limb because research showed that PFPS populations have neuromuscular risk factors. It is worth mentioning that these risk factors are for athletic people with PFPS and they have not been tested in the general population. Moreover, researchers call for more research in athletic or military population. This is surprising as there is evidence to suggest that sedentary people are also predisposed to PFPS (MacIntyre and Robertson, 1992). The above observations will be used to check whether clinical physiotherapists use the same tests and how they influence their practice.

3.4.4 Exercise therapy

With regards to the exercise therapy, there are no many changes over the last 20 years. Earlie studies agree that there was strong evidence that PFPS physiotherapeutic interventions shoulc focus on quadriceps strengthening. Additionally, isometric exercises of knee extensions appeared to be beneficial for patients with PFPS, whilst, there was no evidence that strengthening the hip muscles could be beneficial. Although recent studies of high-level systematic reviews of RCTs with meta-analysis (Heintjes et al., 2009; Collins et al., 2012; Harvie et al., 2011) were published, only limited further evidence was added to literature as many methodological contradictions between primary studies were observed. In addition, fundamental principles such as whether exercise is better than no exercise were still debated. Heintjes et al. (2009) reported that there is still not enough evidence to report that patients would benefit from exercise than just from rest alone. In terms of the use of closed or open kinetic chain exercises, OKC exercises were found to be as good as CKC exercises (Heintjes et al., 2009; Collins et al., 2012; Selfe, 2004). However, Collins et al. (2012) revealed that CKC exercises are better for short-time period treatment. Additionally, recent reviews still suggested the use of quadriceps strengthening, whilst the use of hip strengthening is still under debate. Although four of the systematic reviews (two of which were systematic reviews of RCTs with meta-analysis and high level of evidence; (Heintjes et al., 2009; Harvie, et al., 2011) reported positive use of hip strengthening in the treatment of PFPS patients, the third high level systematic review of RCTs reported that recruiting the hip muscles would not make any difference to the PFPS patients. Stretching was mentioned in two systematic reviews only (Harvie et al., 2011; Frye et al., 2012). These two reviews agreed that ITB stretching was useful for PFPS patients. However, taking the higher level evidence and methodology from Harvie et al. (2011) would conclude that the use of hamstrings, quadriceps, gastrocnemius and anterior hip muscles stretching is also necessary. Finally, since the study of Collins et al. (2012) was of higher level of evidence compared to Frye et al. (2012) it could also be concluded that supervised exercising in PFPS is no better that unsupervised exercise.

3.4.5 Outcome measures

Only recently authors reported outcome measures on PFPS. The earliest review, which was found to have low level evidence, was the one from Selfe, (2004) who reported the FIQ, MFIQ and Flandry as outcome measures that had previously been used in PFPS and concluded that the MFIQ (designed and tested by the same author)was the most appropriate. However, these individual primary studies could not be considered as evidence. The two high-level of evidence systematic reviews that were identified cannot be compared because of their different scope and suitability for PFPS. Howe et al. (2012) investigated several outcome measures for different knee conditions some which were for PFPS whilst, Esculier et al.

(2013) reported which of the 5 most used PFPS outcome measures were best for clinical use according to their reliability, validity, responsiveness and cultural adaption. Howe et al. (2012) reported that only the AKPS was designed for PFPS whilst the LEFS was not, although the latter had better responsiveness. The AKPS was also problematic because it included questions not suitable for PFPS when other questions, such kneeling, should be included. The review from Esculier et al. (2013) had better methodological evidence and suggested that the AKPS could be used as one the most appropriate scales for PFPS if it gets further tested in more participants. The FIQ (which was suggested from Selfe, 2004) and Lysholm scale should be excluded from PFPS use. The only scale which was the most appropriate for PFPS patients because of its reliability, validity and responsiveness was deemed the ADLS.

3.4.6 Secondary questions

The systematic reviews revealed a large number of studies on PFPS which mostly took place in university settings. Most of the studies recruited participants from physiotherapy clinics or outpatients hospital departments. However the actual research took place in university laboratories. Only a few studies were conducted in a clinical environment, therefore, the question that could be raised is whether the evidence base regarding tests and techniques can be translated from the laboratories to the routine physiotherapy clinic

In addition, the fact that only 24 studies out of 144 were found to be RCTs shows a strong need for better evidence in research studies. The total number of participants divided by the number of studies revealed that approximately 28 PFPS participants per study. This is a small number especially if it is considered that this number would be much smaller if the large military studies with the hundreds of participants were excluded.

As women are more likely to get PFPS it was not surprising that female population was the larger. However, there was no evidence regarding whether women should be assessed or treated differently to men. Additionally, one of the most important observations was that researchers tend to use athletic rather than non-athletic populations, whilst Lankhorst et al. (2012) reported that more research should be conducted in athletic populations. However, there is no evidence whether sedentary patients with PFPS have the same risk factors, or whether they should be assessed with the same outcome measures and be treated in the same way as athletic patients. A stronger case could be made about the patient characteristics if it is considered that most of the primary studies did not report whether their patients with PFPS were athletic or not. Having known this information, it is essential to identify the characteristics of the patients NWW physiotherapists have to deal with and check whether the PFPS research population (athletic people) is the same with the target clinical population.

As mentioned previously, most of the studies were conducted in universities where the required for testing equipment and the research environments are usually the same and do not differ from country to country. Therefore, the research evidence from different countries (as Appendix 18 showed) can easily be adopted from different research centres for research use. However, when it comes to research in clinical environments, the different conditions of different national health systems may differentiate the applicability of the findings across countries.

Finally, strength assessment was mostly done by non-portable isokinetic dynamometers, probably because most of the research took place in university laboratories where dynamometers did not have to be portable. These dynamometers may not be available in clinics or military bases. Therefore, other studies reported the use of portable hand-held dynamometers. However, the reliability and validity and therefore the applicability of those tools were not mentioned in the studies.

3.4.7 Limitations

A major limitation of this RoR was that meta-analysis was not possible because of the different methodologies that both primary and review studies used. Additionally, some of the primary studies were reported in more than one review and this duplication of evidence is shown in Appendix 18. Although duplicates were reported, the identification of the duplicate evidence in the reviews was in most cases impossible. In addition, some of the primary studies were difficult to be identified because they were either very old or not available. In some other cases the primary papers were in languages that the author of this RoR is not familiar with. These factors may help explain why some of the questions were unresolved.

3.5 SUMMARY

Early studies on PFPS were trying to find a gold standard clinical test for PFPS assessment while, nowadays the use of functional tasks such as the squat or the measurement of pain during functional task are suggested for clinical assessment instead. With regards to the risk factors, there are still a lot of contradictions in terms of muscle strength deficits. Today, the quadriceps strength deficits are still the only evidence based risk factors along with the dynamic malalignment of lower limb. More research is still required regarding strength and flexibility deficits of other muscles. Isometric exercises of quadriceps along with OKC and CKC exercises of the lower limb were suggested in the early studies, whilst today the quadriceps based exercises are still the only ones to have strong evidence together with hamstrings, quadriceps, gastrocnemius and anterior hip muscles stretching. There is a need of more research on hip muscle exercises to establish their benefits in PFPS treatment whilst exercise dosage focusing on endurance and high repetitions of hip exercises should also be considered. Evidence on outcome measures was absent in the earlier studies whilst the usage of ADLS is recommended today for clinical use. Finally, there is no evidence on whether the above treatment and assessment methods should be used in sedentary people or differently across population groups or gender. More RCTs with large populations, powered correctly, in clinical environments are called for in further research, whilst the country where the evidence comes from and the use of portable dynamometers for strength assessment should also be justified and considered.

3.6 REFLECTION

Phase 1 was the base for all main and secondary questions of this thesis. It displays the numerous components of PFPS assessment and treatment suggested by the literature and the many contradictions between the studies. There is still a lot of research to be done in the future in order to be able to conclude in several treatment outcomes. This phase also reports the gap between the patient characteristics displayed by the secondary studies and the patients physiotherapists claim to see in their clinic (Phase 2).

CHAPTER FOUR

PHASE 2: APPLIED PFPS REVIEW- ASSESSMENT AND TREATMENT IN PRACTICE

4.1 INTRODUCTION

As discussed earlier, when this research study was conceived (2008) no gold standard clinical tests were reported for PFPS, while the risk factors only included the quadriceps strength deficits, large q-angle, pain on patellar compression and low lower limb functional ability. Back in 2008 the recommended treatment was isometric exercises of quadriceps along with open and closed kinetic exercises. Finally insufficient evidence was reported regarding the outcome measures that should be used. Following Phase 1 which included a RoR,, the next step was to identify the clinical practice of NWW physiotherapists and compare it with the literature. To achieve this, the physiotherapists in NWW were questioned about how they assess and treat patients with PFPS and what they think about their practice.

The survey and interview methods detailed in Chapter 4 were designed to explore two key areas: (i) the methods that physiotherapists use to assess and monitor the treatment of PFPS and their beliefs for doing so (ii) the current treatment modalities and home exercise programmes physiotherapists prescribe. Interviews had a further aim of (iii) exploring physiotherapists' knowledge about PFPS and how they kept themselves up to date with current assessment and treatment methods and what were the potential barriers.

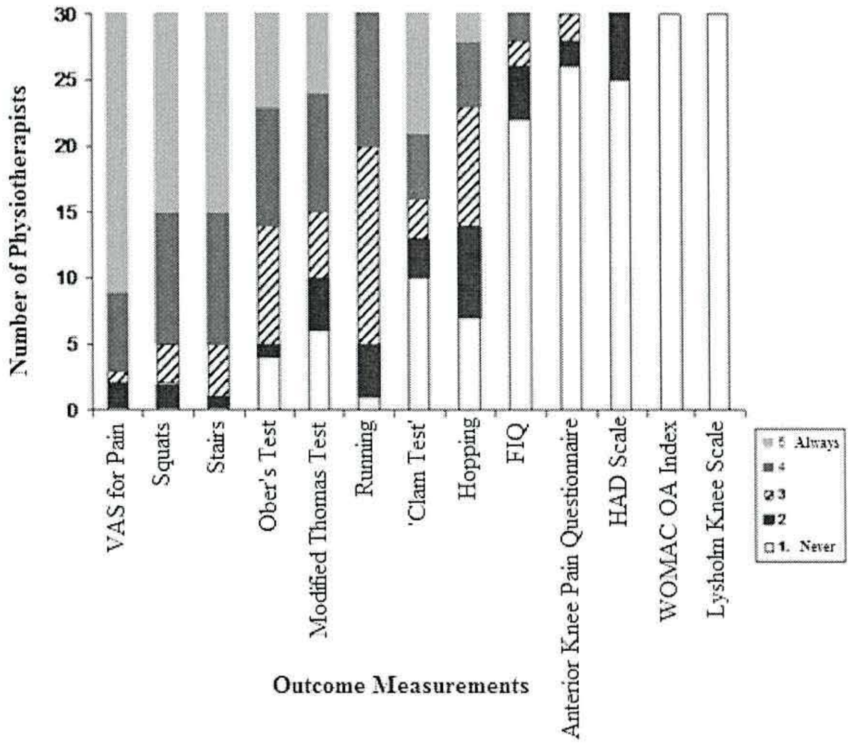
4.2 RESULTS

4.2.1 Survey

Assessment and outcome measurements

The most frequently used outcome measurements mentioned in the survey were; the VAS for pain, squatting, ascending and descending stairs, Ober's test, the modified Thomas test, the 'clam' test and hopping on one leg test (Figure 10). Questionnaires were used less frequently; the WOMAC OA Index (Bellamy and Buchanan, 1988) and the Lysholm knee score (Tegner and Lysholm, 1985) not being used at all. As well as the MCQ outcome measures listed, the questionnaire revealed 15 other outcome measures repeatedly used by the respondents. The most common were: functional exercises (6/12) e.g. lunges, small knee bends (SKB), single leg squats; the Lower Extremity Functional Scale (LEFS) (Binkley et al., 1999) (5/12); other questionnaires (5/12); patella position (3/12); the Oxford scale (2/12), foot biomechanics (1/12) and using patients own goals (1/12).

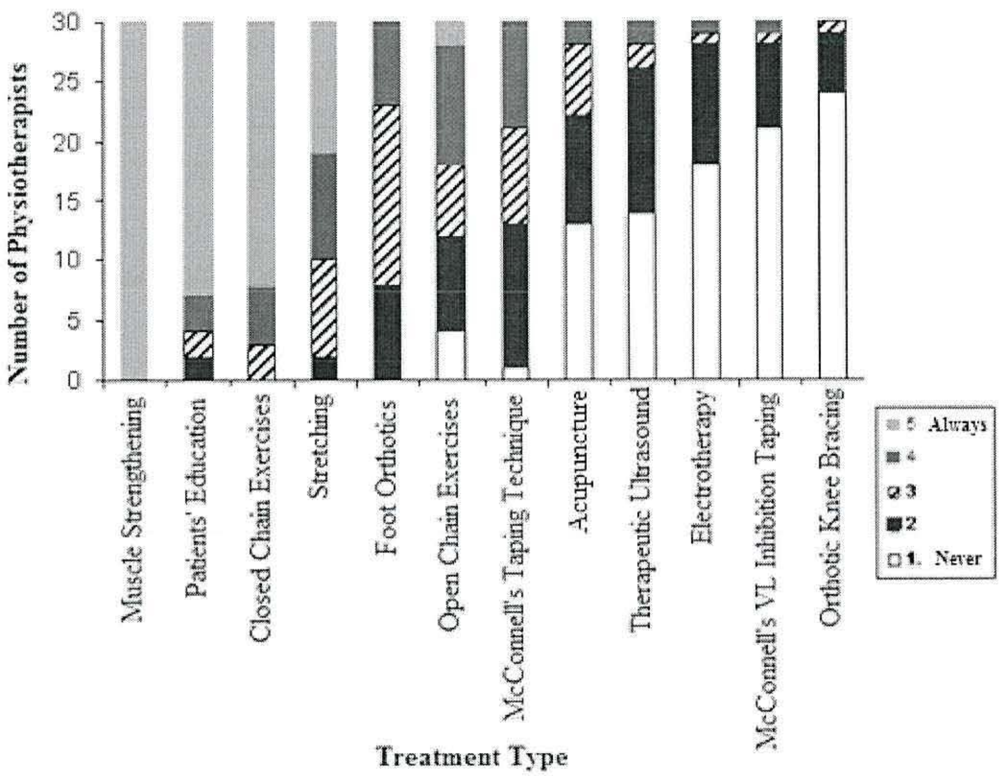
Figure 10. PFPS outcome measurements found via the questionnaire



Treatment methods of PFPS

The most frequently used treatment methods of PFPS in clinical practice listed in the questionnaire (Figure 11) were: muscle strengthening, patient education, closed chain exercises and stretching. The treatment methods least likely to be used were electrotherapy, McConnell's VL inhibition taping technique and orthotic knee bracing. Sixteen respondents added further treatment methods to the open question. The main open responses were soft tissue mobilisation/release techniques including trigger point therapy (9/30; e.g. '*specific soft tissue mobilisations - Glen Hunter style*' P.14), patella mobilisation (8/30), general and proprioceptive exercises (8/30; e.g. '*general body conditioning exercise - exercise by invitation scheme*' P.14) and core stability training (4/30). Other techniques mentioned included acute pain management (e.g. ice), neural dynamics, biofeedback for VMO and lumbar spine mobilisation.

Figure 11. PFPS treatment methods found via the questionnaire.



The muscles that the respondents (29/30) said they strengthened during treatment were the quadriceps (27), with all but 4 of these specifying the VMO (e.g. '*Quadriceps with VMO emphasis*' P.5, '*VMO (progression of SKB)*' P.22); gluteal muscles (23), especially Posterior Gluteus Medius (e.g. '*GM–glut med especially*' P.20); hamstrings (9); core stability (5) (e.g. '*transabdominal muscles (core stability)*' P.22); and calves (4), 'hip external rotators, abductors' P.2; and 'ankle' P.1. Only 3 physiotherapists mentioned that they would strengthen only 1 muscle group.

One physiotherapist observed:

> *'This would depend entirely on the presenting weakness. Commonly, Vastus Medialis, Tibialis posterior and gluts. However, I would not usually work just on individual muscles. I would work with relevant motor control issues and synergistic patterns of movement'.* ***P.6***

The muscles the physiotherapists stated they stretch were: hamstrings (25/28), Iliotibial Band (ITB)/ Tensor Fasciae Latae (21/28), quadriceps (20/28) and calves (18/28). The other muscles mentioned were hip flexors including psoas (5/28) and gluteals (2/28) and piriformis muscle (1/28). One physiotherapist stated in an open response:

> *'ITB (+/- lateral retinaculum), Rectus Femoris, hamstrings, gastrocnemius. It depends how they present, I use a muscle imbalance approach'.* ***P.28***

Twenty-two respondents used open chain exercises with 18 listing the quadriceps, including 3 Inner Range Quadriceps, 6 Straight Leg Raises (SLR), 6 mentioning hamstrings and 4 the GM. For closed chain exercises, 22 out of 28 responders listed VMO based exercises including SKB, 14 squats, 12 steps (up and/or down) and 10 general exercises. Other exercises often mentioned were core stability/balance (including using a gym ball) (8), lunges

(7), exercises against a wall (7) and gluteals (4). For example one physiotherapist added the following explanation:

> *'Mini squats; Step ups / downs; Lunges; Wall slides; Leg presses. Progressing to dynamic exercises e.g. hopping; progressing to sports specific exercises if necessary'* ***P.12***

Home exercise programmes

The most frequently used home exercise programmes found in the survey were: stretching (14/22), quadriceps and especially the VMO strengthening (13/22), gluteal strengthening (10/22), SKBs (8/22).

One physiotherapist explained their decision-making as follows:

> *'Depends on finding in the initial assessment. Usually incorporate quads strengthening in correct alignment and then adding stretches, glut strengthening depending on findings'* ***P.30.***

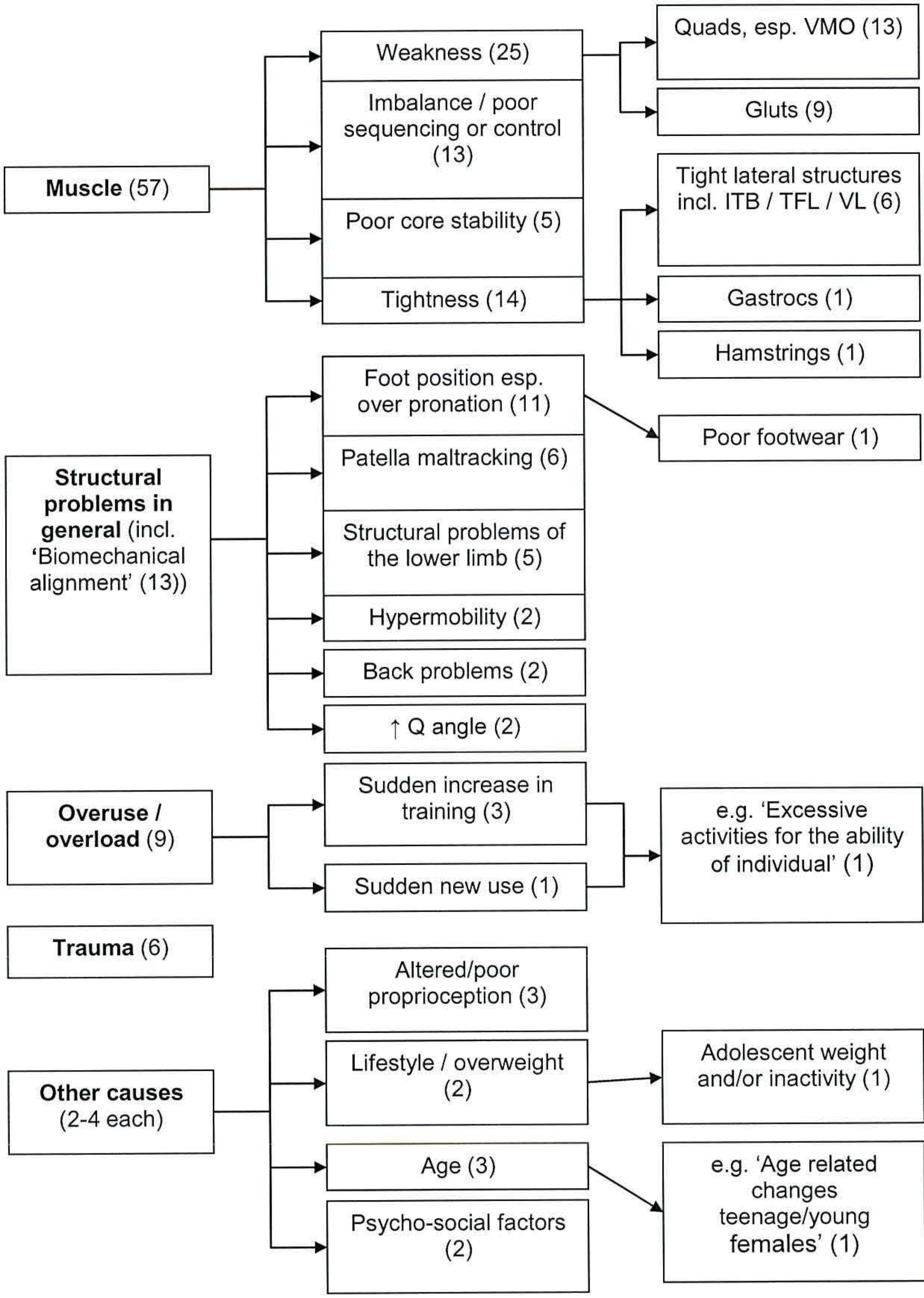
However another physiotherapist described a more individually-tailored approach:

> *'This is always specific to the patient - I do not follow a set routine - nor would I ever recommend that -the exercise programme will always complement the treatment goals. Understanding the limitations of patient compliance!, the programme is generally specific, goal orientated and with only a few relevant exercises needing to be done, which would be modified and progressed as appropriate'.* ***P.6***

Beliefs about causes of the syndrome

In the questionnaire, physiotherapists were also asked what they thought about the causes of the syndrome. As shown in Figure 12, most of the physiotherapists reported muscle weakness tightness and imbalance as the most usual causes they see, while the muscles affected the most were the VMO, gluts and lateral structures. Other structural problems such as the foot position, patella maltracking, and general structural problems of the lower limb were in the second place. Finally, overuse and overload were in the third place followed by trauma and other causes. Most respondents listed more than 3 possible causes.

Figure 12. A summary of the physiotherapists' beliefs about the causes of PFPS.



{The numbers in brackets show the number of times physiotherapists listed the item. A maximum of 6 causes were permissible}

Treatment effect

Finally, most physiotherapists in the survey (20/24) agreed it took 2-4 weeks after the first session to see any improvement (shortest period 1 week, longest 6 weeks). Of these, 22 physiotherapists thought that their patients would be 'symptom free' after treatment (range 10-80% of their patients), with most saying that their patients would be 'much better' (between 10-80%). Although, all of the respondents said that they would have some patients who were 'no better' (5-40%) and 13 respondents said that some of their patients would be 'worse' (0-10%) after treatment.

4.2.2 Interviews

Assessment and outcome measurements

In interviews, physiotherapists said the first physiotherapy session was used only for condition assessment. Physiotherapists looked at posture while their patient walked into the cubicle or stood upright. The following quote illustrates a typical approach to beginning the assessment:

> *'The first thing I look at is the way they are standing, their posture, the way they are walking in the physio cubicle, how they are holding their leg...'* (Interview: **P3**)

All the physiotherapists asked their patients where their pain was located (including low back), what aggravated the symptoms, and what functions they could do and could not. Physiotherapists checked for an effusion, ligament dysfunction and patella position. Muscle length, bulk and tone, restrictions in range of motion and altered biomechanics were assessed. They considered foot pronation/supination and patients' footwear. Patients were assessed for valgus or varus knees, alteration of foot biomechanics and Q angle. Physiotherapists used generally applied manual resistance to check muscle tone. The most frequently used objective outcome measures were testing isometric strength (manually, without a dynamometer) of quadriceps, gluteus medius (GM), hamstrings and calves (6/11), lunges (forwards/backwards) (2/11), hopping-landing on one leg-squatting test (3/11). Some of the tests were used under different conditions; such as bilateral knee bends (9/11) and one leg knee bends (8/11). Two types of visual analogue measurements were used: the scale (4/11) and the score (2/11), with the latter being divided in 10 subsections.

Follow-up reassessment usually took a few minutes (8/11) with physiotherapists using their objective markers (6/11); what they visually observed (3/11); how patients felt (3/11); and patient function (3/11).

In addition, physiotherapists observed patients walking or running on the treadmill, cycling or walking up, down and sideways on stairs. Depending on what patients found difficult, Physiotherapists used the same initial tests and assessments the patient found difficult on initial assessment to assess progress. The following quote illustrates that most patients found the tasks challenging to master.

> *'Yeah, I think they (patients) all find the tasks quite difficult in the start, but it depends on their condition of course.'* (Interview: **P3**)

Nor did physiotherapists consider patients could always make an accurate assessment of their progress. For example:

> *'Most people come and say: 'I feel much better'; or 'I feel the same'; sometimes though they say they feel the same although it is obvious that they are in better condition. I tend to use how they feel as a guide but sometimes there are patients who are better but they say: 'I feel worse or the same': you just have to see what they can do and what not.'* (Interview: **P4**)

Treatment priorities and options

Physiotherapists in interviews considered PFPS as complex and some compared it with 'tennis elbow' syndrome. They agreed that there was no ideal treatment (8/11). Treatment selected depended on 1) clinical finding during assessment (9/11), 2) identified patient needs (5/11), 3) pain relief (4/11), 4) patient motivation and goals (5/11) and 5) patient function (6/11) and level of activity (4/11). Pain was an important factor, which could alter the treatment at any time. Priorities and options were often influenced by the short time available for NHS appointments.

An individually tailored approach was favoured, as illustrated by the following physiotherapist:

> *'If your patient is young you have to make the exercises more interesting; if they are older you should think more about their level and what they can achieve'.* (Interview: **P.1**)

The first priority physiotherapists managed was swelling and pain. They then focussed on patellar position, alignment and any biomechanical issues. The most important aspects they would address were: strengthening of the quadriceps (especially the VMO) and GM (8/11), flexibility of all muscles (4/11), altered biomechanics (4/11), lower limb alignment (4/11), lifestyle (4/11) and patellar mobilization (4/11). Finally, they looked at general fitness and educated the patient about what activities to do and what not. The following example illustrates variations within this broad approach:

> *'The major thing I would do is to look at the foot position/knee position and teach them what the alignment should be; also why they get this pain and finally I would try to send them off with 3 or 4 exercises.'* (Interview: **P.1**)

Physiotherapists had different views on intervention effectiveness. Treatments used were patella mobilization (5/11), patella taping (8/11), stretching (5/11) and alignment treatment (4/11). Patella mobilizations were considered by some to be effective in patients with a tight patella, whilst patella taping could restore the patella position and help with quadriceps strengthening. Other interventions included cryotherapy to reduce swelling, whilst acupuncture, ultrasound and electrotherapy were mostly used in the acute condition to relieve pain. The following physiotherapist, for example, did not consider taping to be effective but still used it:

> *'I do not use taping. I only use it for the psychological effect it has. I am sorry but I do not really believe it works.'* (Interview: **P.4**)

Another physiotherapist described the important interplay between different interventions:

> *'The orthotics can decrease the pain but if no exercise takes place the no pain level/normal condition will never be achieved.'* (Interview: **P.1**)

Home exercise programmes

In the interviews, physiotherapists reported that the choice of exercises in the clinic depended mostly on individual patient assessment (7/11) and patient function (6/11). Any exercises patients could do with control and within pain limits were considered.

Physiotherapists generally selected a maximum of 3 or 4 functional home exercises (e.g. stan on one leg while washing dishes, SLR when sitting). The selection was based mostly on patient compliance (9/11) and patient motivation. They believed that patients would not comply with too many exercises. The following physiotherapist described their decision-making process:

'I ask my patients to do kind of things at home that would support what I am doing here. If I am doing passive treatment here I would ask them to support with specific exercises.' (Interview: **P.3**).

Physiotherapists considered that most patients had an intention to comply, but actual compliance depended on their motivation and lifestyle. Once patients experienced an improvement in pain they often stopped exercising. Critical success factors included patients taking responsibility and having belief in the treatment. Physiotherapists considered that their role was to educate and prescribe exercises applicable to the everyday life of the patient.

The following experience was typical:

'The problem is that when they start feeling better they usually do not comply any more. If they abstain from their exercises just because the pain stopped and they have not reached a satisfactory level, they will come back very soon.' (Interview: **P.1**).

Acquiring and maintaining knowledge and skills

According to the interviews most physiotherapists stated they acquired basic knowledge from their University training and enhanced their knowledge by: reading articles in physiotherapy journals or the internet (10/11), attending courses or NHS professional updates (7/11) and postgraduate studies (3/11). However, their clinical practice depended mostly on interaction with their colleagues (11/11). Colleagues were considered the most important source of knowledge and influence on practice. The following two physiotherapists describe typical experiences:

'In general, if there is a problem I need an answer, I pick up the phone and I call a colleague.' (Interview: **P.1**).

'I do some taping from the book but then you see other people doing it slightly different; you try that; not just taping but the way people handle and assess. Understanding and doing what other people do: Learning from them.' (Interview: **P.4**).

Case studies

Although physiotherapists used an individually-tailored approach to all patients, the case studies showed that they separate their patients in two categories; the one includes patients who perform their exercises and the other patients who do not. For the first case study (elite athlete), physiotherapists stated they would capitalise on her motivation in identifying appropriate exercises and some would add interventions to manage pain after exercise. For example:

'For the 1st case I would apply ice after every training session. She is very active and this would relieve her from pain'. (Interview: **P.4**).

The second and third cases (busy mother and overweight student) were considered to have similar lifestyle and motivation factors and physiotherapists approached them in a similar way. They would be looking for biomechanical issues, general activity, fitness and lifestyle rather than specific treatment. Because these patients had little time and/or enthusiasm about exercises the treatment of choice included only three or four simple exercises and with the major emphasis on lots of education and self-management techniques including taping, For example:

'If the 2nd case wants to get better she needs to find some time'. (Interview: **P.6**).

'The 3rd case is the most challenging. It is very unlikely to perform any exercises.' (Interview: **P.6**).

4.3 SYNTHESIS

Overall, the interviews confirmed what physiotherapists reported in the questionnaire as there were no great differences between the two approaches. Physiotherapists agreed that PFPS is a very challenging syndrome with multiple clinical complexities. Since there are no guidelines to follow, physiotherapists use the first session with patients on assessment and plan management. Treatment depends on what patients can do; their compliance and what they want to achieve while the effect of treatment depends on the home exercises which patients not always perform. Physiotherapists' beliefs about the causes of the pain are numerous and they match what literature suggests, showing that they update their knowledge with the latest evidence. However, their greater source of evidence is still their colleague.

4.3.1 Assessment and outcome measurements

However, the interviews revealed that although physiotherapists were aware of the variety of outcome measures for PFPS (as highlighted by the questionnaire); in practice they only used the VAS routinely and sometimes not at all (as highlighted by the interviews). Physiotherapists generally preferred to use subjective approaches as they often omitted using written outcome measures with patients. If physiotherapists did not have a written objective measure from the previous session, they asked patients whether they subjectively felt better whilst performing a task such as SKBs or stair climbing/descending. Their re-assessment depended on their ability to memorise the patient's previous ability to perform a task, rather than on objective measures. Subjective approaches included observation of change in performance of the selected tasks and patient feedback during examination, e.g. manually assessing strength and pain. Subjective assessments made by patients did not consistently match with the subjective assessments of physiotherapists.

4.3.2 Treatment priorities and options

Both questionnaire and interviews showed similar treatment priorities. The most important priority was the pain. Patients must be pain-free in order get any other exercise treatment from physiotherapists. In addition, the physiotherapists reported in both questionnaire and interviews the same muscles that they would strengthen or stretch. However the interviews revealed that physiotherapists would not focus on one muscle. They would use functional tasks such as squats, hopping on one leg, ascending and descending stairs to get the muscles stretched or strengthened. This approach was probably because of physiotherapists' belief that their patients would not comply in any specific-muscle exercise.

4.3.3 Home exercise programmes

Similar to treatment priorities and options, both the questionnaire and interviews revealed similar home exercises aimed to strengthen and stretch specific lower limb muscles. The treatment has to be supported by home exercises. However the interviews reported that the home exercise treatment depended on patients' compliance. Most of the patients do not comply because they do not have the time to perform the exercises, or they stop doing them as soon as they feel better or because they are not convinced that they have to perform them. Therefore, physiotherapists give maximum 3 exercises at home because they know that more exercises would not be performed. Additionally, the home exercises have to be easy and functional so that patients can perform them while they do other things at home or at work (SLRs, small squats). This is also clear from the three cases physiotherapists were asked to discuss. The reason they would give the same exercises to case two and three was because they were cases who would have similar lifestyle and not much time to work on their exercises. Both cases would have issues with compliance.

4.3.4 Treatment effect

The questionnaire showed that most of the physiotherapists reported that their patients would be symptom free after they had physiotherapy; however 13 physiotherapists reported that their patients would not be any better or would be even worse. In the interviews this idea is explained further; physiotherapists believe that patients have their share if they do not get any better and the reason is the compliance. They quoted that it is patients' responsibility to get better.

4.3.5 Beliefs about causes of the syndrome

Both questionnaire and interviews reported a number of reasons that physiotherapists thought as causes of the syndrome. However most of these causes were musculoskeletal or biomechanical. Only 9 physiotherapists reported the overuse as a cause of the syndrome. When physiotherapists were asked about this they quoted that their patients are not elite runners like in the first of the three presented cases, therefore, their patients is more likely to have PFPS because of other causes but not because of overuse.

4.3.6 Acquiring and maintaining knowledge and skills

According to the interviews and questionnaire the physiotherapists were well updated regarding their knowledge and skills. They reported to attend postgraduate courses, conferences and seminars while internal services took regularly place at YG. However, the most important source of evidence was their colleague. This can be understood since they quoted that they need to try something in order to make sure that it works. For the same reason when they have not tried or seen something before but one of their colleagues has, physiotherapists prefer to trust their colleagues' experience than blindly follow literature and books.

4.4 SUMMARY

Phase 2 enabled a greater understanding about the local context of PFPS treatment and identifies the potential barriers for implementation of new evidence and practice. The major finding was that all physiotherapists used strengthening especially of the quadriceps with both closed and open kinetic chain exercises while stretching of several lower limb muscles came third. Both decisions are supported by the RoR (Chapter 3). Education also played an important role since it comes second in their list of preferred treatments. However, it was not clear whether education was important for all their patients or just for those who do not comply with specific exercises.

4.5 REFLECTION

Phase two of the thesis played an important role for the research questions of this study since it revealed common physiotherapy clinical practice. The fact that physiotherapists do not use any clinical tools to assess PFPS other than, in some cases, the VAS shows one more difficulty in the implementation of evidence base in the applied physiotherapy clinical practice. However, future frameworks should consider reliable and valid clinical tools that physiotherapists would be convinced to use as part of their everyday practice. Although physiotherapists appeared not to use clinical tools because of the several barriers they faced in the clinic, they were well updated. Therefore, this evidence enabled the next phases to reveal the usefulness of the clinical tools that a PFPS framework should consider in the applied physiotherapy practice, but also whether the available literature can be used (and if not why) by the NHS physiotherapists.

CHAPTER FIVE

PHASE 3: UTILITY REVIEW – MEASURES AND METRICS IN PRACTICE

5.1 INTRODUCTION

As shown in the review of reviews (Chapter 3) there is no gold standard for assessment, treatment, risk factors and outcome measures in patients with PFPS. Researchers first looked at clinical tests were for assessment such the q-angle, tilting and patellar compression; however, the reliability or sensitivity of those tests was low or untested (Fredericson and Yoon, 2006). Since none of the tests could be used for clinical assessment the use of functional tasks such as squatting have been suggested (Nunes et al., 2013); however, these the authors question about the homogeneity and test standardisation of such a test (Chapter 3, clinical tests). Additionally, with regards to the risk factors in PFPS, there was a lot of contradiction between studies (see risk factors, Chapter 3). Quadriceps tightness and reduced functional performance of patients with PFPS have been reported (Waryasz and McDermott, 2008) whilst only knee extension deficits have been reported as a sure risk factor (Lankhorst, et al., 2012). Although only little research had been conducted on outcome measures, the ADLS and AKPS are considered the most appropriate outcome measures for PFPS patients (Esculier et al., 2013). However, their test retest-reliability, content and construct validity is still under debate (see outcome measures, Chapter 3). Finally, regarding the exercise for patients with PFPS, along with the quadriceps strengthening using OKC and CKC exercises (Bolgla and Malone 2005), the strengthening of other muscles such as the gluteal and the stretching of muscles such as ITB (Frye et al., 2012; Harvie et al., 2011) seems to be more dominant. However, because of the large number of studies, the different study aims, methodology of the exercises and the different results, there are still many contradictions (see exercise treatment, Chapter 3).

Additionally, there is no evidence to support the use of the above clinical tests, outcome measures and exercises by physiotherapists in the clinic. On the other hand, the mixed method study investigating how physiotherapists in NWW assess their patients with PFPS (Chapter 4) specified a large number of assessment and treatment methods (mainly on strength and flexibility) while a series of outcome measures were also proposed by the therapists. Many of these were subjective functional manoeuvres with no means of objective verification (such as the strength deficits of the quadriceps and gluteal muscles; tested subjectively by hand, or the stiffness of the hamstrings and the ITB; tested without a goniometer) which were reported as clinical tests that can be used in the clinic. The lack of an evidence base to support the use of these tests and the absence of the use of any objective clinical measurements in the physiotherapy clinic, point to a need to establish which of these clinical tests are able to identify a case of PFPS and how reliable and valid these tests are for clinical use. This study will primarily focus on the main clinical tests and outcome measures relating to strength, flexibility, and scales discussed in the previous chapter. What is lacking in the literature is a series of studies investigating the validity and reliability of these tests and their day to day, use in subjects with PFPS.

Differences identified between patients with PFPS and healthy controls may reveal potential risk factors and possibly which groups of muscles physiotherapy exercise treatment should focus on. In order to identify which of the methods are best to use in PFPS, clinical tests and outcome measures in patients with PFPS were compared with other conditions of the lower limb. If valid and reliable assessment methods are identified, they can then be used in the clinic for screening and diagnosis of PFPS as well as outcome measurements. This study will fulfil the third aim of the PhD which was to identify the usefulness of the clinical assessment tests that NWW physiotherapists reported to know about.

The researcher considered several different ways of investigating the most effective clinical tests and outcome measures. In this study, the first step was to establish the test-retest reliability of the selected outcome measures and their validity. The clinical tests found to be reliable and valid were then applied to patients with PFPS and healthy controls within a controlled laboratory setting to determine which clinical tests differentiated between PFPS patients and controls. Those tests had to be applied to patients in a clinical environment where the same ways of measuring strength do not take place. Therefore an innovative and transferable way needed to be tried out regarding measuring strength in the clinic. This study was conducted to determine the practicality and reproducibility of the use of a portable dynamometer to measure lower limb strength in a clinical setting against the 'gold standard' isokinetic dynamometer (see Appendix 9). Finally, the performance of the clinical tests in the clinic was compared using patients with PFPS and patients with other lower limb conditions.

5.1.1 Aims of the study

The aims of the study were to identify:

a) Which of the tests commonly proposed by the NWW physiotherapists were reliable and which of the outcome measures were valid.
b) The sensitivity, specificity and predictive values of the clinical tests which could be identified as positive or negative.
c) The ability of the clinical tests to differentiate patients with PFPS from healthy controls with no knee pain and with patients with other lower limb conditions.

5.2 RESULTS

5.2.1 Part A and B: Test-retest reliability and validity of common outcome measurements for PFPS

No significant differences were found between the age, height and weight of the PFPS and control group (Table 5).

Group	Age (years)	Height (m)	Weight (kg)
PFPS group	29.10 ± 6.70	1.70 ± 0.10	76.80 ± 12.20
Control group	31.50 ± 10.50	1.71 ± 0.10	78.30 ± 19.70
p value	0.39	0.18	0.77

Table 5. Comparison of age, height (meters) and weight (kilograms) of PFPS and control groups. Data are mean ± SD

The majority of outcome measurements were found to have good reliability with no differences between week one and two (Table 6). Reliability of tests is reported for the total number of participants (patients and healthy controls). However, the same analysis for patients with PFPS only, showed the same number of reliable and less reliable tests.

Outcome measures for all participants (n=40)	Week 1 Mean ± SD	Week 2 Mean ± SD	SEM	Corre-lations	p value
RELIABILITY:					
Flexibility tests					
ITB & TFL flexibility (Ober's Test) (degrees)	-11.05 ± 9.07	-11.49 ± 7.15	6.65	0.79**	0.69
Iliopsoas flexibility (modified Thomas Test) (degrees)	-1.38 ± 11.10	-1.62 ± 10.82	3.67	0.97**	0.55
Quadriceps flexibility (modified Thomas Test) (degrees)	30.48 ± 11.02	29.56 ± 10.68	8.85	0.79**	0.52
Hamstring flexibility (degrees)	63.45 ± 15.54	61.83 ± 15.89	6.75	0.95**	0.13
Calf flexibility (degrees)	57.55 ± 11.91	57.73 ± 12.62	6.60	0.92**	0.87
Knee hyperextension (degrees)	3.22 ± 3.08	3.20 ± 3.46	1.61	0.93**	0.93
Isometric strength tests					
Knee extension torque (N x m/kg)	2.71 ± 0.61	2.77 ± 0.77	0.40	0.92**	0.43
Hip abduction torque (N x m/kg)	1.75 ± 1.79	1.77 ± 0.52	0.29	0.91**	0.61
Hip ext. rotation torque (N x m/kg)	0.54 ± 0.15	0.56 ± 0.15	0.05	0.96**	0.14
Hip abduction torque ('clam' test position) (N x m/kg)	1.07 ± 0.55	1.04 ± 0.50	0.29	0.92**	0.52
Functional stress test					
'Clam' test: set 1 (N x m/kg)	0.74 ± 0.41	0.87 ± 0.47	0.26	0.89**	0.003+
'Clam' test: set 2 (N x m/kg)	0.84 ± 0.42	0.91 ± 0.46	0.25	0.92**	0.034+

Pain scales (patients only)					
AKPS (/100)	63.70 ± 11.59	62.2 ± 12.17	9.22	0.82**	0.47
LEFS (/80)	52.35 ± 14.65	52.0 ± 13.83	10.99	0.82**	0.89
VAS-UP (cm)	4.46 ± 2.21	3.83 ± 2.11	0.19	0.75**	0.16
VAS-WP (cm)	5.03 ± 2.83	5.16 ± 2.21	2.44	0.69*	0.82
VAS-LBP (cm)	1.92 ± 2.76	1.85 ± 2.61	1.44	0.92**	0.85
VAS-'clam' test (cm)	1.26 ± 1.89	2.23 ± 2.59	2.02	0.74**	0.06
VALIDITY: Correlation with 'Gold standard' VAS-U	**Lower bound**	**Upper bound**	**SEM**	**ICC**	
AKPS	-3.95	0.23	0.36	- 0.96**	
LEFS scale	-3.36	0.28	9.19	- 0.81**	
VAS-WP x10	0.29	0.89	19.13	0.72**	
VAS-'clam' test x10	0.00	0.84	20.80	0.61*	
VAS-LBP x10	-1.51	0.82	28.65	0.39	

Table 6. Reliability and validity of the outcome measurements.

*Data are mean ± SD. Standard Error of Measurements (SEM), ICC and p value of paired t-tests are presented for reliability between week 1 and week 2. Lower and upper bound for mean, SEM and ICC are presented for validity of scales against the 'gold standard' VAS for usual pain. The confidence interval was 95% in all cases. ICC correlations as indicated by ** = strong, * = moderate correlation. + = paired t-Test significant difference between week 1 and week 2. Negative numbers in the modified Thomas and Ober's test show that the hip was extended and adducted more than 0 degrees, respectively. Negative correlation on AKPS and LEFS was found because they have inversed scoring.*

The least reliable scale was the VAS-WP as patients stated that the pain could change according to the activities they performed. However, it only revealed borderline moderate reliability (0.69). The functional stress 'clam' test was found to be reliable; however, there were significant differences in the scores between the two weeks and therefore its reliability is questionable. The least valid scales were the VAS-LBP test and VAS-'clam' as there was no significant correlation of VAS-LBP with knee pain (VAS-U) plus, the functional stress 'clam' test showed an increase in pain compared to VAS-U. Bland and Altman plots of the above correlations are provided in the appendixes (Appendix 8).

5.2.2 Part C: Diagnostic tests

The patella compression test and the Ober's tests were found to have good specificity and positive predictive value 100%; however the sensitivity and negative predictive value was moderate <90%. The modified Thomas test revealed moderate diagnostic values, <90%. Table 7 shows the sensitivity, specificity and predictive values for modified Thomas, Ober's and patella compression tests in both PFPS and control groups.

Tests	Positive PFPS	Positive controls	Sensitivity	Specificity	Predictive value of positive test	Predictive value of negative test
Modified Thomas test	13/20	3/20	65%	85%	81%	70%
Ober's test	3/20	0/20	15%	100%	100%	54%
Patella compression test	10/20	0/20	50%	100%	100%	66.6%.

Table 7. Sensitivity, specificity and predictive values of modified Thomas, Ober's and patella compression tests. Data come from 20 healthy controls and 20 patients with PFPS

5.2.3 Part D: The ability of the clinical tests to differentiate patients with PFPS from healthy controls with no knee pain

Flexibility Measurement Tests

Only the iliopsoas and hamstring flexibility tests differentiated between the groups. The PFPS group was found to have their thigh at 11.10 degrees more flexed than that of the controls. Patients were also less flexible in term of hamstring flexibility to 10.70 degrees (15.90%) than that of the controls. No differences were found between the groups in term of knee hyperextension and calf flexibility. See Table 8 for details.

Assessment tasks	PFPS Group	Control Group	p value
ITB and TFL Hip abduction (degrees)	-9.45 ± 7.96	-13.5 ± 5.74	0.073
Iliopsoas Hip flexion (degrees)	3.95 ± 10.83	-7.15 ± 7.65	0.001***
Quadriceps Knee flexion (degrees)	28.95 ± 11.68	30.15 ± 9.85	0.727
Hamstring flexibility (degrees)	56.5 ± 16.83	67.15 ± 13.26	0.032*
Gastrocnemius flexibility (degrees)	58.70 ± 13.44	56.75 ± 12.02	0.631
Knee hyperextension (degrees)	3.55 ± 3.68	2.85 ± 3.30	0.530
Patella position. Lateral movement (centimetres)	1.25 ± 10.37	1.9 ± 4.89	0.801
Pre-task maximum isometric knee extension (N x m/wt)	2.44 ± 0.68	3.09 ± 0.73	0.006*
Pre-task maximum isometric hip abduction (N x m/wt)	1.67 ± 0.52	1.91 ± 0.49	0.214
Pre-task maximum isometric hip external rotation (N x m/wt)	0.49 ± 0.15	0.62 ± 0.13	0.004**
Pre-task isometric hip abduction ('clam' position) (N x m/wt)	0.79 ± 0.39	1.30 ± 0.48	0.001***
'Clam' functional stress test set 1 (N x m/wt)	0.79 ± 0.46	0.92 ± 0.49	0.313
'Clam' functional stress test set 2 (N x m/wt)	0.80 ± 0.43	1.03 ± 0.48	0.114
Post-task maximum isometric knee extension (N x m/wt)	2.29 ± 0.64	2.73 ± 0.62	0.033*
Post-task maximum isometric hip abduction (N x m/wt)	1.55 ± 0.53	1.82 ± 0.45	0.090
Post-task maximum isometric hip external rotation (N x m/wt)	0.46 ± 0.15	0.59 ± 0.11	0.003**
Post-task isometric hip abduction ('clam' test position) (N x m/wt)	0.82 ± 0.53	1.17 ± 0.46	0.032*

Table 8. Comparison of assessment tasks performed by PFPS and control groups.

N x m/wt = Newton x metres / weight; * = little significant differences $p \leq 0.05$; ** = moderate significance $p \leq 0.005$; *** = high significance $p \leq 0.001$

Pre functional stress isometric strength tests

The maximum isometric knee extension, hip external rotation and hip abduction from the 'clam' position all differentiated between the groups, whereas isometric hip abduction with extended knee did not. In more detail, the PFPS group showed 26.60% decrease in the isometric knee extension test, 26.50% in the isometric hip external rotation test, 64.50% in the isometric hip abduction from the 'clam' test position than that of the controls whilst the difference in the hip abduction test with extended knees (not significant) was 12.60% (Table 8).

The functional stress 'clam' test

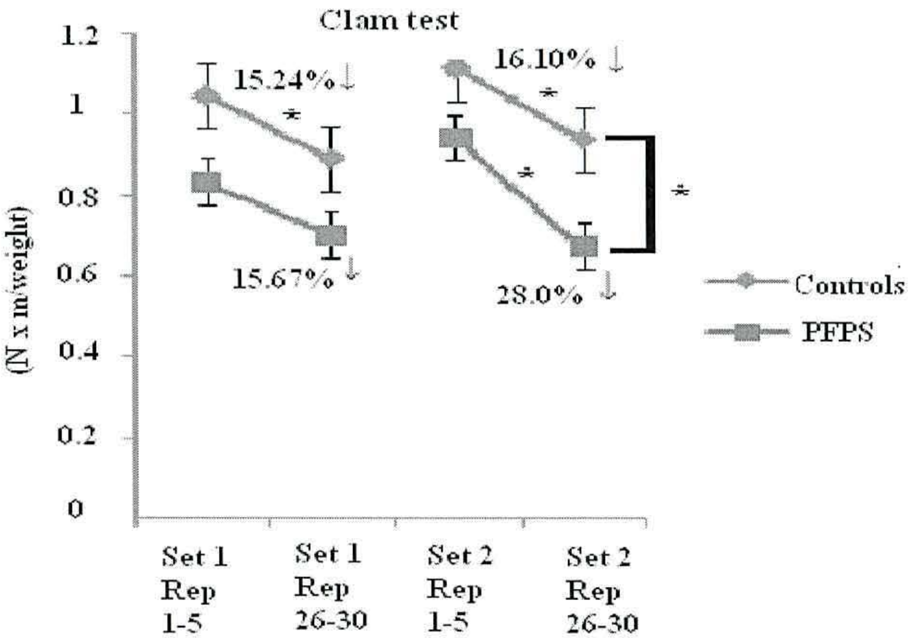
When all 30 repetitions of each set of the 'clam' functional stress protocol was compared there was no difference between groups (Table 8), however when the first 5 and the last five contractions of each set were compared, there were significant differences between the PFPS and the control groups. (Table 9). In the first set, a significant reduction in concentric strength was found between the first and last five contractions only for the control group (15.20%). After the second tiring set there was a marked reduction in both groups between the first and last five contractions (16.10% in the controls; 28% in the PFPS group). At the end of the functional stress 'clam' the PFPS group showed a significantly more rapid decline than controls (11.90%), see Figure 13.

	Set 1, Rep 1-5	**Set 1, Rep 26-30**	**Paired t-Test**	**Set 2, Rep 1-5**	**Set 2, Rep 26-30**	**Paired t-Test**
Control Group Performance (N x m/wt)	1.05 ± 0.57	0.89 ± 0.43	p=0.01*	1.12 ± 0.49	0.94 ± 0.41	p≤0.00*
PFPS Group Performance (N x m/wt)	0.83 ± 0.57	0.70 ± 0.36	p=0.08	0.93 ± 0.52	0.67 ± 0.38	p≤0.00*
Independent t-Tests between patients and controls	p=0.24	p=0.13		p=0.24	p=0.04*	

Table 9. Analysis of concentric performance of the first and last five repetitions of the two sets of 'clam' functional stress test protocol in control and PFPS groups.

*Data = mean ± SD. Rep = repetition; N x m/wt = Newton x metres / weight; * = Shows significant differences (p<0.05).*

Figure 13. Analysis of concentric performance normalised by weight of the first and last five repetitions of the two sets of 'clam' functional stress test protocol in control and PFPS groups.



*Rep = repetitions; * = significant difference (p<0.05).*

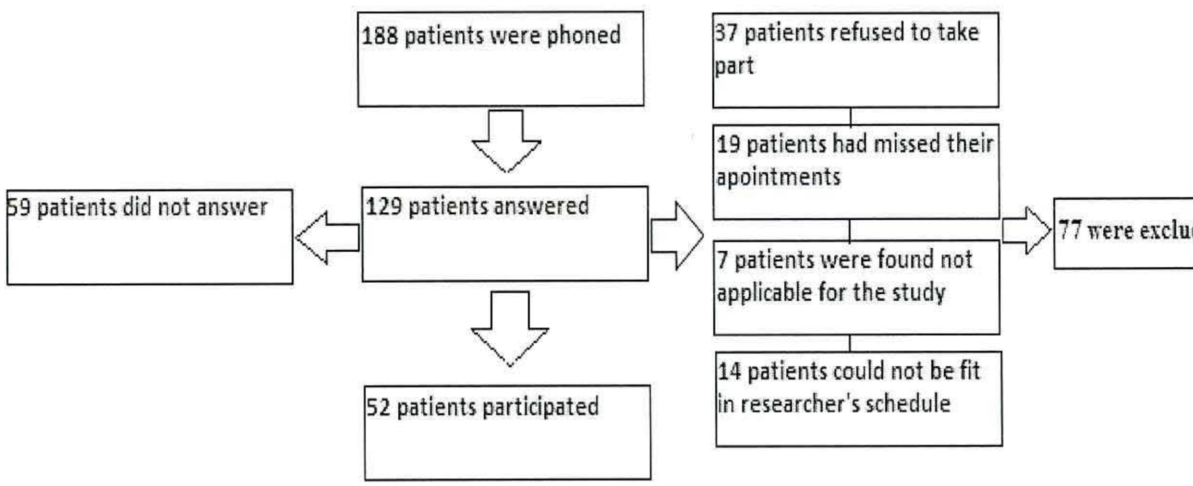
Post functional stress isometric strength tests

After the functional stress protocol the maximum isometric strength of knee extension still differentiated between the two groups as the PFPS group revealed 19.2% less isometric activity ($p<0.05$). There was less 28.2% hip external rotation activity ($p<0.05$) and 42.60% significantly less isometric hip abduction activity ($p<0.05$) from 'clam' position in PFPS group than that of the control group. The hip abduction test with the knees extended did not differentiate between the two groups (albeit 14.90% less activity in the PFPS group than that of the controls).

5.2.4 Part E: clinical tests for differentiating between patients with patellofemoral pain and those with other lower limb conditions

188 potential participants were phoned by the rheumatologist (JJ) before the 52 participants were recruited. Fifty-nine did not answer when they were called, 37 refused to take part, 19 had missed their appointments and had to be re-referred, 7 of them were found to be not applicable for the study after they were called and 14 could not be tested as the researcher or the equipment was not available at the time the patients had their treatment booked (Figure 14).

Figure 14. Recruitment procedure for Part E.



Among the men in the non-PFPS group, there were 4 cases with ankle sprains, two with patella dislocations, two with anterior cruciate ligament injuries and one with a meniscal tear. Among the women in the non-PFPS group, the conditions included hip pain (n=3), patella dislocations (n=2), ankle sprains (n=2), medial cruciate ligament injuries (n=2), Achilles tendon injury (n=1), greater trochanteric bursitis (n=1), knee meniscal tear (n=1), plantar fasciitis (n=1), calf tightness (n=1), psoas syndrome (n=1), knee injury (n=1) and jumpers knee syndrome (n=1).

Demographics

Table 10 shows the characteristics of the PFPS and the non-PFPS groups. No significant difference was found for age, height and weight between the two groups. The PFPS group had been experiencing pain for 43.90 ± 50.20 months, compared with the non-PFPS group (28.80 ± 53.10 months). No significant difference was found between the groups, however (p=0.29). Only 4 PFPS patients reported permanent pain, while the rest (22) reported on/off pain. Nine patients from the non-PFPS group reported permanent pain. No significant difference was found between the two groups in the proportion of people reporting permanent pain (p=0.20). Finally, only 12 out of 26 PFPS patients reported that they were involved in sports or fitness clubs, compared with 9 in the non-PFPS group. The difference, however, was not statistically significant (p=0.57).

	PFPS group	Non-PFPS group	p value
Age (years)	35.00 ± 9.11	39.7 ± 10.81	0.10
Height (meters)	1.72 ± 0.08	1.68 ± 0.06	0.09
Weight (kilograms)	77.40 ± 18.86	78.12 ± 15.48	0.90
Gender (male/female)	9 males/17 females	9 males/17 females	1.00
Permanent pain	4 patients	9 patients	0.20
Athletic/non athletic population	12 were athletic (3 runners, 3 footballers, 3 fit people who went to the gym three times per week, 1 basketball player, 1 horse rider, 1 netball player)	9 were athletic (3 cyclers, 3 footballers, 1 long distance walker, 1 rugby player, 1 swimmer)	0.57

Table 10. Subject characteristics of the PFPS and non-PFPS groups.

The values (except for gender, permanent pain and population) are presented as mean ± SD.

Diagnostic tests

The modified Thomas test was found positive in 17 out of the 26 of the PFPS group and in the group with the other conditions 9 people demonstrated a positive modified Thomas test before they received physiotherapy treatment. The patella compression was positive in 10 PFPS people before treatment and in 3 people with other conditions. Table 11 shows the sensitivity, specificity and predictive values of the two tests in PFPS patients. There was no significant difference for any of the tests between the two groups (modified Thomas, p=0.05; patella compression, p=0.05).

Tests	True positive cases	True negative cases	Sensitivity	Specificity	Predictive value of positive test (+)	Predictive value of negative test (-)
Modified Thomas test	17/26	17/26	65%	65%	65%	65%
Patella compression test	10/26	23/26	38%	88%	77%	58%

Table 11 True positive, true negative, sensitivity, specificity and predictive values of the diagnostic tests in PFPS patients.

Data from 26 patients with PFPS and 26 with other conditions and are presented as %, unless otherwise indicated.

Flexibility tests

The analysis of the flexibility tests showed that iliopsoas tightness differentiated the PFPS group from the group with other conditions (p=0.04) before treatment. There was no difference between these two groups in the other flexibility tests (Table 12).

Strength tests

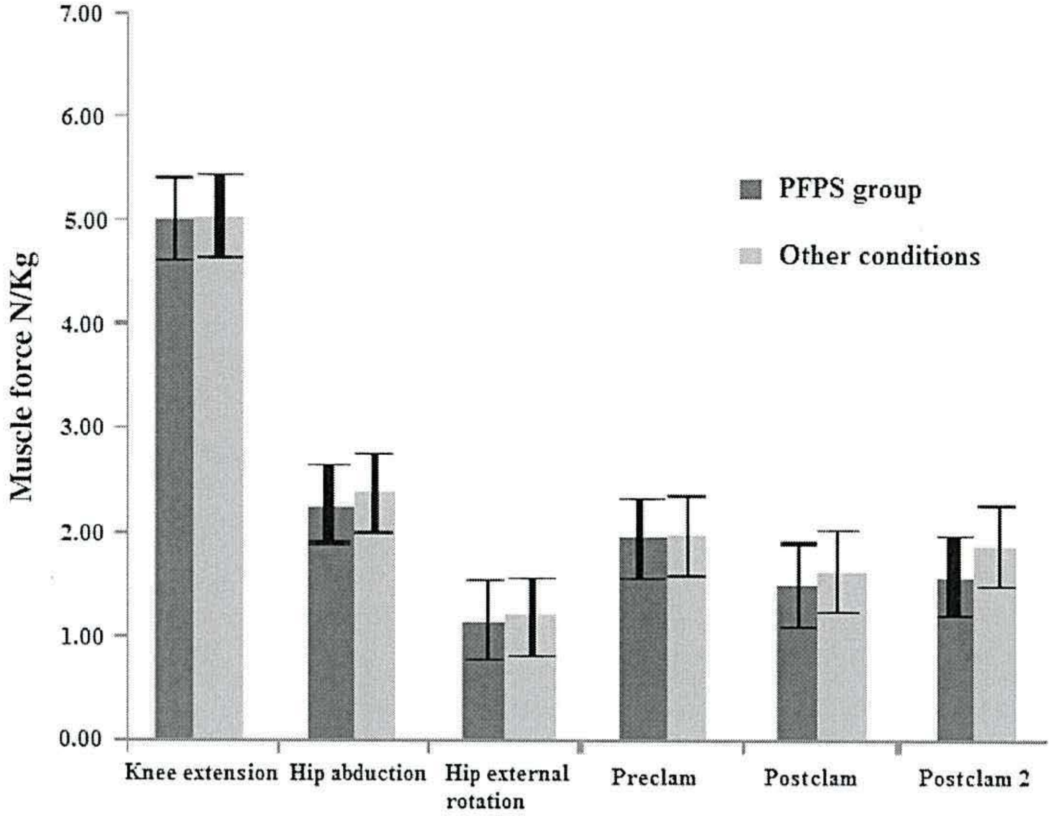
The series of strength tests showed that there was no difference between the PFPS and the other conditions group (see Table 12). Figure 15 displays the strength results for this study.

	PFPS group	Other lower limb conditions group	p values between groups
Flexibility tests			
Thigh flexion for iliopsoas flexibility (degrees)	6.38 ± 7.31	2.65 ± 5.20	0.04*
Knee extension for quadriceps flexibility (degrees)	63.96 ± 15.39	64.15 ± 13.88	0.96
knee extension with the hip flexed for hamstrings flexibility (degrees)	33.31 ± 18.12	28.00 ±15.64	0.26
Strength tests			
Isometric knee extension N/kg	5.02 ± 1.69	5.05 ± 2.71	0.97
Isometric hip abduction from 'clam' position N/kg	1.94 ± 0.75	1.97 ±1.16	0.90
Isometric hip external rotation N/kg	1.13 ± 0.56	1.19 ± 0.70	0.74

Table 12. Flexibility and strength outcome measurements between PFPS patients and that of patients with other lower limb conditions.

*The values are presented as mean ± SD. * = significant difference p≤0.05.*

Figure 15. The figure demonstrates the activity of both PFPS and other conditions group in the series of isometric strength tests.



'Clam' functional stress protocol

The 'clam' functional stress protocol showed tiredness in both groups before and after treatment activity. (Table 13). However, the second post-'clam' exertion part of the protocol showed that the group with other conditions could recover more successfully than that of the PFPS group.

	Pre functional stress 'clam' activity N/kg	Post 1 functional stress 'clam' activity N/kg	Post 2 functional stress 'clam' activity N/kg	p value between pre and post 1 functional stress 'clam' activity, N/kg	p value between pre and post 2 functional stress 'clam' activity, N/kg	p value between post 1 and post 2 functional stress 'clam' activity, N/kg
PFPS group	1.94 ± 0.75	1.49 ± 0.68	1.58 ± 0.66	p≤0.00*	p≤0.00*	p=0.11
Other lower limb conditions group	1.97 ±1.16	1.63 ± 1.15 1.63	1.87 ± 1.22 1.87	p≤0.00*	p≤0.09	p≤0.00*
p values between the groups	0.90	0.57	0.24			

Table 13. The table shows the mean scores ± standard deviations and p values between the two groups and between pre, post 1 and post 2 functional stress protocol exertions of each group.

*Post 1= the isometric 'clam' contraction which took place straight after the functional stress 'clam'. Post 2= the isometric 'clam' contraction which took place 2 minutes after the functional stress 'clam'. *=significant difference, p≤0.001.*

Questionnaire and scales

None of the questionnaires or scales showed significant difference between PFPS patients and patients with other lower limb conditions (Table 14).

	AKPS	LEFS	VAS usual pain	VAS worst pain	VAS on the day	VAS after functional stress 'clam'
PFPS	66.23 ± 16.26	55.03 ± 15.85	4.32 ± 2.74	5.30 ± 3.43	2.35 ± 2.33	2.32 ± 2.52
Other Lower limb conditions group	57.46 ± 19.53	45.85 ± 16.73	4.67 ± 2.32	6.56 ± 2.33	3.71 ± 2.86	3.45 ± 2.77
p value from group comparison	0.20	0.05	0.61	0.13	0.07	0.13

Table 14. Mean values, standard deviations and p values for the AKPS, LEFS and 4 VAS in PFPS and other conditions.

5.2.5 Results synthesis

In summary, Parts A through E of this chapter demonstrated that although most of the outcome measures have merit in one or several of the sub-studies, there were very few that were reliable, valid and could differentiate PFPS from other groups. Among the strength, flexibility tests, diagnostic tests and outcome measures, only the iliopsoas component of the Thomas test was found to be able to stand out as a diagnostic method (Table 15).

Outcome measures for PFPS	RELIABILITY: Test-retest (n=40)	validity	Sensitivity, specificity	PFPS vs. Controls	PFPS vs Other Lower Limb Conditions (OLLC)
Diagnostic tests					
Ober's test	Reliable	-	Not sensitive but **specific** in PFPS and healthy controls comparison Not used between PFPS and (OLLC)	-	-
Modified Thomas test	Reliable	-	Not sensitive or specific within PFPS and healthy controls Not sensitive or specific in PFPS and (OLLC)	-	-
Patella compression test	-	-	Not sensitive but **specific** within PFPS and healthy controls Not sensitive and specific in PFPS and (OLLC)	-	-
Flexibility tests		-			
Iliopsoas flexibility (modifies Thomas test) (degrees)	Reliable	-	--	Significant	Significant
Quadriceps flexibility (modified Thomas test) (degrees)	Reliable	-	-	Not significant	Not significant
Iliotibial Band and Tensor Fascia Latae (degrees)	Reliable	-	-	Not significant	-
Knee hyperextension (degrees)	Reliable	-	-	Not significant	-
Hamstring flexibility test	Reliable	-	-	Significant	Not significant
Gastrocnemius flexibility	Reliable	-	-	Not significant	-
Isometric strength tests					
Knee extension torque (N x m/kg)	Reliable	Valid compared to Humac	-	Significant	Not significant

		Norm			
Hip abduction torque (N x m/kg)	Reliable	Valid compared to Humac Norm	-	Not significant	-
Hip ext. rotation torque (N x m/kg)	Reliable	Valid compared to Humac Norm	-	Significant	Not significant
Hip abduction torque ('clam' test position) (N x m/kg)	Reliable	Valid compared to Humac Norm	-	Significant	Not significant
Functional stress test					
'Clam' test: set 1 (N x m/kg)	Reliable	-	-	Not significant	Not significant
'Clam' test: set 2 (N x m/kg)	Reliable	-	-	Not significant Significant in 26-30reps	Not significant but PFPS patients did not restore activity significantly
Pain scales (patients only)					
AKPS (/100)	Reliable	Valid	-	-	Not significant
LEFS (/80)	Reliable	Valid	-	-	Not significant
VAS-UP (cm)	Reliable	'Gold Standard'	-	-	Not significant
VAS-WP (cm)	Not reliable	Valid	-	-	-
VAS-LBP (cm)	Reliable	Not Valid	-	-	-
VAS-'clam' test (cm)	Reliable	Not valid	-	-	-

Table 15. The table displays the, reliability, validity and differentiation ability of the clinical tests after being applied on PFPS patients, healthy controls and patients with other lower limb conditions

5.3 DISCUSSION

Because of the lack of a gold standard protocol to assess PFPS (Fagan and Delahund, 2008) NWW physiotherapists use many clinical tests in the assessment of patients with PFPS. To achieve a standard assessing method, manoeuvres and outcome scales should be first tested regarding their reliability, validity and their ability to differentiate patients with PFPS from healthy controls and patients with other conditions of the lower limb. The main findings of this study were that there was strong intra-rater/test-retest reliability of most of the functional assessments commonly used for PFPS. Additionally, the diagnostic tests did not perform well enough for routine use in the clinic. Tightness of the iliopsoas muscle and weakness of hip external rotation and hip abduction in 'clam' test position strongly differentiated PFPS from controls. Weaker associations were found with tightness of hamstring muscles and weakness of knee extension. The PFPS group got tired more rapidly when performing the 'clam' test. Contrarily, strength of hip abduction with knee extended, flexibility of the gastrocnemius, quadriceps, ITB and TFL, patella position and the knee hyperextension tests did not differentiate PFPS from controls. When the tests were performed from PFPS patients and patients with other lower limb conditions it was revealed that the strength, flexibility and diagnostic tests did not differentiate PFPS people from people with other lower limb conditions. In addition, while the PFPS group was found to have less iliopsoas flexibility (Thomas test), the hamstring flexibility test showed no difference between the groups. There was a significant decrease in isometric 'clam' force after the functional stress 'clam' for both groups, however recovery in the PFPS group was significantly slower than in the group with other conditions of the lower limb.

5.3.1 Part A and B: Test-retest reliability and validity of common outcome measurements for PFPS

Regarding the reliability of the clinical tests, the current data agree with Piva and colleagues (Piva et al., 2006; Piva et al., 2009) who also found high reliability in most of the functional tests. In addition, in terms of the outcome measurements, both AKPS and LEFS were found very reliable which supports the results of Watson et al. (2005) (ICC for LEFS=0.98, ICC for AKPS=0.95). However, when in the current study the two measurements were correlated with the VAS-U, the AKPS revealed a higher correlation (-0.96) than LEFS (-0.90). This might show that although AKPS questions aim more towards function, it correlates only moderately with a pain scale. On the other hand, the LEFS, which is not a scale specific for PFPS, aims more toward function and might, tends to reveal lower scores when the pain increases.

Crossley et al. (2004b) also reported that the AKPS and the VAS for worst pain are reliable and valid outcome measurements. Moreover, Bennell et al. (2000) also reported that AKPS was found to be the most reliable measurement (0.90). The same study revealed high reliability for the VAS-WP (0.79) and VAS-U (0.77). The current study agrees with these results, having found high reliability for the VAS-U (0.75); however, the reliability of the VAS-WP was found to be moderate (0.69). Crossley et al. (2004b) reported moderate AKPS validity; however, the AKPS was compared with the global rating of change and not with the VAS-U that the current study has used. Additionally the Bland and Altman plots showed good reliability of the flexibility and strength test methods with small average discrepancy between the tests and narrow limits of agreement, However, when it comes to the pain scales, average discrepancy between them is bigger and the limits wider. Same results showed the validity plots, which compared the correlations between the VAS-UP with the rest of the scales. These results showed that there is no confidence to generalise the reliability and validity results of the scales.

5.3.2 Part C: Diagnostic tests

When the diagnostic tests were tested in healthy controls and patients with PFPS, the modified Thomas test was found to be the most sensitive diagnostic test and more able to assign people correctly to both the PFPS and the non-PFPS category than the Ober's and the patella compression tests (see Table 7). Contrary to Puniello (1993) who identified 12/17 PFPS with positive Ober's test the current study found the test to be positive in only 3/20 PFPS participants. Additionally, the Ober's test was found to be more specific than the modified Thomas test for PFPS. The sensitivity of the patellar compression test was found to be similar with a previous study [(50%) (Niskanen et al., 2001)]; however, the specificity was different as the current study found 100% of PFPS patients and not 55% as previously (Niskanen et al., 2001). Similarly, two other studies (Naslund et al., 2006; Cook et al., 2012) reported sensitivity at 82% and 68% correspondingly whilst both studies showed 54% specificity of the patella compression test. The reason that the specificity of this test was found to be 100% was the fact that in the current study none of the healthy controls considered the compression painful. A small number reported a discomfort feeling but no one admitted real pain.

Only two of the diagnostic tests were used in the comparison study between PFPS patients and other conditions group (Ober's test was excluded because it could not differentiate PFPS from controls). The two diagnostic tests (Table 11) (the modified Thomas and patella compression test) were not very useful in distinguishing patients with PFPS and those without. This is because the tests revealed many positive cases in the non-PFPS group. The sensitivity and specificity values of these two tests were also not that satisfactory (<90%). Comparisons with other studies are difficult because of the heterogeneity of the non-PFPS group in our study. However, it should be noted that the proportion of people who were tested positive in the modified Thomas test and patella compression test was substantially higher in the PFPS group than in the non-PFPS group, and statistical significance was almost reached (p=0.05-0.06). Significant results may have been obtained if a larger sample size had been used.

5.3.3 Part D: The ability of the clinical tests to differentiate patients with PFPS from healthy controls with no knee pain

Flexibility

Hamstring tightness differentiated PFPS group from healthy controls. This finding agrees with other reports (White et al., 2009; Piva et al., 2005; Smith et al., 1991) but disagree with Witvrouw et al., (2000) who reported no significant difference between PFPS and healthy controls.

Tightness of quadriceps and gastrocnemius muscles was not found significant in this study. This disagrees with other studies which found these muscles significantly tight (Piva et al., 2005; Witvrouw et al., 2000). ITB/TFL tightness did also not differentiate the two groups in the current study. These results agree with Piva et al. (2005) who also reported no significant difference. On the other hand, the results of this study disagree with a case control study of Hudson and Darthuy (2009) who presented iliotibial tightness after comparing 12 patients with PFPS with 12 healthy controls (p=0.008).

Isometric tests

The findings of weakness of the hip external rotation are in agreement with others (Willson et al., 2008; Cichanowski et al., 2007, Souza and Powers, 2009a; Souza and Powers 2009b). No other reports of tests of iliopsoas flexibility in PFPS have been found, so the finding that tightness of this muscle was strongly associated with the presence of PFPS is of interest. Iliopsoas is a secondary external rotator of the hip (Tyler et al., 2006) and it is possible that tightness of this muscle might interfere with the biomechanics of external rotation and contribute to the weakness and probably to mechanical dysfunction.

At first sight, the findings of the current study that hip abduction is weak in the 'clam' test position but not when tested with the hip in neutral position and knees extended, appears contradictory. However, additionally to testing the hip abductors, the 'clam' test also involves the external rotators which in this study have been shown to be significantly weaker in PFPS than healthy controls. No other studies of isometric strength testing in the 'clam' position in PFPS have been found. The reports of isometric strength testing of hip abduction in a neutral position and knees extended are contradictory. Piva et al (2005) and Willson et al (2008), similar to the present study, found normal isometric strength, whilst others reported reported weak hip abduction in this position (Dierks et al., 2008; Willson and Davis, 2009; Ireland et al., 2003).

The finding of significant weakness of the quadriceps muscles during isometric knee extension in the PFPS group compared to that of the controls is supported by many studies (see Chapter 3) except for Messier et al. (1991) and Milgrom et al. (1991).

Functional stress protocol

The functional stress 'clam' test was designed to assess the consistency of concentric muscle strength. Stressing muscles is the key to muscle growth and muscle endurance (Brooks et al., 1996) and the functional stress 'clam' demonstrated that as might be expected the weak hip external rotators and abductors in the PFPS group did stress more rapidly at the end of this tiring test. This finding supports the use of the concentric 'clam' exercises (Chapter 4, figure 10) by physiotherapists in the clinic (either by using their hands to produce resistance or exercise bands) in a gluteal strengthening programme.

5.3.4 Part E: clinical tests for differentiating between patients with patellofemoral pain and those with other lower limb conditions

Flexibility

Although the PFPS group tended to have less hamstring flexibility than that of the other conditions group, the difference was not significant. The reason could be the fact that muscle tightness appears in other syndromes or lower limb conditions too (i.e. jumper's knee syndrome) as well as PFPS. In addition, some patients in the non-PFPS group were referred to physiotherapy because of muscle tightness (e.g. psoas muscle and calf muscles) and it is possible that their muscles tended to generally tight. On the other hand, the hip flexion in the modified Thomas test showed a significant difference when the two groups were compared, with more hip flexor tightness for the PFPS group. This is in line with the results obtained by Tyler et al. (2006), who assessed 35 patients with PFPS and found that 31 out of 43 lower limbs with PFPS were positive in the hip flexion component of the modified Thomas test, concluding that there was a need of hip flexors stretching in PFPS patients. However, the modified Thomas test was not routinely performed in the clinic by a goniometer (see Chapter 4).

Isometric tests

Both groups generated similar force in the isometric tests. This can be explained by the fact that all patients, despite the group they belonged, found it difficult to perform the strength tests because of the problem/injury they had. Although the strength tests (except from hip abduction) differentiated PFPS patients from healthy controls they could not differentiate PFPS from other lower limb conditions indicating that differences in a specific force or forces in the strength tests do not differentiate PFPS cases from those with other lower conditions.

Functional stress protocol

The isometric hip abduction from 'clam' position did not show any difference between the two groups and the 'clam' functional stress protocol fatigued both groups in a same manner. However, the inability of the PFPS group to recover after two minutes of the first post 'clam' isometric exertion indicates that the 'clam' fatigue test might be of use as a diagnostic test.

Limitations

A limitation of this study was that only criterion validity was measured whilst content validity was not. The reason was that not all important aspects of the scales were covered therefore the study cannot generalise about all components of the scales. Another limitation of the study was that the non-PFPS group in part E consisted of several conditions of the lower limb. This design was used to show how the clinical tests could differentiate PFPS patients from patients with other conditions. However, the varying pain and function severity of those patients could not be easily predefined. This is a major issue when reporting the sensitivity of PFPS tests. A better design would include the comparison of a PFPS group with several other groups of lower limb conditions with specific pain and function comparing it one at a time. This is a recommendation for future studies however; the big number of studies and the time limits within a PhD study did not allow this design.

5.4 CONCLUSIONS/IMPLICATIONS

The current study has helped in the understanding of the lower limb strength and flexibility of PFPS people referred to the physiotherapy department of a district hospital when compared with individuals without knee pain and those with lower limb conditions in several ways

This actual study has shown how difficult it is to identify clinical findings diagnostic of PFPS and that the current clinical tests and outcome measures are not effective. Cook et al. (2010) came to a similar conclusion and suggested that because of the nebulous pathology PFPS should be a diagnosis of exclusion. At this point it is important to state that history is of vital importance in making the diagnosis; i.e. the symptoms of PFPS is getting worse on going down the stairs, during prolonged sitting and on squatting (Cook et al., 2012)

The results of the current study which has shown that patients with PFPS possess less strength in the quadriceps and external rotators, and have shorter hamstrings and hip flexors compared to healthy controls, suggests that clinicians should include strengthening and stretching these muscles in their rehabilitation programme for PFPS.

In addition, employing the 'clam' test as a means to engage hip abductors and external rotators could be involved in the rehabilitation programme. The 'clam' exercise could replace the frequently prescribed hip abduction with extended knee exercise to strengthen and decrease the easily fatigable gluteal and external rotation muscle groups.

Additionally, only the hip flexion component of the modified Thomas test can be used to identify a possible PFPS case.

5.5 SUMMARY

The results of Phase 2 of the thesis demonstrated that patients with PFPS possessed less strength in the quadriceps and external rotators, and had shorter hamstrings and hip flexors compared to healthy controls. This suggests that clinicians should include strengthening and stretching these muscles in their rehabilitation programme for PFPS. In addition, employing the 'clam' test as a means to engage hip abductors and external rotators could be involved in the rehabilitation programme. The 'clam' exercise could replace the frequently prescribed hip abduction with extended knee exercise to strengthen and decrease the easily fatigable gluteal and external rotation muscle groups. Additionally, only the hip flexion component of the modified Thomas test can be used to identify a possible PFPS case.

The clinical tests which will be used to identify the effect of treatment in the subsequent study in the physiotherapy clinic (Chapter 7) will be those which differentiated PFPS patients from healthy controls. The AKPS and LEFS have been found to be generally reliable and valid, however the author has noticed different point of views when conducting the RoR with regards to these scales. Therefore, a further analysis of those two scales will take place in Chapter 6. The results of this analysis will help in the process to design a Modified AKPS (an example is given in Appendix 10) which will also be used in Chapter 7.

5.6 REFLECTION

This phase of the thesis identified an important part of the research question which was the ability to identify a PFPS case via clinical tests. The results validated the difficulty that treatment providers confront when they see patients with PFPS. The multifactorial cause does not allow clinical tests to be very specific for PFPS. This probably explains the reason that physiotherapists have modified the way they assess the syndrome by using the same methods when treating it (functional methods; such as squats and stairs).

CHAPTER SIX

PHASE 4 - AN EVALUATION OF TOOLS OF THE ANTERIOR KNEE PAIN SCALE AND THE LOWER EXTREMITY FUNCTIONAL SCALE IN PATELLOFEMORAL PAIN SYNDROME

6.1 INTRODUCTION

The RoR showed that apart from a few preliminary studies, outcome measures for PFPS were largely untested at the time of the PhD design (2008). Among different outcome measures only the AKPS [(Kujala et al., 1993) (Appendix 5)] had been designed for PFPS (Howe et al., 2012) According to Esculier et al. (2013) the AKPS could be recommended for PFPS use but there was a need for further testing in larger populations. Another scale which was assessed in the aforementioned systematic reviews was the LEFS [(Binkley et al., 1999) (Appendix 6)] which is a generic scale for any lower extremity pain. This scale is used in many primary studies but was also one of the outcome measures NWW physiotherapists reported in the mixed method study survey (Chapter 4). In fact, the LEFS was mentioned more frequently than the AKPS. Howe et al. (2012) reported that although the AKPS shows evidence of content validity and responsiveness, the LEFS revealed excellent reliability and better responsiveness. However, LEFS does not include questions such as locking, swelling and giving way of the knee.

Although these scales are used widely, there is currently not enough evidence regarding their specific reliability in PFPS patients. Crossley et al. (2004b) reported that the AKPS was one of the most efficient measures for detecting a treatment effect; however, Bennell et al. (2000) demonstrated that although the AKPS was a reliable tool amongst others, the size of the measurement error should be considered. Other researchers (Watson et al., 2005; Paxton et al., 2003) tested the test re-test reliability of both scales finding them extremely reliable for PFPS patients. However, they commented that both scales include questions which are meaningless from many patients whilst other questions should be included (e.g. about kneeling). In addition, other authors (Callaghan et al., 2009) challenged the specificity of those questions and whether they can differentiate PFPS from patients with other knee condition. Finally, all the above studies call for further research to determine whether modification of these scales would produce a tool with better sensitivity and specificity.

The aim of the current study was to identify which individual questions used in the questionnaires make the scales less appropriate for use in PFPS cases. This would be accomplished by investigating the test-retest reliability of the overall scores of the AKPS and the LEFS (also reported in Chapter 5), and looking at internal and test-retest reliability of the individual questions.

6.2 RESULTS

Twenty patients (10 males and 10 females) were included in this study. They were aged between 18 and 40 (29.00 ± 6.60 years). Most of the patients (17/20) reported to have on/off pain (rather than permanent) which was aggravated with several activities (e.g. sports). In addition, the patients had been in pain for 62.20 ± 61.90 months. The total scores of the two scales performed on two occasions (also reported in Chapter 5) were highly reliable [AKPS; ICC = 0.82, F (19, 20) = 5.82, sig<0.00; LEFS; ICC=0.82, F (19, 20) = 5.44, sig<0.00] and so was the internal consistency for each scale [AKPS; Cronbach's alpha = 0.78, LEFS; Cronbach's alpha = 0.92].

However, within the reliability (test-retest) of each separate question there were some less reliable questions (<0.70=moderate reliability) as highlighted in Table 16. The standard error of measurement was satisfactory as it was found very low in most cases. The AKPS revealed five questions with moderate test re-test reliability (questions one, two, five, nine, and 11) with four in the LEFS (questions nine, 11, 13 and 19). Analysis of the individual questions in the AKPS revealed two questions (question one & 12) that would increase the overall internal consistency if they were 'deleted' from the scale. Similar analysis of LEFS showed only one (question 13). Additionally, both scales included questions that may be considered as meaningless as patients with PFPS answered as 'no problem' on both occasions; In the AKPS these were question number 10, 12 and 13 and in the LEFS the questions were three, four, five, seven, 10 and 20 (Table 16).

Questions in AKPS	Mean ± SD occasion 1	Mean ± SD occasion 2	ICC	SEm	Cronbach's alpha if item deleted	N/A Questions
Question 1 (Limp)	3.9±1.0	3.3±1.1	0.69*	0.07	0.79+	4
Question 2 (Support)	3.4±1.2	3.6±0.9	0.45*	1.92	0.78	1
Question 3 (Walking)	3.3±1.3	3.2±1.3	0.83	0.50	0.76	5
Question 4 (Stairs)	4.1±2.3	3.1±2.4	0.85	0.34	0.76	0
Question 5 (Squatting)	3.5±1.0	3.1±1.3	0.46*	1.14	0.77	1
Question 6 (Running)	4.0±2.2	5.4±2.8	0.79	1.21	0.78	1
Question 7 (Jumping)	5.9±2.7	5.3±2.9	0.81	1.22	0.72	1
Question 8 (Prolonged sitting with knees flexed)	6.4±2.3	6.5±2.4	0.95	1.30	0.73	3
Question 9 (Pain)	5.4±2.3	5.1±2.4	0.66*	1.66	0.77	0
Question 10 (Swelling)	9.0±2.4	8.9±2.4	0.95	0.31	0.75	13#
Question 11 (Instability giving way in the knees)	6.8±2.6	6.6±2.4	0.63*	1.89	0.82	4
Question12 (Atrophy of thighs)	4.5±1.3	4.6±1.2	0.97	0.12	0.90+	17#
Question13 (Flexion deficiency)	4.3±1.3	4.4±1.3	0.90	0.33	0.77	13#
Questions in LEFS						
Question1 (Usual work activities)	3.0±1.1	2.7±1.1	0.83	0.45	0.91	2
Question 2 (Hobbies)	1.5±1.2	1.5±1.3	0.77	0.63	0.92	1
Question 3 (Into out of the bath)	3.6±0.9	3.6±0.8	0.92	0.17	0.91	12#
Question 4 (Walking between rooms)	3.8±1.1	3.8±1.0	0.86	0.37	0.92	15#
Question 5 (Putting on/off socks)	3.3±0.9	3.3±0.9	0.93	0.17	0.92	10#

Question 6 (Squatting)	2.1±1.4	1.8±1.3	0.78	0.68	0.92	1
Question 7 (Lifting an object)	3.7±1.0	3.7±0.9	0.97	0.02	0.92	13#
Question 8 (Light activities at home)	3.3±1.0	3.3±0.8	0.70	0.57	0.92	7
Question 9 (Heavy activities at home)	2.5±1.1	2.6±0.9	0.55*	0.82	0.92	2
Question 10 (Getting into car)	3.3±0.9	3.2±1.0	0.88	0.30	0.92	10#
Question 11 (Walking 2 blocks)	2.9±1.2	3.0±1.1	0.59*	0.92	0.91	6
Question 12 (Walking a mile)	2.3±1.1	2.6±1.1	0.80	0.52	0.92	3
Question 13 (Up or down 10 steps)	2.4±0.8	2.5±1.1	0.64*	0.71	0.93×	1
Question 14 (Standing 1 hour)	2.8±1.1	2.5±1.2	0.91	0.26	0.92	6
Question 15 (Sitting 1 hour)	2.8±1.3	2.9±1.0	0.75	0.61	0.92	4
Question 16 (Running on even ground)	1.9±1.2	2.0±1.1	0.88	0.38	0.92	1
Question 17 (Running on uneven ground)	1.6±1.1	1.6±1.1	0.89	0.32	0.92	1
Question 18 (Making sharp turns while running)	1.6±1.4	1.8±1.4	0.91	0.31	0.91	3
Question 19 (Hopping)	2.1±1.4	2.2±1.5	0.61*	1.12	0.91	2
Question 20 (Rolling over in bed)	3.7±1.0	3.8±0.9	0.93	0.19	0.92	15#

Table 16. ICC: Intraclass Correlation Coefficient. SEm: Standard Error of measurement. N/A questions: the number of patients who answered the question as 'no problem' in both occasions.

**: questions with moderate test-retest reliability. #: considered meaningless questions for PFPS. +: AKPS questions with internal consistency less than 0.78. ×: LEFS question with internal consistency less than 0.92. The confidence interval was 95% in all cases.*

This study demonstrated high test-retest reliability for the total scores of AKPS and LEFS in PFPS patients and is in agreement with previous studies using similar methodology to detect test-retest reliability of the two scales (Watson et al., 2005; Paxton et al., 2003). In addition, both scales revealed high overall internal consistency. Although the AKPS is said to be more appropriate for PFPS patients (Bennell, 2000), it revealed a lower Cronbach's alpha (0.78) than the more generic LEFS (0.92). The explanation of this is likely to be that some of the questions in the AKPS focus on pain (question nine), other on function (question three) and other on self-assessment (question 12), while the LEFS focuses only on function.

Not all questions demonstrated the same internal consistency. The two questions regarding limping and atrophy of thigh muscles (questions 1 & 12) in the AKPS, would increase the overall internal consistency if they were excluded ('deleted') from the scale, while such a question in the LEFS was found to be the one about going up and down 10 steps (Question 13). These three questions were found to correlate poorly with the other questions within the scales and to diverge from the consistency of results across questions (Rattray and Jones, 2005). The reason that these questions lowered the overall internal consistency is probably because of the great divergence in the answers of these questions from different patients. Some patients had significant problem with limping and walking up/down the stairs. However, this would depend on whether they were in pain on the day they completed the scales. On the other hand, although the stair question is mentioned in both scales, the question was found to lower the internal consistency only in the LEFS. The reason was probably that the question in the LEFS was referred to walking up and down ten stairs whilst patients with PFPS usually have problem only when they go down the stairs. It is possible that if the question was reworded the results of this question would be different. Finally, although some people could detect their 'wasting of thigh muscles', some others could not because they did not what this question meant (question 12 AKPS).

The current study has also revealed several questions within the two scales which are unreliable for PFPS. These were questions that PFPS patients did not probably know how to answer because there were terms that patients were not familiar with (e.g. instability/giving way in the knees) or because they are not appropriate and every time patients completed the questions they may had a different activity in their mind (e.g. heavy activities at home). On the other hand, cultural differences relating to the understanding of the words used in the questions could be another reason for moderate test-retest reliability. Such an example could be the question about walking. This question revealed high test-retest reliability in the AKPS (0.83) but moderate in LEFS (0.59). The latter scale asks about the problem that patients have when they have to walk two blocks. The word 'block' is mostly used by Americans and not used by British people and does not apply to a rural area where there are no 'blocks'.

As these scales were not designed for PFPS only, they include questions that could be considered as meaningless, i.e. where the patients completed them as 'no problem' on both occasions. Meaningless questions will reduce the ability to discriminate change. Such an example would be question number 12 (atrophy of thigh muscles) of the AKPS which revealed "excessive" reliability (0.97) because 17 out of the 20 patients reported it as 'no problem'. This study agrees with the work of Kujala et al. (1993) who also found extremely small or no differences for questions 10, 12 and 13 in a PFPS group compared with healthy controls in the AKPS.

The limitation of this study was that no randomised methods were followed; therefore, participants were assigned to procedure by not a random method. If participants completed the scales in different order within their testing procedure the outcomes would be more valid regarding the internal validity. However, all participants completed the scales before they started their muscle testing in order to avoid potential pain or tiredness affecting the completion of the scales.

The author of this thesis agrees with suggestions that a modified version of the above scales excluding the less reliable and meaningful questions (Heintjes et al., 2003) and replacing them with questions which can discriminate PFPS from other knee pain conditions (Callaghan et al., 2009) would improve their effectiveness. The present study has provided information about which questions should be replaced or reworded (e.g. the question about squatting was more reliable in LEFS than in AKPS). Also, because all people do not perform the same activities (e.g. running and jumping) and cannot assess themselves (e.g. wasting of thighs) it is suggested that all questions in a modified scale need to include a 'not applicable answer' choice. The PFPS patients did not report consistent pain (17/20 reported on/off pain rather than permanent pain), so questions should focus more on function in activities (as the LEFS does) and not on pain (AKPS focuses more on pain). The reason that some of the questions reported less reliability may be the absence of a specified time for the occurrence of pain.

6.3 SUMMARY

Although the scales were found to be generally reliable, both have been shown to include non-appropriate PFPS questions. The AKPS has revealed 10 questions with less reliability or meaningfulness for PFPS whilst the LEFS revealed 11. These questions could be reworded or replaced with other questions more appropriate for individuals with PFPS. Further research with more patients is called to support this evidence. This study provides valuable information for the development of a modified or a new PFPS scale which will be more responsive to change and may help indicate if they are ready to return to their sport or working activity. Therefore, a modified AKPS (MAKPS) was designed by the researcher (see Appendix 10). Since the MAKPS had not been validated, it could not be used as the only outcome measure to assess the effectiveness of physiotherapy in the feasibility study (Chapter 7). Although the AKPS and the LEFS were found to include problematic questions, they revealed high test-retest reliability and internal consistency. These questionnaires have also been validated for use in PFPS elsewhere (Kujala et al., 1993; Binkley et al., 1999). Therefore, it was decided that all three scales should be used as outcome measures to assess the effectiveness of a six-week course of physiotherapy on PFPS.

6.4 REFLECTION

This phase shows the lack of appropriate outcome measures for patients with PFPS. Perhaps this was already known by the clinical physiotherapists who reported not to use them regularly. However, there is a strong need for reliable, valid and meaningful scales in PFPS which will enable researchers and clinicians to assess and measure treatment results. The scales that are used today are not appropriate for PFPS and can be modified.

CHAPTER SEVEN

PHASE 5: AN EVALUATION OF APPLIED PRACTICE - A SIX-WEEK PHYSIOTHERAPY TREATMENT PROGRAMME

7.1 INTRODUCTION

A search of the literature did not reveal previous research studies which have investigated the effectiveness of the NHS physiotherapy treatment of PFPS in a non- academic setting. Having identified the exercise-based interventions that the literature suggests (Chapter 3) and the matched clinical methods that NWW physiotherapists use when treating patients with PFPS (Chapter 4), it was important to identify the effectiveness of a six-week period of NHS physiotherapy treatment. In Chapter 4, NWW physiotherapists reported to use a selection of physical activities aimed at strengthening and stretching lower limb muscles. Harvie et al. (2011) reported in their review that a six-week intervention should be considered for programmes targeting patients with PFPS (Chapter 3). Therefore, this study aimed to investigate the effect on muscle strength, flexibility, pain and function of a six week programme of physiotherapy for PFPS delivered in a district NWW NHS hospital.

7.2 RESULTS

7.2.1 Participants

26 patients with PFPS were referred by a consultant or general practitioner to NWW physiotherapy department and were recruited after the recruitment procedure explained in Chapter 5; part E.

7.2.2 Diagnostic tests

Before treatment the modified Thomas test was found positive in 17 out of the 26 patients and 16 of them were found positive after treatment. The patella compression was positive in 10 PFPS people before treatment and 4 after the treatment. There was no significant difference for the diagnostic tests before and after treatment (modified Thomas test p=0.76; patella compression test p=0.09).

7.2.3 Flexibility tests

The analysis of the flexibility tests showed that there was no significant effect (p<0.05) of the six-week treatment on the length of the quadriceps and iliopsoas muscles. Additionally, the effect sizes 'r' were small for all tests (Table 17).

7.2.4 Strength tests

The series of strength tests showed that there was no difference after treatment (see Table 17) Figure 16 displays the strength results. Strength tests similar to flexibility tests reported small effect sizes 'r'.

7.2.5 Clam' functional stress protocol

The 'clam' functional stress protocol showed that although strength was reduced before and after the 'clam' test protocol at both time points (Table 17), the physiotherapy treatment had no effect in this performance decrement (Pre functional stress 'clam', p=0.36; Post 1 functional stress 'clam', p=0.13; Post 2 functional stress 'clam', p=0.26). All these tests reported moderate effect sizes 'r'.

7.2.6 Questionnaire and scales

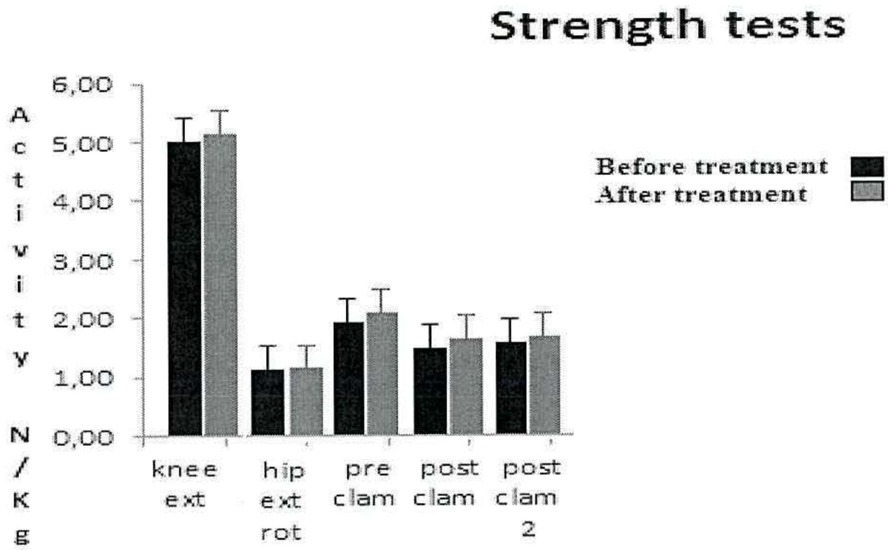
The MAKPS and the AKPS showed significant improvement in PFPS patients after they received their treatment. The LEFS did not show any change in the PFPS group; however the difference was very close to be significant (p=0.06) (Table 17). The two VAS which are included in the MAKPS (the VAS for the pain on the day of the assessment and the VAS for usual pain) showed significant change after treatment. In addition, the VAS after the functional stress 'clam' test was not affected by treatment. The VAS after the functional stress 'clam' did not reveal any deterioration in pain when it was compared with the pain they had the day of the assessment (before treatment p=0.96; after treatment p=0.08). The MAKPS reported the highest effect size (r=0.24). All scales reported a small effect size 'r'.

Flexibility tests	**Before treatment**	**After treatment**	**p values following treatment**	**Effect size r**
iliopsoas flexibility (degrees)	5.84 ± 6.89	4.24 ± 5.59	0.13	0.13
quadriceps flexibility (degrees)	62.72 ± 14.31	64.16 ± 14.19	0.33	-0.05
hamstrings flexibility (degrees)	33.48 ± 17.98	30.84 ± 15.48	0.49	0.07
Strength tests				
isometric knee extension N/kg	4.99 ± 1.71	5.13 ± 1.41	0.39	-0.04
isometric hip abduction from 'clam' position N/kg	2.22 ± 0.76	2.39 ± 0.76	0.14	-0.11
isometric hip external rotation N/kg	1.13 ± 0.57	1.15 ± 0.37	0.80	-0.02
'Clam' stress protocol				
Pre functional stress 'clam' activity N/kg	1.79 ± 0.79	2.12 ± 0.80	0.17	-0.20
Post 1 functional stress 'clam' activity N/kg	1.46 ± 0.65	1.67 ± 0.73	0.26	-0.15
Post 2 functional stress 'clam' activity N/kg	1.52 ± 0.61	1.72 ± 0.72	0.26	-0.14
Questionnaires and Scales				
Modified AKPS	2.49 ± 0.75	2.09 ± 0.80	0.00*	0.24
AKPS	66.23 ± 16.26	72.04 ± 12.83	0.01*	-0.19
LEFS	55.03 ± 15.85	59.40 ± 13.81	0.06	-0.14
VAS usual pain	4.32 ± 2.74	3.29 ± 2.33	0.02*	0.20
VAS on the day	2.35 ± 2.33	1.59 ± 1.87	0.02*	0.18
VAS after functional stress 'clam'	2.32 ± 2.52	2.18 ± 2.36	0.59	0.03

Table 17. The table presents the effect of treatment on flexibility, strength tests, 'clam' stress protocol and questionnaires and scales.

**=significant difference*

Figure 16. The figure displays the isometric strength tests prior to and following physiotherapy treatment



7.3 DISCUSSION

The main finding of this study was that the patients with PFPS got improved, regarding their pain and function following physiotherapy treatment at a NHS hospital, while their strength and flexibility did not. The MAKPS showed that it could detect the effect of treatment; more than the validated AKPS. The LEFS, showed no significant change in PFPS after treatment. The two VAS (for usual pain and for pain the day of the assessment) reported significant change after treatment and this justifies the possibility to include these in the modified AKPS. The VAS for usual pain could detect the average pain that patients were experiencing, but as PFPS appears more as an on/off condition than a constant pain, a VAS for the pain on the day of the assessment was deemed necessary. Thus, one of the benefits of using the modified AKPS was that each patient got three scores; 1 for the questions and 2 for the pain scales.

7.3.1 Treatment effect

Although the pain was shown to be reduced after treatment, there was not a significant increase in strength or flexibility, post treatment. The portable dynamometer showed the ability to detect changes in strength; however the six-week treatment did not show any improvement on the tested muscles. With regards to flexibility, the same goniometer used in the laboratory tests was also used in this study. However, when using such instruments, there is always a potential measurement error that should be considered. Physiotherapists aimed to reduce pain and improve function but also to increase strength and flexibility (as reported in Chapter 4) however; this was not achieved. It seems that although physiotherapists wanted to improve those two components, they actually only improved function and pain, thus, the modified AKPS and the VAS for usual pain and for the pain on testing day were improved. All other scales which showed statistically significant results (AKPS, VAS for usual pain, VAS for pain on the day) with small effect sizes should be taken into consideration with regards to their practical importance

Cook et al. (2010) suggested the pain during a single squat as another outcome measure to detect physiotherapy effect. In the current study the 'clam' performance was used. However, physiotherapy treatment had no effect on the 'clam' performance decrement. The non-significant results in strength and flexibility are not in line with the systematic review of Harvie et al. (2011) who reported that a six-week exercise intervention could be effective (strength and flexibility-wise) for patients with PFPS. However, the authors reported that the majority of studies prescribed five or more days of exercises per week and the intensity of the exercises was high. A similar review from Bolgla and Malone (2005) included studies with a minimum of 12 visits in a four week intervention. This frequency of visits is not possible in a NHS physiotherapy clinic where physiotherapists see their patients once per week at maximum. Additionally, if the exercises were prescribed for home use, neither the compliance nor the intensity could be guaranteed since physiotherapists reported in Chapter 4 that their patients do not often comply with their exercises. Non-compliance may be related to the fact that many patients are not used to exercising and in this study most of the patients were not athletes (14/26; see Chapter 5 for more details) and did not previously perform any sports exercises or sport activities. The decrease in pain following treatment may have thus come from the factors, other than strength improvements, reported in the RoR, such as patient education -including activity recommendations, treatments with conflicting evidence such as acupuncture, low intensity exercises and anti-inflammatory or analgesic drugs (Frye et al., 2012). Frye et al. (2012) reported that these modalities have been found to play an important role in improving patient outcomes. Because of the plethora of interventions they stated that it was difficult to isolate the precise source of improvement.

7.3.2 Limitations

The sample size was calculated according to the needs of a comparison study (to report differences between PFPS and other conditions group) and not to the needs of an intervention study.

Additionally, the modified AKPS was not validated before or implemented to a large number of patients. However, it was designed carefully by finding the limitations of the AKPS and by consulting other authors regarding what questions and design a new AKP questionnaire should have.

7.4 CONCLUSIONS/IMPLICATIONS

Physiotherapy treatment did not improve strength or flexibility in this feasibility study. Treatment did however, improve pain and function. There are several possible explanations for this including the therapeutic effect of the physiotherapeutic consultation, explanation of the cause of the knee condition and what the patient could do about it, a placebo effect and improving posture and the quality of movement. Having established that physiotherapists use exercise-based interventions and having identifying the effectiveness of the treatment, the next step will be to identify possible barriers in the fully adoption and implementation of the suggested research interventions by the NWW physiotherapists. Therefore the following study (Chapter 8) will investigate what physiotherapists think about the results of the present study and look further into what they want to achieve when they treat patients with PFPS. If their major aim was to improve pain and function, then their treatment works. If this turns out to be the case then there is a need to look at the implications of this practice.

7.5 SUMMARY

This chapter aimed to evaluate the applied physiotherapy practice via the monitoring of a six-week physiotherapy treatment at the local NHS physiotherapy department. The results were not completely in line with what physiotherapists reported in chapter 4 about the aims of their treatment. Therefore, no significant strengthening or flexibility was achieved after the six-week treatment. However pain and function were increased significantly.

7.6 REFLECTION

This phase of the thesis was a part of the research question about the transferability of the literature in the clinical environments. The phase reported some unexpected results. The six-week treatment did not appear to help patients in the way physiotherapists thought and reported in phase one. Therefore no strength and flexibility changes were achieved in those patients, however; patients appeared to get better regarding pain and function. These results revealed that there were important barriers in the clinical physiotherapy practice (patient and organisational contexts) that would not allow physiotherapists to achieve what they wanted to achieve. Therefore the results were the subject of a new discussion between the research and the physiotherapy team who gave an explanation of their practice and their real focus of their treatment (phase 6).

CHAPTER EIGHT

PHASE 6: AN EVALUATION OF THE ROLE OF PHYSIOTHERAPY AND APPLIED PRACTICE ON PAIN AND FUNCTION

8.1 INTRODUCTION

This chapter details the results from a qualitative phase of the thesis that sought to understand at greater depth the nature of the applied context for physiotherapy practice in relation to PFPS. It sought to understand from the perspective of practitioners the complex issues underpinning their practice behaviours, expectations of treatment and the possible links to patient outcomes.

In Chapter 4 NWW physiotherapists reported using a series of strength and flexibility tests to assess and treat PFPS. However, the research undertaken in Phase 5 (Chapter 7) investigating the effect of a six week period of physiotherapy performed in the same physiotherapy department, showed that strength and flexibility of patients with PFPS did not increase significantly. Interestingly their pain levels improved significantly. This was a surprising finding and to investigate it further a focus group study was set up. The objective of this was to investigate what NWW physiotherapists, who treat NHS patients with PFPS, think about the findings of this study and how they might explain it. In addition, this phase of the thesis was designed to compare physiotherapists' contradictions and explanations regarding their practice expressed previously (Chapter 4) and after the study regarding the treatment effect (Chapter 7). The focus group phase enabled the research question to be investigated more fully through the sample of NWW physiotherapy practice and understanding the applied context of physiotherapy relating to PFPS.

8.2 RESULTS

Physiotherapists were not surprised with the results of the six-week physiotherapy treatment. After talking to each other they realized that what they did was not strengthening and stretching but rather muscle coordination, muscle tone-up and corrections of the biomechanics. Strengthening was not part of their normal treatment. They used functional techniques and education to improve their patients, although they knew that this is not enough. However they would not change their treatment because if they did, their patients would not comply.

8.2.1 Data collection and hypotheses

1. **Hypothesis that the results were surprising to physiotherapists**

   Physiotherapists were asked to discuss the finding that a six-week course of physiotherapy did not increase strength and flexibility in PFPS patients. This finding was not in line with the reported physiotherapy treatment objectives, according to which, they aim to get patients stronger and more flexible (Chapter 4). However, the hypothesis was rejected because the physiotherapists did not appear to be surprised by the results. The main reason given was there was not enough time to physically increase strength and flexibility. Participants believed that longer than six weeks was required to increase muscle strength while increased flexibility would not occur before the muscles gained other characteristics such as control. These are illustrated by the following quotes:

Strength

FG2P3:...*I was not surprised that there was no change in strength. As much as I am concerned it takes more than 6 weeks to become stronger anyway.*

FG1P5:.... *and I think it takes more time to strengthen than 6 weeks. I know studies that have been done before, they have shown it could take more than a year to build up good strength back, in conditions like ACLs or something; it takes more time to build up muscle strength; at least to get an obvious difference that you could pick up statistically, so I think it might takes longer than just 6 weeks.*

Flexibility

FG2P3:...*maybe not enough time.*

Researcher: *not enough time from you or from the patients?*

FG2P3: *For the muscles, to get some length...*

FG2P6:...*I think there is some evidence that some of the muscle are reducing strength and becoming tight because they are trying to stabilize joints because the muscles around them aren't controlling them. So, in six weeks if you give them flexibility exercises, and you have not increased the control of the muscles then you won't get any muscle length.*

Evidence statement 1: Physiotherapists did not deny that their practice aimed to increase strength and flexibility. However, a six-week time period was not enough to demonstrate improvement in strength and flexibility. Additionally, they reported that if patients were measured later than those six weeks, those results would probably be significant. This shows that physiotherapists believed that their treatment has a long term effect which lasts even after patients are discharged from the physiotherapy department.

2. Hypothesis that physiotherapists used methods to improve strength and flexibility

Physiotherapists were asked whether they believed that patients with PFPS really became stronger and more flexible with treatment. This statement was supported in the mixed method study (Chapter 4). Their answer was positive and the hypothesis seemed to be accepted (Figure 17). However, when discussion revealed how they increased strength and flexibility, it became apparent that what physiotherapists meant by increasing strength was not what physiologists/sport scientists mean. There was a disagreement about how strengthening can be achieved, with physiotherapists believing strengthening is achieved by general functional exercises, whereas physiologist/sports scientists believe that an increase in strength can only be achieved with intense exercises. The same issue appeared regarding flexibility. The physiotherapists appeared to be uncertain regarding the severity of exercise that is needed to be applied to gain strength or the stretching techniques required for a significant measurable muscle lengthening effect.

Strength

FG1P2: *I think strengthening is what makes functional…I think to me strengthening is getting the muscle in a functional way.*

FG1P5:*…I still think a lot of it, I mean there is an element to strength; a lot cannot just be that proprioceptive, I mean this is not necessarily condemned to strength…it is about the quality of movement and the finding that the firing of different muscle is there.*

FG2P4: *I give some people to do repetitions of sitting to stand in a proper alignment and that is functional but it strengthens as well.*

Flexibility

FG1P5:...*again, unless flexibility is actually changing the functional angle... it is probably not going to change that much...is it?*

FG1P4: *I might give them ITB stretch, like a small squat flattening back against the wall then try to hold it...like a squat...but again it is the quality of movement rather than...stretch...and core stability.*

Evidence statement 2: NHS physiotherapists do not have the same perception as physiologists/sport scientists regarding how strength and flexibility can be achieved. Physiology evidence shows that an increase in muscle strength can be achieved in six weeks if intense and precise strength and flexibility programs are applied 3 times per week or in a day by day basis.

3. Hypothesis that physiotherapists did not measure outcomes of strength and flexibility

One of the key messages of the mixed method study (Chapter 4) was that North-West physiotherapists hardly use outcome measures in their practice. Therefore, the hypothesis was that physiotherapists did not increase strength and flexibility because they did not measure the outcomes of this practice. The hypothesis was appeared to be rejected in the beginning because physiotherapists agreed that it would be ideal to have an isokinetic dynamometer to measure strength or an electronic goniometer to measure flexibility. However, after some discussion the physiotherapists appeared to change their mind for two major reasons; the first was that such instruments would need a lot of time to be set up and this would waste the little time they have for each patient (20 minutes) and second, they realized that it is not a typical physiotherapy practice to measure these two muscle characteristics. Therefore, the hypothesis was accepted (Figure 17).

FG1P3: *...If we had that (isokinetic dynamometer) with patients it would be great.*

FG1P5: *...But it needs something to be simple. Like the grip strength with hands. So it has to be something very practical. To be realistic, the time we have with a patient is not enough for something complicating.*

FG2P4:*...we do not measure strength, we do not have these results. That is not our normal practice. We do not aim to reach a specific amount of strength.*

FG2P2: *...but we do measure muscle bulk don't we?*

FG2P4: *...the thing is that when you measure muscle bulk your points might be different to mine...it is very subjective isn't it? We do not really measure it, do we? But if you had a measure to point 'this is where these patients are' this wouldn't depend on which physio does it because it would be in the same platform.*

Evidence statement 3: It is not a typical physiotherapy practice to measure strength an flexibility. This evidence shows that exact level of these two characteristics was not intended to be achieved.

4. **Hypothesis that patients referred to the outpatient physiotherapy department are not athletic**

The RoR (Chapter 3) showed that most of the patients who took part in PFPS research studies were athletic. However, the hypothesis was that the patients physiotherapists se in the NHS clinic were not athletic since the mixed method study and the researcher's experience at a district hospital supported this opinion. When physiotherapists were asked whether their patients are similar to those the literature reports, they answered negatively, reporting that most of their patients are not athletic. They also reported that they see patients with different activity levels (from very active to no active at all). Their belief was that most of their patients have PFPS because they do not do any exercise rather than from overuse. In fact some of the physiotherapists reported that if their patients were active they would not be needed consultation. Therefore, the hypothesis was accepted.

FG1P2:...*we think that 80% of them aren't and this is a problem we have to confront.*

FG2P7:...*they vary massively; you can get sport people with high level of motivation and people who do actually nothing.*

FG1P3:...*If they were active, would they be here? I do not know...*

FG2P3:...*the active ones might go private first because they would like to see a sport physio and they want to see someone quickly.*

FG1P2:...*In private practice you do not get to see these people (non-active patients) very often and they are keener to do what they are told...*

Evidence statement 4: Physiotherapists have to deal with non-athletic patients. This kind of patients are not familiar with sport activities, thus physiotherapists prescribe simple and generic exercises (otherwise patients will not perform them) which may lead to a non-significant increase of strength and flexibility. This contradicts the first evidence statement according to which a longer time period would change patients' strength and flexibility.

5. **Hypothesis that patients do not comply with the prescribed exercises and that played an important role to the non-significant results of strength and flexibility**

The hypothesis was that patients did not comply with the prescribed exercises and this was supported by the mixed method study (Chapter 4) which reported that physiotherapists believed that most of their patients would not comply with the prescribed exercises. The hypothesis was accepted as physiotherapists reported three major reasons; first, patients' lack of interest in doing exercises, second, their busy schedule and third, physiotherapy is at some cases an 'exit route', which means that physiotherapy can be a way to discharge patients from hospitals. Physiotherapists also reported that the fact that patients do not comply with their prescribed exercises has to do with patients' physical activity. Less active patients are unlikely to comply at all.

FG1P1:...*It depends on whether they are used to exercising.*

FG1P2:...*well some of them may would, if they do not work.*

FG2P5:...*people who want to get better and more active will tend to listen more, while those who are obese and not active are most likely to referred to the physiotherapy by a GP just because it is an exit route. These patients do not really want to be here...*

FG2P7:...*I think that even the athletic patients do not necessarily comply, some of them do some of them don't. I think the problem with these high activity level patients is that even if they do their exercises they do not stop their activity because they are determined to carry on.*

Evidence statement 5: Patients' perceived lack of compliance with prescribed exercises affects physiotherapy practice by inducing physiotherapists to prescribe a few and simple exercises. This may lead to a non-significant increase of strength and flexibility at 6 weeks.

6. **Hypothesis that correction of bad biomechanics/bad posture, useful tips/education psychosocial factors might have played a role in the patient improvement.**

This hypothesis was created from the mixed method study where physiotherapists reported a series of different treatment components they use when treating PFPS patients. The hypothesis was accepted. However, more treatment methods than expected were reported. The treatment methods could be separated in three major categories. The first two categories were the two major components of their treatment which included 1) education and 2) functional exercises/getting patients do any activity, while the third one included all the other biomechanical components entitled as: 3) Increase control, balance, quality of movement, core stability, proprioception, get the muscle fire off better. Evidence statements were created for each of the three components of their treatment separately.

Education

Education was reported as one of the most important treatment component achieving pain decrease. Education contained three different components (psychological effect, knowledge and reassurance and self-managing). Having patients know why they have to do the exercises, can designate compliance.

Psychological effect

FG1P5:*...yes it a sort of placebo effect as well.*

FG1P3:*...it is a psychological thing...you know, pain is felt in here (showing the head) rather than in here (showing the knee) so I think we cannot discount that* *coming to physio and being assured that everything is alright and that they just need to get moving, probably improves the function and pain.*

Knowledge and reassurance

FG1P2:... *We usually explain to patients why they have the pain...they understand why they are having the problem...because the muscles aren't firing in the right way, there is no balance…and we tell them 'let's get them work in the right way'.*

FG1P4:...*some patients come and say 'oh I am glad I heard that, I was scared of doing exercises'...and then after a couple of weeks they come back and say: 'I do not have any knee pain anymore'.*

Self-managing

FG1P1: ...*I also teach them to do their own patellofemoral moves so they can do their own stretches at home with that.*

FG1P5:...*I think if you encourage them long term to do more activity that can keep it away for longer, otherwise they might come back very soon. You need to change their function long terms and encourage them to start going to the gym and build up strength and keep it for long period.*

FG2P5:...*if the patients know why they are doing it, it is more likely they comply. If they know that they are going to get some benefit from doing the exercises then they are going to do them if not then there is no chance.*

Evidence statement 6: Education (psychological effect, knowledge and reassurance and self-managing) plays an important role in reducing patient's pain and improving function, enhancing patient compliance and keeping patients without pain in the long-term.

Functional exercises/getting patient do any activity.

Physiotherapists reported that they mainly prescribe functional exercises to patients (e.g. walking up and down the stairs correctly, controlled knee bends) and in some cases they only ask from their patients to get involved in any sport activity (gym, ball games) since their muscle tone is extremely low. This practice can also be linked with patients' reluctance to comply since they often are not athletic and not keen on doing precise exercises. However, this can also be another reason why strength and flexibility are not increased after a six-week treatment.

Functional exercises for strength and flexibility

FG1P2:*...getting them to do normal everyday things, standing properly, and walking up and down the stairs, just normal functional things.*

FG1P2:*...for the calves we usually ask them to do some small knee bends, to get some small stretch when they are doing that...or the usual one of the edge of the step...for the hamstrings we usually ask them to do this..(flex their trunk over their legs) they also get to have the control of their trunk when we ask them to do that...*

FG1P3:*...Similar...I might give them hip flexors stretch when the gluts are weak...I give them hamstring too...strength wise I give quads closed chain exercises...*

FG1P2: *I think that they key is the function and this doesn't need any muscle length or muscle strengthening.*

Getting patients do any activity

FG1P2:*...yes sometimes you have to draw a line and think that...yes you are dealing with AKP but...the only thing you can do is to get them do ANY muscle working just to make any difference.*

FG1P5:*...And I think with teenagers I go away from specific exercises; I just tell them to go to the gym to get some muscle tone.*

FG1P5:*...and sometimes, I think with the older patients if you just encourage them to keep moving...because if you get them moving there is blood supply and this improves the pain anyway...so even if you get them do some sittings on the desk, this can make a difference, however you are not improving any of their muscle strength.*

Evidence statement 7: Functional exercises/inducing patients to do any activity are suitable for the type of patients physiotherapists see in the clinic and play an important role in reducing patients' pain and improving function; however they do not increase strength and flexibility.

Increase control, balance, quality of movement, core stability, and proprioception; get the muscle fire off better.

This hypothesis included all other components of physiotherapy treatment that decreased pain and increased function. Physiotherapists reported that they use them according to patients' needs. All patients do not necessarily need to get stronger and more flexible but they might need some other kind of improvement.

Treatment components that increase function and decrease pain

FG1P5:*...yeah the quality of the posture and movements and the quality of right muscle working at the right time.*

FG1P2:*...changing how they move and what muscles work.*

FG2P6:*...their muscle control as well...you do not need to have strength to control your muscles in a better way...control and maybe proprioception makes the difference as well.*

FG1P4:*...the balance as well.*

FG2P6:*...we also do proprioception, core stability, foot posture and other things as well, so, it is not that we are only looking at strength and flexibility.*

FG2P7:*...I think we assess any biomechanical issues anywhere around.*

Strength and flexibility is not always the case

FG1P3:*...you can have a young male/female with good strength and still have Anterior Knee Pain (AKP), so it might be a matter of just getting the quality better...*

Evidence statement 8: A variety of different treatment modalities are used to increase function and decrease pain. They are all patient-dependent. Focusing on these components rather than active treatments may have played an important role in not increasing strength and flexibility however; all patients do not need better strength and flexibility.

7. Hypothesis that physiotherapy aims to improve strength, flexibility pain and function

This hypothesis differs from hypothesis 2 which refers to whether physiotherapists used precise methods/exercises to improve strength and flexibility. Hypothesis 7 refers to whether their physiotherapy practice aimed to achieve such an improvement or they aimed to other components of physiotherapy practice such as pain and function. The mixed method study revealed that physiotherapists believed that they increased strength and flexibility when treating PFPS patients. The feasibility study which aimed to show the physiotherapy effect, showed no improvement of strength and flexibility but there was improvement of pain and function. The hypothesis was rejected because when asked about how they wanted to see their patients after a six-week treatment, they replied that they aimed to see their patients with less pain, better control and back to their activities. However, physiotherapists reported that the way patients appear after treatment, also depends on the patients' characteristics and what they want to achieve.

Pain and function improvement

Physiotherapists reported that strength and flexibility are not part of the physiotherapy practice while pain, control and function improvement are.

FG1P2: *...With less pain, good control and be able to do their sports and their activities.*

FG2P7: *...symptoms to be improved.*

FG2P5: *...being able to achieve functionally what they want to do.*

FG2P4: *...also some objective markers to be improved, like the lower limb alignment, control of their muscles, then, it is more unlikely to come back again.*

FG2P1:*...if this affects their pain levels then that makes us happy too.*

Evidence statement 9: Physiotherapy aims to improve pain and function which is something shown by previous research. Strength and flexibility improvement is not one of their aims.

8. Hypothesis that practice depends on the patients

This statement mirrors physiotherapists' perception regarding their approach to their practice. This appeared to be patient rather than treatment-specific. Although their evidence statements showed some constant expectations of their treatment (pain and function improvement, better muscle coordination and fire-off); these could be the basic expectations. Analysis shows that physiotherapy practice depended firstly on what the problem appears to be in each individual patient but also on what the patient hoped to achieve from their physiotherapy treatment. This explains why pain and inability to perform everyday activities functionally comes as first priority. This implies that the patients' characteristics (non-athletic patients and not willing to comply) affect physiotherapy practice significantly.

<u>Practice depends on patients' characteristics</u>

FG1P1:*...I would not necessarily give them flexibility exercises...*

Researcher: you wouldn't?

FG1P1:*... Well, it depends...*

FG1P2:*...It depends, yeah.*

FG1P1:*...It is something that I might do or might don't but I think, I firstly would go for the posture.*

FG2P6:...*this is where your advice needs to change. You get people who need some rest from their activities and others who need to do something active.*

FG1P5:...*it depends whether it is too painful to squat...sometimes is a useful exercise and sometimes they find it painful, it depends on what the patients can do as well. So again it depends on your patients and how they present.*

Practice depends on what patients want to achieve

FG2P4:...*and a lot of the time they want you to do something around the knee... they do not think it is useful to do other stuff.*

FG1P5:...*I think it is a little bit different if you work with top elite sport people because the aim is different isn't it?*

Evidence statement 10: Physiotherapy practice aims to increase function and decrease pain and from this point of view the treatment works. Treatment depends on how patients present and what they want to achieve.

9. **Hypothesis that physiotherapists would think about changing their practice**

Physiotherapists claimed that they work on getting patients stronger and more flexible, however this thesis has shown that there was no improvement after a six-week period of treatment. Therefore it was hypothesised that physiotherapists might consider changing their practice. However the hypothesis was rejected because, although they appeared to be willing to change (if they were told to), they did not think that they needed to change because they believed that what they do works. However, it appeared that physiotherapists knew that there is also a need for improvement in strength and flexibility; in fact they reported that if strength and flexibility were achieved their patients would not have to return after a short period of time.

Treatment works…

FG1P2:*…I do not know…if the outcomes show that patients are feeling better, then that is the main thing isn't it?*

FG2P1:*…I think we would be opened to try anything…*

FG2P7:*…well even though we do not increase strength or flexibility we obviously do something and it is definitely worth doing. So maybe the thing about the strength and flexibility is not actually be needed to make difference anyway…*

…but long-term effect of the treatment is needed

FG2P5:*…in terms of the demand of the physios these days, I know from back point of view, we do back education classes, that potentially we could group AKP patients into a group and we could get a programme with serious strength and stretching for longer term. This will also increase the education effect and the psychological because patients aware that they are not the only one with this problem.*

FG2P2:*…we can also provide them with tools for longer term, because they tend to come back with the same problem…they do their exercises and when they find that their pain is reduced they stop doing them. They usually come back in six months. So, that would keep the education in long term and make it lifestyle.*

Evidence statement 11: Physiotherapists believe that what they do is effective. However, their treatment has a short-term effect, probably because no change in strength or flexibility was achieved. This contradicts what physiotherapists reported regarding the long-term effect of their treatment. Group classes and longer term-tools might achieve this and reduce the number of patients coming back for more treatment.

10. Hypothesis that functional improvement was not enough

In the mixed method study physiotherapists reported that they strengthen and increase flexibility in patients with PFPS. Therefore, the hypothesis that functional exercises would not be enough was generated. The hypothesis was accepted although some physiotherapists reported that low level functional exercises were enough to treat PFPS patients. However, the participants who initially said this, started to change their mind when they considered that functional exercises would not help their patients in the long term. Patient characteristics and compliance appeared to be a great barrier. This even applied to those who said that they would definitely do both functional and precise exercises for strength and flexibility.

These are illustrated by the following quotes:

<u>Functional exercises are enough for low level patients but the pain easily comes back</u>

FG2P2:...*I think they need to be patient specific, probably they are OK for lower level patients but for high level patients you might need something much more specific.*

FG2P3:...*for me I find that general exercises for gluts and quads, like pain free squats often work...and you are not targeting, you are just getting everything...everything going really...*

FG1P2:...*as P5 said, when you are getting them to do normal everyday things, standing properly, and walking up and down the stairs, just normal functional things you don't get any overflow because you do not change any of the motor patterns; and they feel easier to do the exercises, but the pain comes back when this stops.*

Functional exercises are not enough

FG2P6:*...I you have assessed a specific problem you cannot leave it aside can you? You need to strengthen it back up.*

FG2P5:*...both of them (function and specific). And also you need to improve the endurance of the muscles. Not just the strength. Because... if the problem comes after 20 minutes of run, then you need endurance and not just strength.*

FG1P1:*...I might do both (function and specific), it depends on the patient and what you can get them to do. But I think sometimes if you get them to do quads is good because it is a start to wake everything up again...but then again...it depends on the patient really.*

Evidence statement 12: Functional exercises are not enough. The prescription of functional exercises alone depends on the patient characteristics (not motivated patient) and affects long-term physiotherapy results.

11. Hypothesis that physiotherapists would have to change their exercise prescription

This code reflects physiotherapists' perception regarding whether they need to change their exercise prescription and prescribe more precise exercises which would have more impact in strength and flexibility. Before the conduction of the study it was believed that physiotherapists would decide to change their prescription in order to restore strength and flexibility. However the hypothesis was rejected because all physiotherapists replied negatively (Figure 17). Physiotherapists thought that the limited time they had to treat each patient was not nearly enough to explain complicated exercises. Many of their patients are non-athletic and physiotherapists reported that the more non-athletic the patient was, the more time they needed for education and exercise explanation.

FG2P5: *...and because we do not have much time per patient we might not be able to explain the exercises as much as the patients need to understand them. We only have 20 minutes on our patients and there is no much time to explain everything. In these 20 minutes there is not enough time to make a difference in muscles and also explain to the patients what they have to do at home.*

FG1P2:*...I think you should probably progress slower with these people, you might have to see them more often to make sure they comply, because the compliance would be more difficult; and you need more time with them for education.*

FG1P2:*...I think we do not get them to see them enough...you know, you assess them one day and the next appointment maybe after a month...you send them away...you have taught them the exercises and given pictures with the exercises and after a month they come back and you notice they have been doing them wrong. And then you are like ohhh...*

Evidence statement 13: Physiotherapists would not change their exercise prescription because precise exercises take time and they only have a little time with patients to explain them. Precise exercises would make patients comply even less and take time from education.

8.2.2 Hypothesis and explanations

The next step of Ritchie and Spencer, (1994) is charting. In this stage the themes were presented in a chart according to the appropriate part of the prior framework to which they related. Figure 17 shows the merged explanations for each hypothesis. In this way the mapping of the findings were clearly identified in terms of importance and connected to an emerging explanatory framework.

Figure 17. Codes and merging themes developed from focus groups

Prior hypotheses	Rejected/accepted hypothesis	Explanations
The results were surprising to physiotherapists	Rejected	It takes more than six weeks to improve strength and flexibility
Physiotherapists used methods to improve strength and flexibility	Rejected	Confusion over strength/flexibility
Physiotherapists did not measure outcomes of strength and flexibility	Accepted	It is not typical practice to measure strength and flexibility
Patients referred to the outpatient physiotherapy department are not athletic	Accepted	Patients not athletic
Patients do not comply with the prescribed exercises and that played a role to the non-significant results of strength and flexibility	Accepted	Patients do not comply
Correction of bad biomechanics/bad posture, useful tips/education psychosocial factors might have played a role in the patient improvement.	Accepted	Education (psychological effect, knowledge and reassurance, managing themselves-long term) Functional exercises/get non-active patients do any activity Increase control, balance, quality of movement, core stability, proprioception, get the muscle fire off better.
Physiotherapy aims to improve strength, flexibility pain and function	Rejected	Physiotherapy aims to get patients with less pain, better control, back to their activities Practice depends on patients' characteristics and what they want to achieve
Physiotherapists would think about changing their practice	Rejected	Physiotherapists do not think they have to change because their treatment works Long-term effect of treatment is needed
Function improvement would not be enough	Accepted	Functional exercises are enough for low level patients but the pain easily comes back, so, it is not ideal Strength and flexibility are required to keep patients away from physiotherapy
Physiotherapists would change their exercise prescription	Rejected	Specific exercises take time and make patients comply less. Less time due to exercise description means less time for education

8.2.3 Evidence statement and level of consensus

For each of the 13 evidence statements reported by the merger of the answers to the hypotheses, a level of consensus was described using the assistant moderator's notes. The further contextualising of the findings provided an elaboration of the initial framework to identify in detail the evidence statements and the level of consensus (Table 18).

Evidence statement	**Assistant moderator's notes.** **Level of agreement**
Evidence statement 1: Physiotherapists did not deny that their practice aimed to increase strength and flexibility. However, a six-week time period was not enough to demonstrate improvement in strength and flexibility. Additionally, they reported that if patients were measured later than those six weeks, those results would probably be significant. This shows that physiotherapists believed that their treatment has a long term effect which lasts even after patients are discharged from the physiotherapy department.	**High level-11/12**
Evidence statement 2: NHS physiotherapists do not have the same perception as physiologists/sport scientists regarding how strength and flexibility can be achieved. Physiology evidence shows that an increase in muscle strength can be achieved in six weeks if intense and precise strength and flexibility programmes are applied 3 times per week or in a day by day basis.	**Moderate level 9/12**
Evidence statement 3: It is not a typical physiotherapy practice to measure strength and flexibility. This evidence shows that exact level of these two characteristics was not intended to be achieved.	**Moderate level 10/12**
Evidence statement 4: Physiotherapists have to deal with non-athletic patients. This kind of patients are not familiar with sport activities, thus physiotherapists prescribe simple and generic exercises (otherwise patients will not perform them) which may lead to a non-significant increase of strength and flexibility. This contradicts the first evidence statement according to which a longer time period would change patients' strength and flexibility	**High level-11/12**

Evidence statement 5: Patients' perceived lack of compliance with prescribed exercises affects physiotherapy practice by inducing physiotherapists to prescribe a few and simple exercises. This may lead to a non-significant increase of strength and flexibility at 6 weeks.	**High level-11/12**
Evidence statement 6: Education (psychological effect, knowledge and reassurance and self-managing) plays an important role in reducing patients' pain and improving function, enhancing patient compliance and keeping patients without pain long-term.	**High level-11/12**
Evidence statement 7: Functional exercises/inducing patients to do any activity are suitable for the type of patients physiotherapists see in the clinic and play an important role in reducing patients' pain and improving function; however they do not increase strength and flexibility.	**High level-12/12**
Evidence statement 8: A variety of different treatment modalities are used to increase function and decrease pain. They are all patient-dependent. Focusing on these components rather than active treatments may have played an important role in not increasing strength and flexibility however; all patients do not need better strength and flexibility.	**High level-11/12**
Evidence statement 9: Physiotherapy aims to improve pain and function which is something shown by previous research. Strength and flexibility improvement is not one of their aims.	**High level-12/12**
Evidence statement 10: Physiotherapy practice aims to increase function and decrease pain and from this point of view the treatment works. Treatment depends on how patients present and what they want to achieve.	**High level-12/12**
Evidence statement 11: Physiotherapists believe that what they do is effective. However, their treatment has a short-term effect, probably because no change in strength or flexibility was achieved. This contradicts what physiotherapists reported regarding the long-term effect of their treatment. Group classes and longer term-tools might achieve this and reduce the number of patients coming back for more treatment.	**High level-12/12**
Evidence statement 12: Functional exercises are not enough. The prescription of functional exercises alone depends on the patient	**Moderate level 9/12**

characteristics (not motivated patient) and affects long-term physiotherapy results.	
Evidence statement 13: Physiotherapists would not change their exercise prescription because precise exercises take time and they only have a little time with patients to explain them. Precise exercises would make patients comply even less and take time from education.	**High level-12/12**

Table 18. Evidence statements and level of consensus.

8.2.4 Synthesis and further analysis

Previous chapters of the PhD have highlighted how difficult it can be to diagnose or to assess a PFPS case. The physiotherapists sampled within this phase of the thesis reporting that they used a variety of ways to treat the syndrome with the strengthening and stretching of several lower limb muscles among the most important. However, a six week physiotherapy treatment did not significantly improve the strength of any of the lower limb muscles.

This phase of the thesis mapped an explanatory framing of how physiotherapy intervention was constructed and the complexity of NHS physiotherapy treatment with regard to the area of PFPS.

Physiotherapists were not surprised with the results from Chapter 7 because of the type of patients they are dealing with in the NHS. Patients with PFPS who attend the physiotherapy departments of NWW, generally, do not have the same characteristics or the same needs as those patients described in the RoR. Only a few NHS patients are athletic and according to the physiotherapists the rest non-athletic do not get knee pain because of overuse but because of the lack of exercise. These patients are not used to performing exercises; therefore, physiotherapists have to address the patients' reluctance to do prescribed exercises for strength and flexibility. Because of these patient characteristics, physiotherapists only prescribed simple exercises which patients would perform at home during their everyday activities. These exercises, along with the given education, resulted in improvement in pain and function after a six week physiotherapy treatment. Physiotherapists admitted that this kind of treatment may not be enough to induce a physical change because without an increase in strength and flexibility, their treatment will often only have a short period effect with the consequence that some patients come back after a few months. This reflects the experience of Noehren, Scholz, & Davis (2011) who reported that 5 years after rehabilitation 80% of the patients still report pain. In spite of this, physiotherapists believed that in a way, their treatment worked and did not feel the need to change their practice. A major factor here was that because NHS treatment time is so limited, teaching patients how to perform precise complicated exercises for strength and flexibility would leave even less time for education andincrease the risk of low compliance.

As part of the phase the findings were further scrutinised and considered within the contemporary literature. As a consequence the 13 evidence statements were reflected upon while barriers to clinical practice and the lack of fidelity with the literature identified.

Evidence statement 1

The first high-level evidence statement contradicts what literature suggests regarding strength and flexibility recovery and what physiotherapists reported later on in the interviews. Physiotherapists said that a longer period of time might have revealed better results, implying that an average of a six-week period is not enough for muscles to get stronger and more flexible and that their treatment would have a long-term effect even after patients got discharged. Literature (Micheo et al., 2012) and bibliography (Kisner and Colby, 2012) suggest that six weeks can be enough if intense and precise strength and flexibility programmes are applied 3 times per week or in a day by day basis using the 10 Repetition Maximum (RM) (for strength) or continuous passive stretch for 30 seconds and Proprioceptive Neuromuscular Facilitation (PNF) stretches. The second contradiction is that physiotherapists reported later in the interviews (evidence statement 11) that just because their treatment has a short-term effect, some patients return to physiotherapy after a few months. There is a need for long term effective treatment since Noehren, Scholz, & Davis (2011) reported that 80% of their patients still had the same symptoms after 5 years of rehabilitation.

Evidence statement 2

This second moderate-level evidence statement was about the perception that NHS physiotherapists had regarding strength and flexibility. Most of the physiotherapists 9/12 reported that they would increase strength and flexibility with functional exercises such as stair descents/small knee bends. This contradicts what physiologists or sport scientists have in mind when they think about these two characteristics. According to Kroemer (1970) strength is the maximal force a muscle can exert isometrically in a single voluntary effort, whilst, flexibility is the amount of movement of a joint through its normal plane of motion (Knapik e al., 1991). These two muscle characteristics do not get increased with functional exercises but with intense methods described in the previous evidence statement.

Evidence statement 3

The third moderate-level evidence statement shows another contradiction. When it was proposed whether NHS physiotherapists need a better way to assess strength and flexibility most of them (10/12) were positive. However, after a few minutes of conversation they realised that it is not usual practice to measure strength and flexibility. This comes in line witl what physiotherapists reported in Chapter 4. There, they reported to know a number of outcome measures; however, in practice they only used a pain scale (VAS) and most of the time they forgot to use it. Both situations are in conflict with the regulations of the Health and Care Professions Council (HCPC) standards of physiotherapy proficiency which suggest the use of appropriate outcome measures on every occasion (HCPC, 2013).

Evidence statement 4

This high-level evidence statement brought to light an important lack of fidelity between literature and clinical practice. As reported in the RoR (Chapter 3), most reported studies recruited athletic populations; hence, the evidence is based on patients whose PFPS was associated with overuse or other athletic reasons. NWW physiotherapists reported that most of their patients (about 80%) were not athletic and in these cases the syndrome occurred because of lack of activity. This lack of fidelity between the literature and clinical practice is not appreciated. In fact Lankhorst et al. (2012) suggested that more research should be conducted in athletic population. This will not be applicable to NHS clinical practice. The second component of this evidence statement is that because patients are not athletic they are not keen on precise exercises that physiotherapists wanted to prescribe; therefore, physiotherapists only give simple exercises which aim to restore function ability. The last statement contradicts evidence statement 1 according to which physiotherapists reported that their treatment might restore patients' strength and flexibility if more than 6 weeks were given.

Evidence statement 5

This fifth high-level evidence states that according to NWW physiotherapists, patients with PFPS do not comply with the prescribed exercises. This behaviour is typical of non-athletic people when they are asked to perform exercise. Consequently, physiotherapists prescribe simple and interesting exercises that patients can perform in the course of the daily round. If the exercises did not have these characteristics patients would not perform any of them. This evidence may explain why strength and flexibility was not achieved but shows, once again, the lack of fidelity between literature, which suggests the focusing of precise exercises, and the clinical practice which gets patients to perform simple and functional exercises.

Evidence statement 6

This high-level statement showed the importance of education in managing PFPS. According to what the NWW physiotherapists reported, education can be separated in to three categories; psychological effect, knowledge and reassurance and self-managing. Participants believed that physiotherapy has a psychological effect by supporting patients with PFPS and listening to their problem. This is in line with the findings of the RoR (Chapter 3) according to which 'looking for social support' was a significant risk factor for patients with PFPS (Lankhorst et al., 2012). Additionally, explanation about the cause of the painful knee and what the patient can do about it, along with reassurance that it is not a major problem and that surgery is not required, seemed to help patients decrease their pain levels. This is in line with the HCPC standards of physiotherapy proficiency according to which psychosocial, social and cultural factors that influence an individual in health and illness must be understood and supported by physiotherapists (HCPC, 2013). Self-management is an important outcome of patient education. This makes it easier for patients to deal with their condition so that it causes them less distress and disability. Another benefit of successful self-management is a reduction in re-referral for further physiotherapy for the same complaint. Many patients continue to have some pain but have learned to accept it and manage it themselves.

Evidence statement 7

This high level statement shows that NWW physiotherapists chose deliberately to prescribe functional exercises or any sporting activity than precise exercises for strength and flexibility. This evidence shows that there is a lack of fidelity between the literature and clinical practice since the RoR (Chapter 3) showed precise single exercises (single leg squat) for several lower limb muscles such as quadriceps and hip abductors. However, evidence statement 4 showed that physiotherapists have to deal with patients who have PFPS because they do not do any activity. Precise exercises are often unsuitable for these non-athletic patients who have high levels of non-compliance. In fact, physiotherapists reported that it is a challenge to get these patients do any activity. Apart for the three education categories reported in evidence statement 6, patients' education should also include the importance of precise exercises in PFPS treatment.

Evidence statement 8

This high-level evidence statement reports that physiotherapists use most of the treatment components suggested in the literature to improve function and pain (also described in Chapter 3) and demonstrates that they are aware of the cutting-edge physiotherapy for PFPS (key point of Chapter 4). Additionally, physiotherapists said in the interviews that not all PFPS patients need strengthening and stretching, which is acceptable, since not all risk factors are related to muscle weakness or stiffness (risk factors, Chapter 3).

Evidence statement 9

This high-level evidence shows that NWW physiotherapy for PFPS aims to improve pain and function but not strength and flexibility. This statement contradicts what literature suggests regarding PFPS treatment (exercise treatment, Chapter 3). However, the HCPC standards of physiotherapy proficiency (2013) do not include strength and flexibility in the physiotherapy treatment. Therefore, apart from the confusion regarding what strength and flexibility is and how improvements can be achieved (evidence statement 2), there was inconsistency regarding how useful these two muscle characteristics are in treatment. At the beginning of the interviews they reported that strength and flexibility would be achieved if more time was given to muscles, then after consideration they said that they do not aim to restore these muscle characteristics and later on they accepted that if improvement in strength and flexibility were achieved, it might prevent some patients from returning for further treatment.

Evidence statement 10

The tenth high-level evidence statement shows that NWW physiotherapists aim to improve pain and function and Chapter 7 revealed that this was achieved. This is in keeping with the HCPC standards of physiotherapy proficiency report that NHS physiotherapists should implement and manage physiotherapy interventions aimed at the facilitation and restoration of movement and function (HCPC, 2013). Additionally, their physiotherapy practice is patient-specific and dependent on what patients want to achieve. This was explained in the mixed method study (Chapter 4) where physiotherapists reported that they do not treat syndromes but patients' needs. Patients seek help when they are in pain or cannot perform everyday activities.

Evidence statement 11

As reported in evidence statement 10, PFPS physiotherapy treatment works; not through lower limb strength and flexibility improvement but through improving quality of movement and restoration of function. The long-term effect of NWW physiotherapy was beyond the aims of this PhD study; however, physiotherapists appeared to acknowledge that some of their patients are re-referred to the physiotherapy department after a few months with the same symptoms. This shows that in some cases their treatment has a short-term effect which partly contradicts what physiotherapists reported in evidence statement 1. Physiotherapists reported that group classes in the physiotherapy department might help in strength and flexibility improvement because patients would be supervised and all have the benefits of group dynamics. Group treatment has been tested with low back pain patients in NWW physiotherapy department and according to the physiotherapists they have been successful in pain and function improvement. To note however, the RoR (Chapter 3) did not reveal any differences between unsupervised and supervised exercise treatment.

Evidence statement 12

This moderate-level evidence statement confirms that most of the NWW physiotherapists know that what they and their patients do, is not enough to increase strength, and that their practice often has no physical long-term effect. However, physiotherapists believed that the barriers they have to confront (patient compliance and time per patient treatment) cause this kind of practice. Therefore, since there is no 'ideal world' the long-term effect of group classes along with more education are the two suggestions that could be tested in the future. Group classes might get patients more active for more time. On the other hand education should include the importance of right exercise for their problem while self-managing the pain would make them live with it. Noehren, Scholz, & Davis (2011) may reported that 80% of PFPS patients still reported pain after a 5-year rehabilitation and the pooled data of Collins et al. (2008) and Van Linschoten et al. (2009) (n = 310) showed that 40% of the patients still reported persistent complaints one year post intervention; however, if those patients knew how to self-manage their pain and live with it, they probably would not have to return for more physiotherapy.

Evidence statement 13

From the previous evidence statements it is not surprising that the physiotherapists reported that they would not change their practice by prescribing precise exercises to their PFPS patients. According to physiotherapists, precise exercises take time, cause patients to comply even less and reduce the time available for the all-important education. This evidence statement shows the gap between the applied clinical practice and literature based on athletic patients..

8.3 SUMMARY

This phase of the thesis showed the lack of fidelity between literature and clinical practice. The literature is based on athletic patients with PFPS, while patients who are referred in the sample NHS clinic of a district hospital are largely non-athletic. The precise exercises were not effective because they were not used by sample physiotherapists. The exercise-based interventions suggested by the literature were not adoptable in a NHS environment because of several barriers. Given the lack of evidence for non-athletic patients with PFPS, physiotherapists aimed to improve pain and function and in that way their treatment was reported as effective. However, this practice often only had a short-term effect.

8.4 REFLECTION

This phase of the thesis identified an important part of the research question and validated not only the difficulties facing physiotherapists in applied practice in the area of PFPS but also identified potential areas for improvement. It highlighted that physiotherapists were modifying their practice to attempt to bridge the problematic evidence-base in the context of their NHS orientated patients. The qualitative work that worked through evidence, statements through to seeking consensus provided an important platform for drawing together the different phases and seeking to identify ways forward for applied physiotherapy.

CHAPTER NINE

SYNTHESIS AND ANALYSIS

"A case may be simple or complex"

(Stake, 2000 page 436)

9.1 INTRODUCTION

The above statement was used by Stake (2000) to show that it is not always easy to identify the case. A case may have different behavioural patterns or may be depended by the environment. However, boundedness and behavioural patterns can be useful concepts for specifying the case (Stake, 1988). Stake (2000) identifies three types of case study: intrinsic, instrumental and collective. This thesis did not focus on a particular case because the aim was to jointly study a number of cases in order to investigate the PFPS phenomenon and its complexity as an area of practice for physiotherapists in the applied context of practice. Therefore, the overall study and its respective phases focused on discrete instrumental cases that extended to several cases that related to physiotherapy practice, representing an overarching collective case study. The study as a whole identified the complexity of PFPS when considered in terms of the (i) evidence-base, (ii) the application of clear guidance, (iii) the actions of physiotherapists in the applied field context and (iv) and the fundamental dissonance rather than bridging of the evidence-base and applied practice. Yet the research question not only sought to identify key factors that operated in applied practice to potentially influence patient outcomes but also attempted to identify areas for improvement and possible remedial strategies for implementing best practice.

The current chapter will seek to draw together the findings from the respective phases of the thesis and presents an overarching 'model' that articulates the complexity of physiotherapy practice in PFPS treatment and management within an applied context. An important feature of each part (phase) of the thesis was to assemble the 'jigsaw' of evidence from the initial review of the literature to the empirical work, in order to analyse the different parts of PFPS treatment by physiotherapists that make up the whole 'picture'. Importantly the findings enabled the researcher to identify the key factors that shape and influence the treatment of PFPS by physiotherapists in practice. On this basis the implications for implementation of possible remedial strategies emerge, focused on the importance of context. In this way a further model is presented that articulates how PFPS should be viewed as a complex intervention and that a modified PARIHS framework should be utilised to inform addressing the deficits identified in the findings and its synthesised model. In the first instance it is necessary to examine the model that emerged from the collective findings.

9.2 OVERAL RESULTS AND EMERGED MODEL

The respective phases of the thesis provided a series of cases that illuminated the underpinning difficulties in PFPS management and treatment within an applied context. Taken as a whole these provide a collective case study (Stake, 2000) and present insight into the complexity of PFPS and allow theorising about the phenomenon (Stake, 2000). The combination of approaches and different datasets in the study enabled an in-depth understanding to be developed and the articulation of a theoretical account that captured in general the issues surrounding PFPS and applied physiotherapy practice based on the examination of the particular. For instance the qualitative interviews enabled 'storytelling' and physiotherapists to describe PFPS within the naturalistic settings of their own practice contexts, allowing the case to 'tell its own story' (Stake, 2000). Overall the relationship between the (i) evidence base, (ii) applied physiotherapy practice and (iii) tools and approaches were identified. The mixed methods phases of the thesis highlighted respectively the relevant issues in the guidelines and literature based evidence, whereas the additional studies identified application and reliability and utility of tools as well as approaches in practice (Chapters 3-5). Importantly patient outcomes for people with PFPS were a function of the interrelationship between these factors.

9.2.1 Category 1: Interrelationship of Factors and patient outcomes: bridging and surfacing

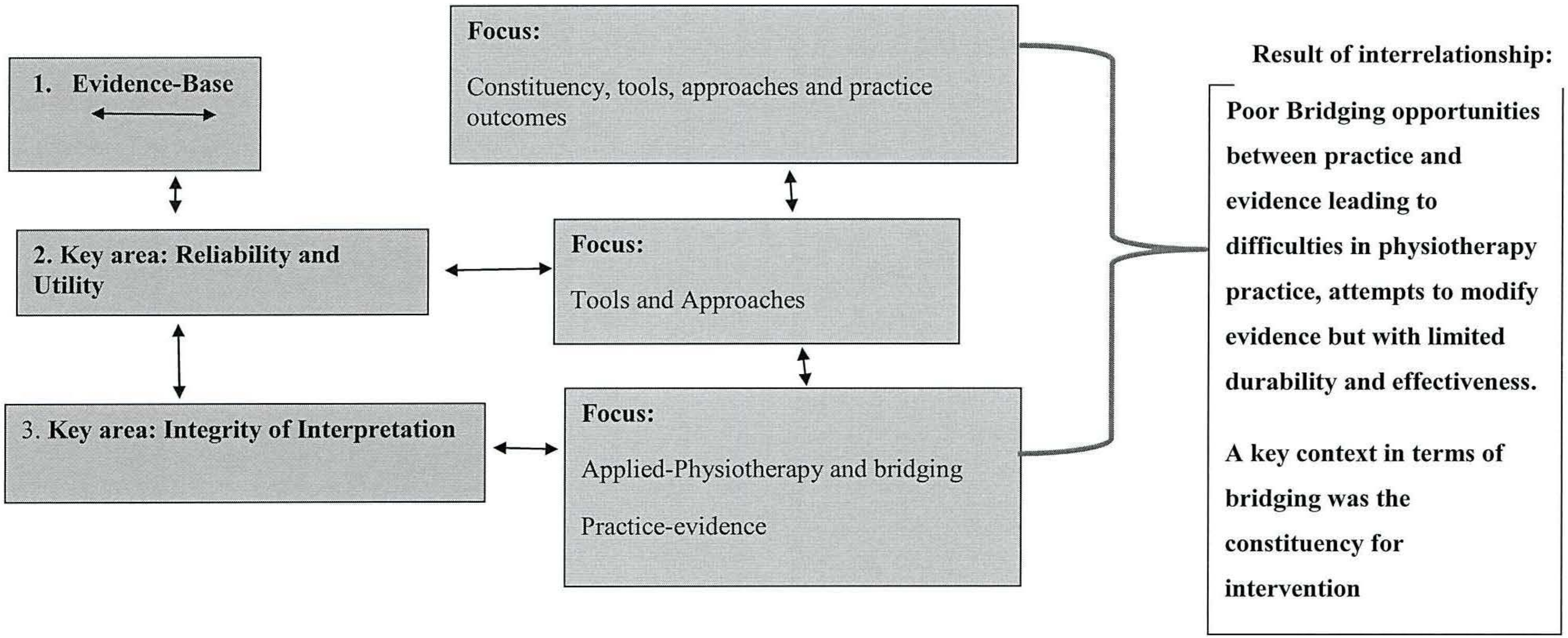
It was clear from the dataset that there were a number of central issues described as poor 'Bridging' (Figure 18). 'Bridging' related to the successful synthesis of applied physiotherapy practice behaviours, approaches and treatments being closely aligned with current evidence-based benchmarks. This involved the following:

1. *Evidence* – this focused on the availability of evidence that was primarily based on athletic patients, both in terms of tools and approaches for intervention, including management. The nature of the 'constituency' of patients encountered in physiotherapy practice was important in bridging or 'surfacing' the evidence base. The surfacing of the evidence meant that physiotherapists identified little relationship between the NHS and athletic constituency and this resulted in modified treatments, with implications for durability and effectiveness of outcomes.
2. '*Reliability and validity*' of tools and approaches used in PFPS by applied physiotherapists. The issues were based on the poor fit of evidence-based metrics focused on athletic context to non-athletic patients, resulting in 'gaps' for physiotherapists in practice.
3. However this operated within a wider context that influenced their use and contributed towards the difficulties experienced by physiotherapists in delivering appropriate intervention for non-athletic patients in the NHS setting. The '*integrity of interpretation*' focused on the gap evident in tools and approaches but positioned in a wider dissonance between physiotherapy practice and the lack of integrated evidence-

based support and guidance for physiotherapists in clinical practice, to frame effective intervention. This was also influenced by the variable of significant agency and autonomy by physiotherapists in shaping the individual programme for patients with PFPS.

These three variables influenced the potential patient outcomes for physiotherapy intervention in PFPS and in the collective case study represented poor 'Bridging' between evidence and its use.

Figure 18. Problematic interrelationship of factors influencing patient outcomes from study phases: identifying poor 'bridging'



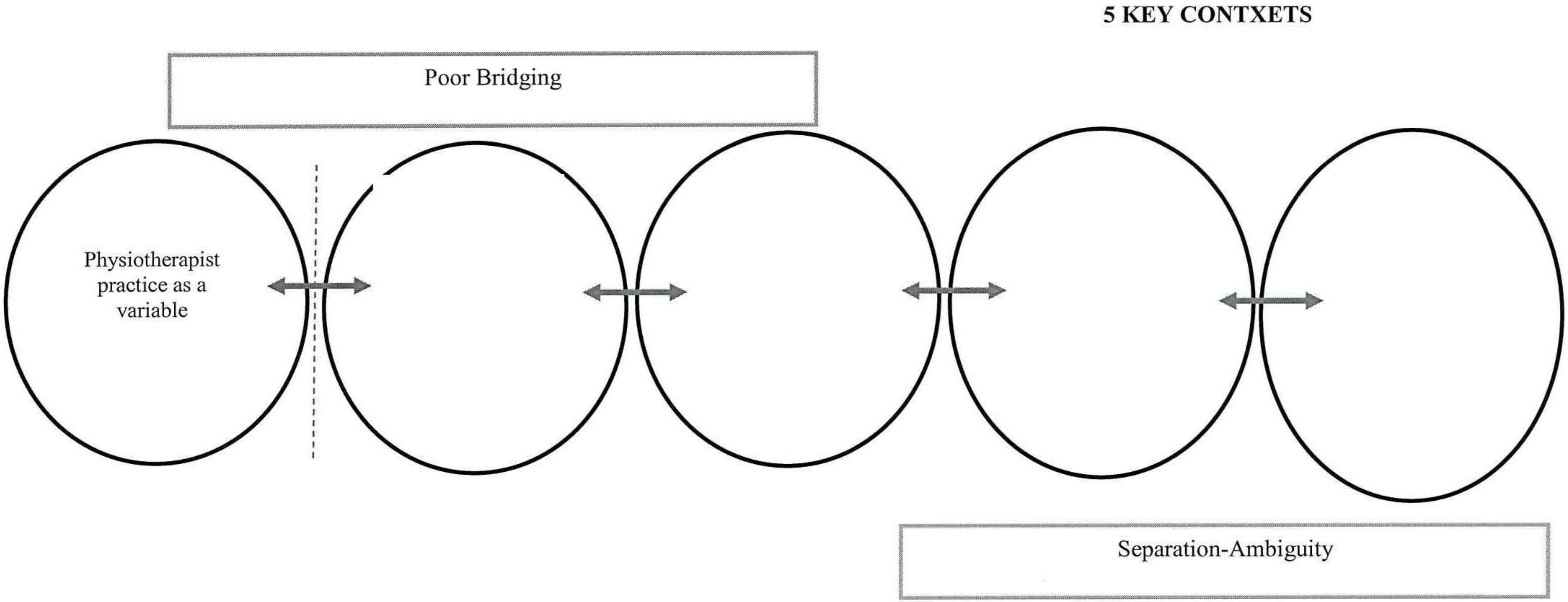
9.2.2 Category 2: Underpinning processes and factors for treatment: key contexts

The findings from the study indicated that there were discrete areas that represented distinct factors and processes that shaped what constituted 'treatment' of PFPS by physiotherapist in practice and possible outcomes. The initial category centred on poor 'Bridging' that highlighted the gaps between physiotherapy practice and the evidence, yet this was a function of a more complex picture based on the case example in North Wales and the literature in the ROR, representing the category 'Key contexts'.

The 'Key contexts' were found to focus on four areas, namely 1) *the physiotherapist practice as a variable*, 2) *treatment as artefacts of evidence*, 3) *patient variables,* 4) *organisational context* and 5) *regional variables* (Figure 19). Overall the 'Key contexts' included the additional factors of organisational and regional processes that exacerbated the poor 'Bridging' of evidence and practice, focused on the athletic parameters for treatment and approaches compared to the physiotherapists constituency of NHS non-athletic patients. An additional context was the 'Separation' at organisational and regional levels of practice from the evidence base, in terms of available guidelines and protocols that would have addressed the bridging difficulties. Also, there was organisational and regional 'Ambiguity' concerning the physiotherapist role in aligning practice to appropriate benchmarks for PFPS.

These respective factors and processes will be examined and subsequently their interaction.

Figure 19. Underpinning processes and factors: Key contexts



Physiotherapist practice as a variable

The first indication of this key factor was the absence of a PFPS protocol for the physiotherapists to follow within the study areas and that their practice varied from clinician to clinician being dependant on each physiotherapist. Such 'Ambiguity' was reflected in the literature as part of the ROR. Furthermore there was the 'Separation' at the organisational and regional level regarding the current issues emerging about the difficulties in the evidence base and the poor bridging between practice and evidence was not addressed by any mechanism, leading to surfacing that focused on autonomous practice by individual practitioners. In this way the variables for patient's outcomes focused on physiotherapy practitioners using different:

- Techniques/methods
- Approaches adopted

The major influencing factors for shaping these two areas of practice were:

- Exposure to PFPS within daily practice
- Autonomy to interpret the evidence and generate a model of individual practice

Treatment as artefacts of evidence

The physiotherapists treated according to two dimensions as an applied practitioner, namely (i) their interpretation of the evidence-base and to the (ii) findings during assessment. This was highlighted in Phase 2 (Chapter 4). In this area the key area was on:

- What was understood as effective, for who and why;
- Accessibility of the evidence;
- Degrees of sophistication and consensus within the evidence.

Patient variables

The area of the physiotherapist and treatment were subject to the important context of the patient. The perspective of the patient as an active not passive context was significant, in terms of expectations of the practitioner and treatment, with the impact of therapy possibly having different characteristics to what patients with PFPS expected. The poor bridging between practice and the evidence-base for PFPS treatment, focused on the emphasis upon athletic patients, resulted in physiotherapists claiming within the study that because the patients they see in the clinic do not have the same characteristics and suffer from PFPS due to a different range of reasons (as exemplified in Phase 6 – Chapter 8), they autonomously developed alternative approaches. In the analysis this was described as surfacing and led to particular problems. The patients encountered by physiotherapists in practice required a different approach in order to make them comply with the treatment which was not always successful. Additionally, the effect of treatment may not only be physical but also psychological, thus, the patients get discharged with less pain but without any physical improvement, as exemplified in Phase 5 (Chapter 7). In this area the focus was centred on:

- History/presentation;
- Expectations and anticipated outcome;
- Impact across function and psychological wellbeing;
- Intractable position.

Organisational context

The organisational context defines the operational, clinical context within which the physiotherapist was positioned, conducting applied practice and from which PFPS treatment was delivered. The NHS is a rather complex organisation and a range of barriers/constraints operate on the area of applied practice as illustrated in the study sample area. Physiotherapy treatment may depend on the waiting lists, the lack of physiotherapy time per session, the patients' attendance and the general compliance which is not supervised at all times. In this area the central areas were:

- Barriers to engagement;
- Local protocols/guidance;
- Exposure to PFPS;
- Opportunities for training/development or skilling.

Regional variables

Finally, the organisational context was situated within a broader NHS and non-NHS setting that incorporated regions and countries, centred on evidence-base drawn from a variety of settings – both geographically and in terms of clinical specialities and disciplines. The study was conducted in the specific contextual parameters of North Wales and in this way represented a particular regional context, set within a devolved Wales subject to Welsh Assembly Government (WAG) and the wider Department of Health (DOH) governance and guidance. In this area the variables focused on:

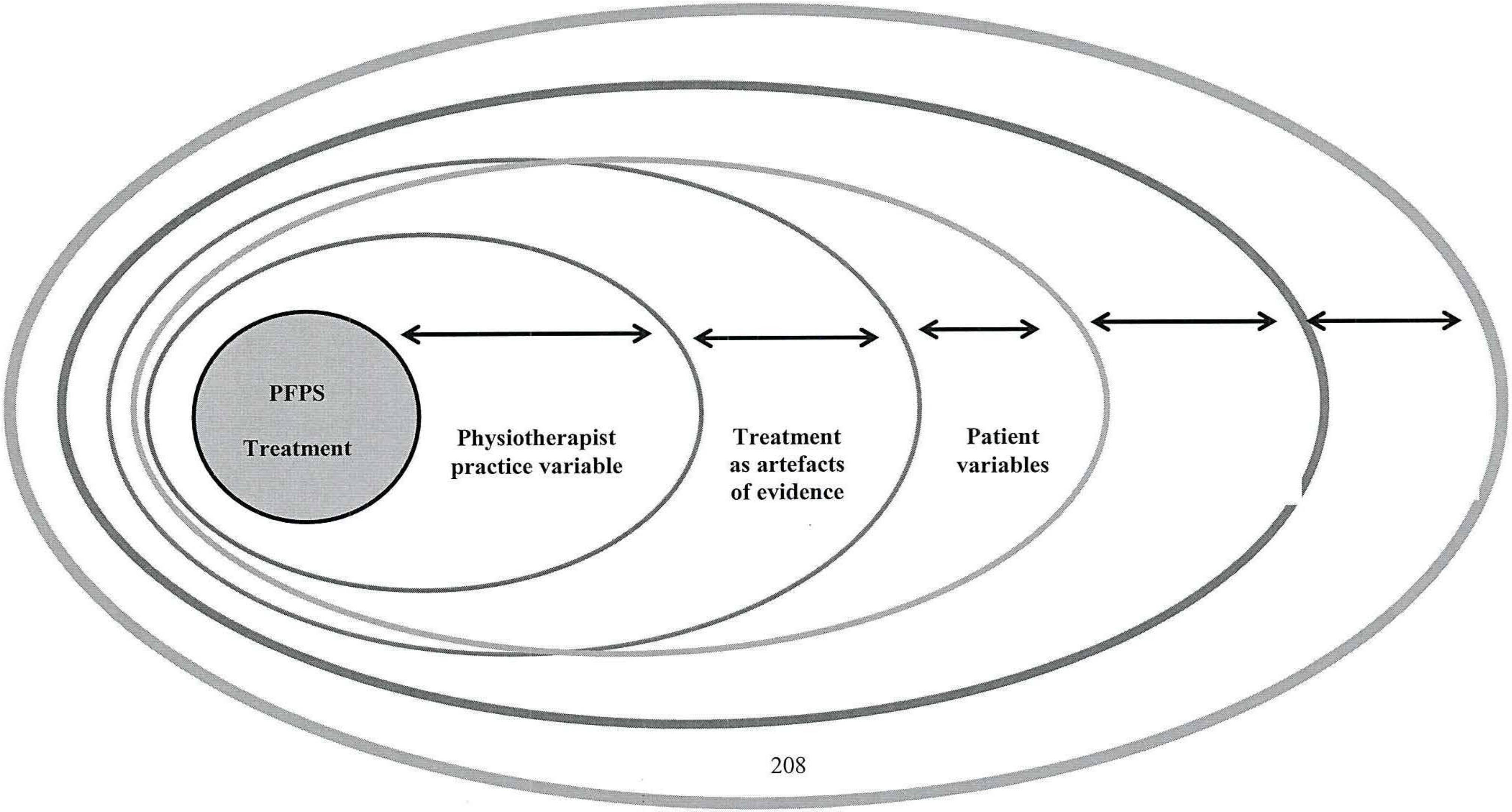
- Access to best practice guidance
- Opportunities for evidence integration/skilling
- Access to National/international protocols/guidance

9.2.3 Category 3: Dynamic interrelationship and interaction

The representation of how treatment was constituted of discrete elements and subject to 'Key contexts' also had a significant dynamic and interrelated element. These relationships represented the complex interplay which resulted in potentially diverse outcomes from intervention for patients provided by applied physiotherapists in the clinical field (Figure 20). The central factor of the ***Physiotherapist practice as a variable*** was interrelated to the other 4 factors and contexts, for instance it was exacerbated by PFPS having multiple and unclear pathophysiology leading to the evidence base suggesting a protocol cannot be suggested (Cook et al., 2010).

The ***Treatment as artefacts of evidence*** was directly related to the area of ***Physiotherapist practice as a variable*** due to the dependency by physiotherapists on accessing and understanding what was the 'best practice' in PFPS to be used in applied clinical practice. There were a number of difficulties in this context highlighting the interrelationship evident in these areas, since as part of the ***Organisational context*** there were barriers within the applied field in gaining information on 'best practice'. The isolation of physiotherapists within the clinical field was exacerbated in the study due to geographical location within ***Regional variables.*** This was further frustrated by the nature of patient contact as part of ***Patient variables***, representing a lack of significant PFPS cases and a wide range of presentations that also diverged from the evidence-base.

Figure 20. Dynamic interrelationship: PFPS in applied contexts



9.2.4 Category 4: Barriers to implementation: Detachment and surfacing

The category of poor 'Bridging' (Category 1) and the implications of 'Ambiguity' and 'Separation' (Category 2) highlighted the challenge to implementation faced by physiotherapists in an applied context. Reflecting on implementation the features of 'Detachment and surfacing' were identified as barriers to best practice in an applied context for physiotherapists as clinicians attempting to treat and manage PFPS (see Figure 18). These features centred on the following:

- Detachment - It represented a mechanism of separation of the physiotherapist from the evidence base that may have facilitated interventions appropriate to both athletic and non-athletic patients.
- Surfacing - The physiotherapist was detached from the patient contexts as the tools and approaches from the evidence centred on athletic contexts, therefore there was little connection to the patient experience and the intervention had a poor fit and response to measurement. In this way there was a surfacing of knowledge about PFPS focused on athletic patients in response to *poor bridging*.

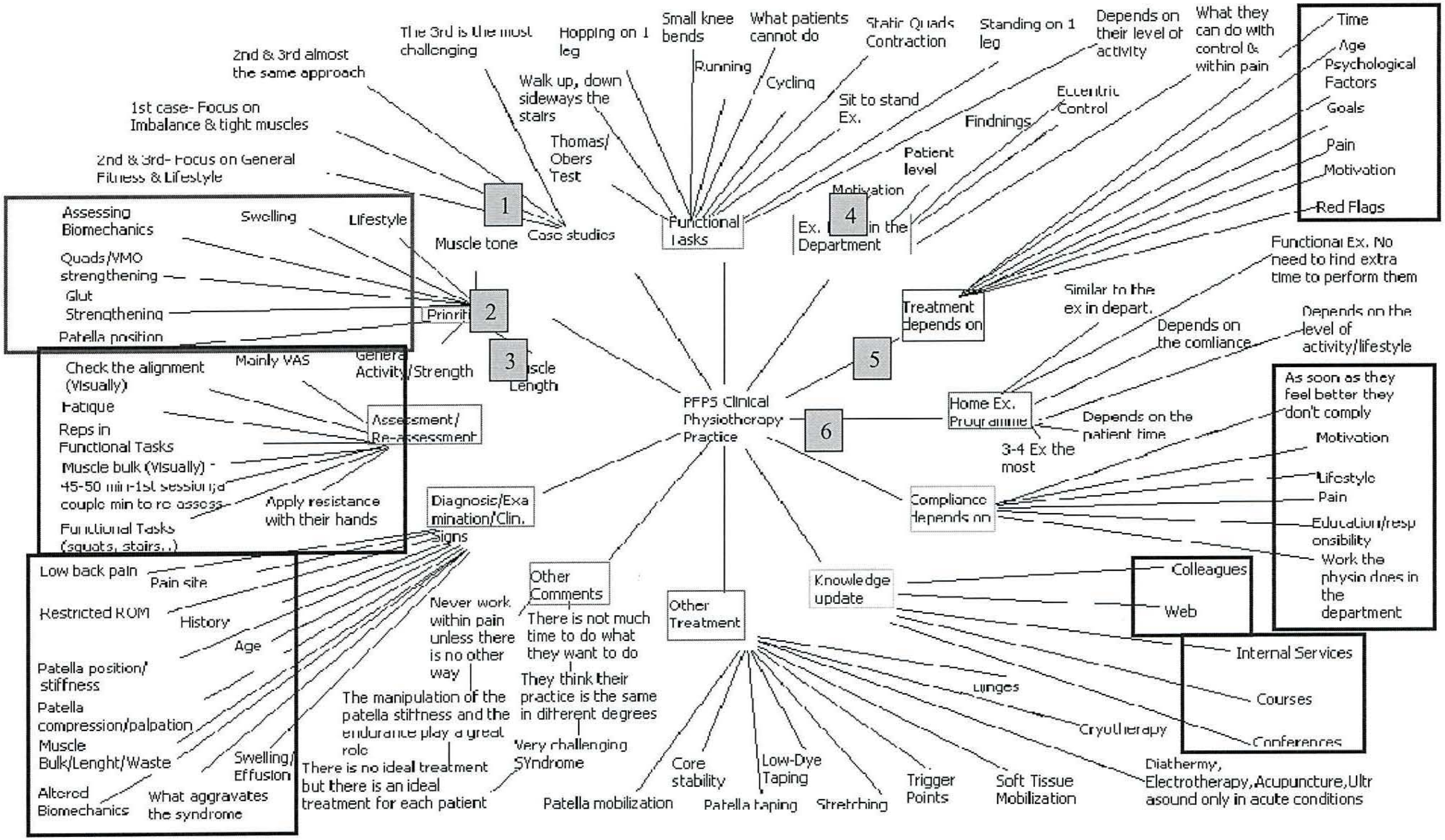
This was depicted in Figure 19 (Category 1- 2) as focused on the discrete separation of particular areas associated with the treatment of PFPS, ranging from ***Physiotherapist practice as a variable, Treatment as artefacts of evidence, Patient variables, Organisational context*** and ***Regional variables.***

Overall the synthesis of the results suggested a complex environment for applied physiotherapy. In this way the area of clinical practice was characterised by isolation of the physiotherapy clinician (***Physiotherapist practice as a variable***) from the potential opportunities for knowledge translation in practice ***(Treatment as artefacts of evidence).***

Furthermore this key detachment was compounded by the ***Patient***, ***Organisational*** and ***Regional variables.***

The data analysis from Phase 2 indicated at a micro level the challenges faced by physiotherapists (Figure 21) within the applied context of day-to-day practice. For instance ***Physiotherapist practice as a variable*** related to (1) priorities, assessment and reassessment (2) and diagnosis/examination (3). Further ***Patient variables*** were focused on *treatment depends on* (4) and compliance depends on (5), whereas ***Organisational context*** and ***Regional variables*** centred on *knowledge update* (6).

Figure 21. Examples drawn from data analysis in Phase 2 (Chapter 4)



9.3 OVERALL MODEL OF APPLIED PHYSIOTHERAPY IN PFPS

The study findings and the further synthesis indicated that a model of applied physiotherapy emerged from the collective case study, based on the discrete results from each respective case. A final model was generated as part of the synthesis that identified the dynamics of practice environments and accounted for the influence of different variables that impacted on the outcomes of physiotherapy practice delivering interventions in PFPS. The model (Figure 22) highlighted that the implementation of a consistent and appropriate management of PFPS operated on a continuum ranging from 'intra-physiotherapy practice', 'inter–physiotherapy practice' to 'extra physiotherapy –practice'. In this way within each component of practice a number of factors operated as mechanisms to shape and direct practice and potential outcome for patients with PFPS. A critical juncture was the 'inter–physiotherapy practice' that represented a potential gateway or barrier between the inner mechanisms of 'intra-physiotherapy practice' and the influences of environmental, regional and evidence variables in the 'extra physiotherapy –practice' end of the continuum. As a series of critical junctures they were subject to the flow or restriction in the movement of evidence to guide PFPS management with applied practice.

Within the key area of 'intra-physiotherapy practice' a number of common key elements were evident:

- **Individual Approach** – At the core of the results was the dominance of autonomous practice by the physiotherapist, deeply influencing approaches adopted towards PFPS. For instance, in terms of beliefs about causes of the syndrome, it was noted that;

  "It can be anything... It is a very challenging syndrome...any part of the leg can be the cause... bad biomechanics mostly" ***(Participant 4).***

The complex area of PFPS highlighted the significant individual approach adopted by physiotherapists in applied practice generated by the autonomous nature of their role.

- **Tailoring per Case -** Within the overarching autonomous framework of practice there were examples of consistent tailoring according to case, for instance: "*From what I have seen, there is no ideal treatment, but there is an ideal treatment for each patient" (Participant 2).* As such there was a poor degree of standardised practice and a significant proportion of interpretation by individual practitioners and accordingly different approaches adopted.
- **Expertise** – Along with autonomous practice and a highly individualised approach there was the development and application of a range of expert practice to patients with PFPS. In this way applied practice represented different degrees of expertise depending on the exposure to PFPS and the available evidence base. For instance, home exercise programmes were utilized but only in a rather limited form: "*I ask them to perform the same exercises they do here (physiotherapy department)". (Participant 6).* This represented a diverse range of what could be constituted as expertise and appropriateness for patients with PFPS: "*It depends... If they have time, I ask them to do 5-10 exercises... if not 3-4 basic ones" (Participant 4).*
- **Treatment** – at the core of applied practice was treatment associated with assessments and outcome measurements by physiotherapists. Reflecting the other 'Intra-physiotherapy' components there was strong individualized framework adopted. For instance: "*In general, the way I assess is similar to the exercises I ask them to do; like quadriceps and VMO strengthening, functional tasks such as squats and stairs" (Participant 1).* Such approaches varied significantly across different physiotherapists and constituted a lack of standardised practice, as illustrated by focusing on measurement:

(Participant 3) *I usually check the muscle bulk, and the alignment.*

(Researcher) *Do you use ways to measure them?*

(Participant 3) *No, I do it visually*

In terms of treatment priorities and options there was a significant differences in the interpretation of what represented best practice:

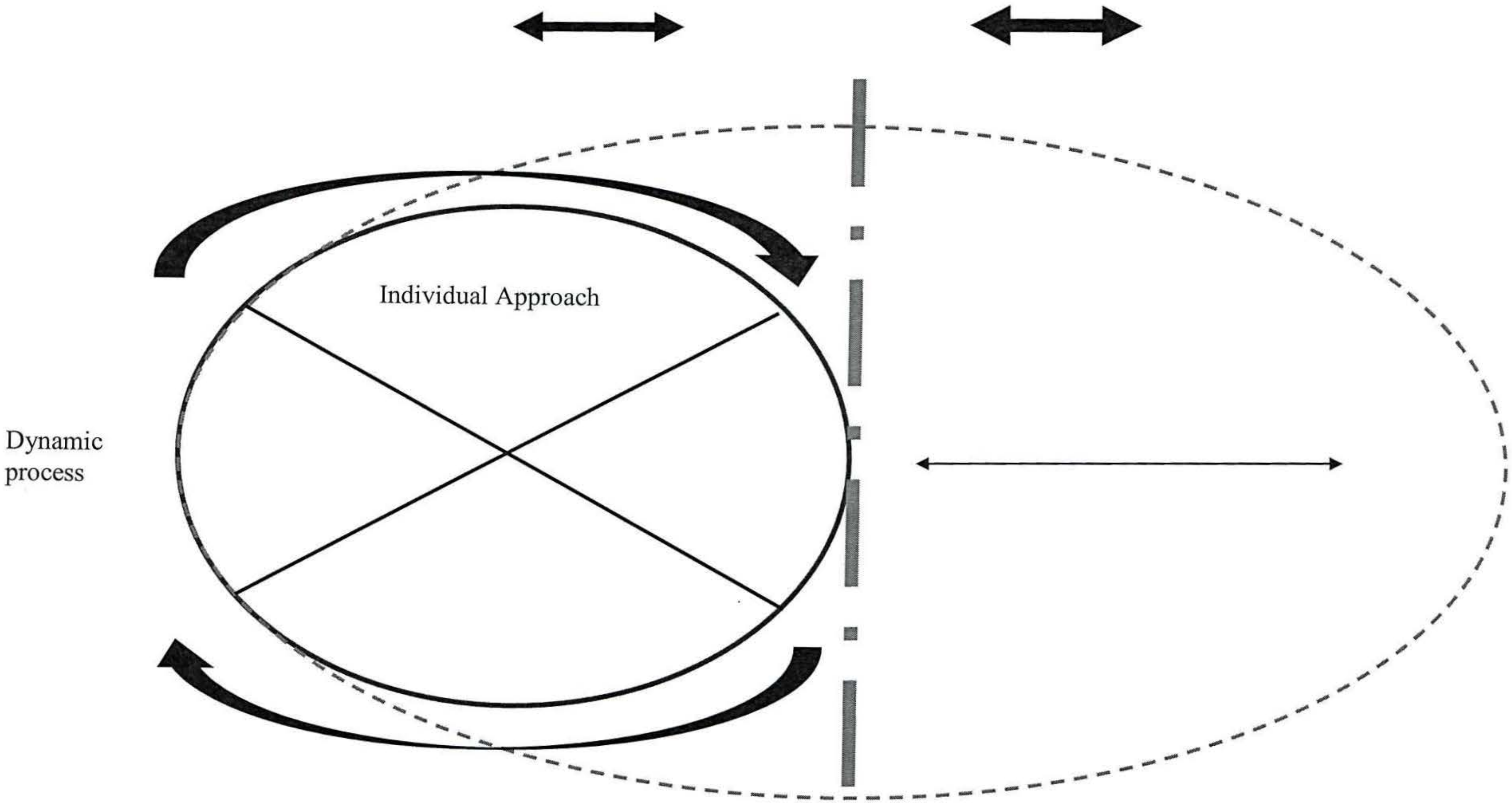
I often check where the patella lies on the knee. That is the first thing I do" ***(Participant 7).***

"You have to do something about the swelling first; ...before anything else" ***(Participant 7).***

"Quadriceps and gluts are the first muscles I check.... Their strength is very important" ***(Participant 2).***

Interactional relationship with wider contextual factors – Yet the importantly individual (intra) physiotherapy practice was subject to wider influences, although the effectiveness of such contextual factors varied. For instance in terms of acquiring and maintaining knowledge and skills there were some opportunities to access a wider evidence-base and peer best–practice but these were often limited: "*We go to many conferences...when we have the time" (Participant 9).* Such external input to applied practice was matched by ad hoc opportunities for locality based intervention: *"We have the internal services, every now and then.... and that helps a lot" (Participant 9).* It was evident that wider influences were relevant in shaping the potential management of PFPS by applied physiotherapists. In this context it focused on the two discrete areas of 'Inter–physiotherapy practice' and 'Extra physiotherapy–practice' which will now be examined in greater detail.

Figure 22. Applied physiotherapy practice in PFPS model



The overall model highlighted the complexity of interactions within the wider context beyond the 'intra-physiotherapy practice'. These parts of the continuum represented what had been respectively identified as organisational and regional variables in the earlier analysis (see Figures 19 to 21). It was evident that there was a dynamic process that centred on the common key components that influenced applied physiotherapy practice (Figure 23).

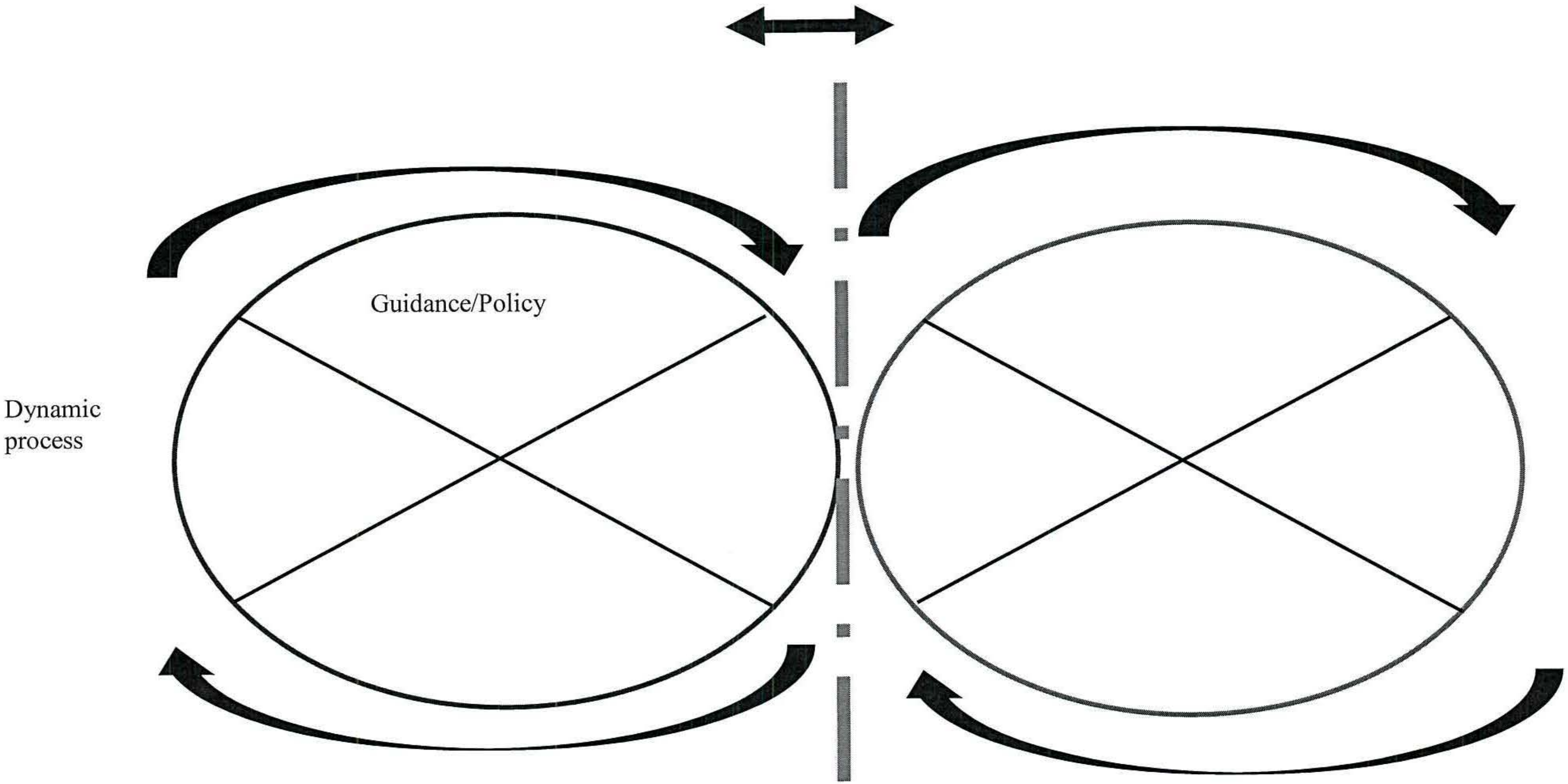
As part of what was defined in the model as the 'Inter-physiotherapy practice' there were a number of key components at an organisational level, operating as driving factors or barriers, representing organisational context and therefore shaping the nature of applied physiotherapy practice:

- Peers – individual physiotherapy practitioners were influenced in their practice towards PFPS by interaction with other physiotherapy peers based on informal mechanisms and networks.
- Guidance/Policy – applied physiotherapists were subject to local guidelines and policy frameworks to guide their practice. However there was an absence of clear guidance anc policy towards PFPS and the role of physiotherapy was outlined only in broad terms within organisations. There was limited linkage to national or international guidelines o policy statements.
- Focus – within the applied context physiotherapists had a particular focus within their own practice which led to autonomous interventions in response to clinical presentations, framed within a broad repertoire of what constituted 'best practice'.
- Training – there was generic training and development for physiotherapists but there was little in terms of supporting the role of managing PFPS.

It was striking that as part of the 'Extra-physiotherapy practice' context of the model there were a further range of driving factors or barriers, which interrelated with the 'Intra-physiotherapy' and 'Inter-physiotherapy' contexts:

- Evidence-Base – there existed a substantive evidence-base regarding physiotherapy practice in general terms yet there was a deficit of robust and implementation focused evidence on the management of non-athletic and athletic PFPS. In this sense the nature of the evidence was problematic as there was a skewed proportion of evidence centred on athletic-management.
- Priority – the degree of priority afforded to different evidence linked to physiotherapy practice was varied and within this set of priorities PFPS had a generally low priority for non-athletic physiotherapy practice, with its management being ill defined and limited exposure to its presentation.
- Guidelines - there was a poor framework for operationalising best practice for PFPS as guidelines were limited and implementation and dissemination to applied practice problematic.
- Culture – there was a cultural context within physiotherapy practitioners of autonomy leading to a degree of not integration to guidelines and the evidence-base but separation.

Figure 23. Critical junctures at 'intra-physiotherapy practice' and 'extra physiotherapy–practice' in model



9.4 IMPLEMENTATION AS A 'WICKED' PROBLEM IN PFPS

In this way the synthesis of the findings highlighted that PFPS in applied physiotherapy practice context represented a 'wicked problem' (Rittel and Webber, 1973). Its main characteristic was the dissonance between physiotherapy encounters with patients and the nature (as well as access to) the evidence base, including protocols and guidance. The synthesis of the findings suggested an overall model drawn from a range of variables influencing the management of PFPS in applied clinical care.

9.4.1 PARIHS and PFPS

Within the findings the dominant theme identified across the thesis and its respective phases was the issue of 'context'. This was evident from the synthesized model but also in the 'raw' data of the empirical work and the review of the literature. The synthesis of the findings from the further analysis generated not only a model of PFPS (Figure 18 to 23) but addressed the second part of the research question which was to address the possible opportunities for moving forward PFPS treatment in applied practice. Within the PARIHS framework (Rycroft-Malone et al., 2013) successful research implementation derives from the relationships among 'evidence', 'context' and 'facilitation' (Figure 24). In this thesis it was shown that the evidence did not inform the interventions or measurements because of the poor bridging while, the context and facilitation did not manage to inform and re-evaluate patient outcomes.

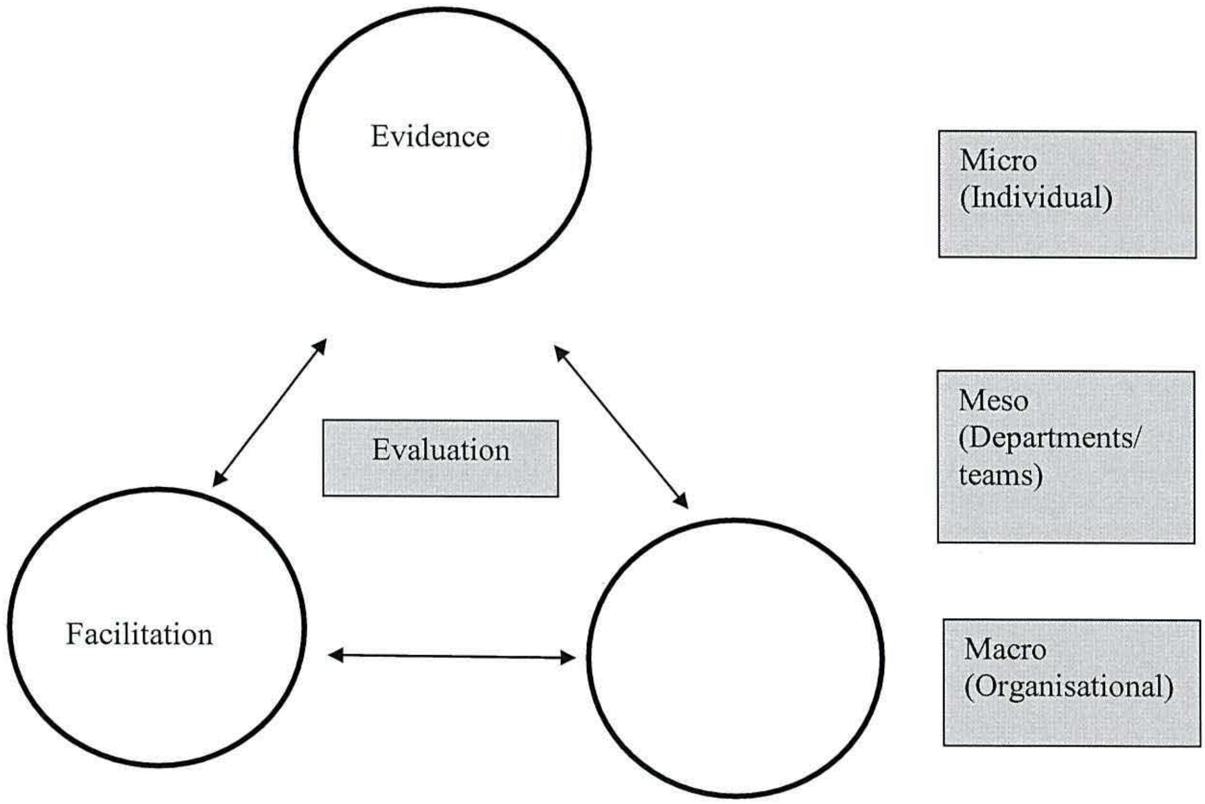
Rycroft-Malone et al. (2013) also suggested that successful implementation can only be defined as the use of the recommendations in practice with associated impact on practice and patient outcomes. This can be achieved by incorporating the idea that there are influential factors at micro, meso and macro organizational layers of the context (in this case micro represents the individual physiotherapy practice, meso the physiotherapy departments and physiotherapy teams and macro the NHS as a complex organization (Figure 24) (Rycroft-Malone et al., 2013).

Based on the overall findings and the synthesis model it was evident that addressing the deficits in PFPS management requires an approach that is context-centered. Across the model from 'Intra-physiotherapy' to 'Extra-physiotherapy' practice the dynamic interplay of factors was shaped by differing contexts increasing barriers or operating as driving forces.

In PFPS evidence-base clinical practice should be derived from a variety of sources that has been subjected to testing and has been found to be credible (HCPC, 2013). Within the study it would seem that physiotherapists update their knowledge with a great variety of sources however; a number of factors identified within the model highlighted the challenge for the implementation of effective knowledge-to-practice, particularly within the complex organization of the NHS context, with a range of multiple factors mitigating effectiveness. Furthermore the nature of the evidence available within the 'Wider environmental' context arguably seems located at the low-level research conducted by researchers and reported in PFPS consensus statements (Powers, et al., 2012). Additionally, patient characteristics reported as part of the evidence-base seem suitable to athletic patients and not to those non-athletic patients physiotherapists see in the clinic. In this way the applied practice is restricted because of the practitioner context, the local NHS environment and wider-evidence-based factors, for instance variables linked to 'organizational' (Inter-physiotherapy) and 'wider environmental' (Extra-physiotherapy) contexts. Patient experience may be high because patients' preferences were reported to guide physiotherapy treatment (physiotherapists reported to aim at patients' problems and not at syndromes); however, this kind of approach may not show significant results on strength and flexibility.

The PARIHS framework acknowledges that facilitation and facilitators play an important role in the implementation of evidence-base practice. This study has shown the lack of facilitation in PFPS patients in NHS physiotherapy departments. There is a need in NHS physiotherapy departments towards adapting from intra-physiotherapy practice' to 'extra physiotherapy–practice'.

Figure 24. Modified PARIHS (Rycroft-Malone et al. 2013)

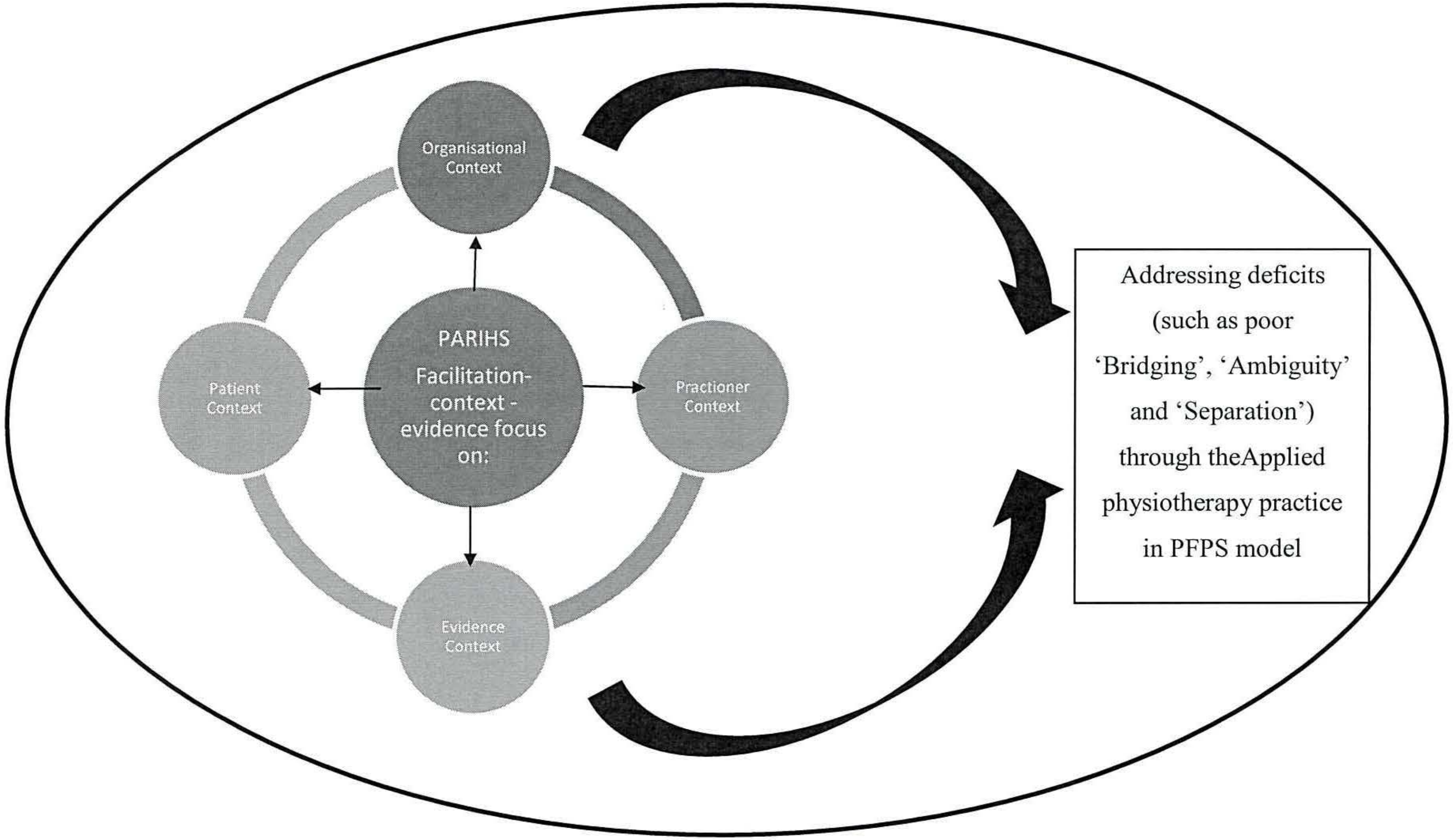


The study findings suggest the utility of adopting PARIHS as a framework for addressing the deficits within current PFPS practice in an applied context such as physiotherapy practice, particuarly addresing the bridging of evidence implementation into practice settings on a local level. The study setting of North Wales highlighted the challenges of implementation when such a range of factors act as barriers, limiting potential drivers. PARIHS emphasises the dynamic interrelationship between micro-meso-macro levels and the importance of evaluating contextual drivers. The final model presented in the synthesis of findings identifies and maps the relevant factors, their dynamic interrelationship and the context in relation to PFPS and physiotherapy practice. PARIHS provides a framework for supporting the development of improved bridging for PFPS along the 'Intra', 'Inter' and 'Extra' physiotherapy continuum with facilitation of connections between macro and micro levels by evaluation of barriers. For instance within the model there were key components that could be targeted (Figure 25) to address improved management as part of the following based on the modelling:

- Practitoner Context
- Patient Context
- Evidence Context
- Organisational Context

PARIHS provides an opportunity to link the model to an appropriate implementation framework that explicitly identifies the areas that require bridging in PFPS.

Figure 25. Dynamic development and implementation: Building on the model in applied PFPS' through the PARIHS Framework



9.5 SUMMARY

The chapter mapped the analytical outcomes from the synthesis of the findings. It highlighted the models that emerged from an inter-case comparison across the phases of the thesis and therefore delineated the main features of how the applied context of physiotherapy is relevant in influencing how PFPS is treated and managed. The chapter developed further the narrative that emerged from the analysis with not only a model of PFPS and applied physiotherapy but also a model that identified the opportunities as well as barriers towards implementation of improvements in the treatment of PFPS by physiotherapists in clinical practice. As such the PARIHS framework was highlighted as potentially providing an approach for advancing PFPS based on the modelling drawn from the synthesis of findings.

CHAPTER TEN

DISCUSSION AND RECOMMENDATIONS

10.1 INTRODUCTION

This chapter reports the contribution and the impact of the current thesis unpacking the PFPS dimensions in the applied PFPS physiotherapy practice. It depicts where the gaps lie between applied physiotherapy and evidence whilst it reports the mechanisms which help evidence become practice. It presents the strength and the limitations of the current evidence base connected to what physiotherapists deal with in the clinic. Additionally, it explains the novel outcomes of the thesis and the pros and cons of each phase. It provides a series of recommendations for different research directions in the future and for better clinical implementation of the evidence base.

10.2 CONTRIBUTION AND IMPACT

Overall the thesis explored the phenomenon of Patellofemoral Pain Syndrome as an area that merited further examination as part of applied physiotherapy practice. The study which is documented in the thesis detailed the limitations of the current evidence base linked to applied practice, exploring not only the evidence base but focusing on the utility of current approaches in assessment, management and treatment of Patellofemoral Pain Syndrome (PFPS) by physiotherapy practitioners.

The detailed research question was focused on understanding applied physiotherapy practice in relation to PFPS. As an area for inquiry the study sought to understand PFPS as a complex rather than a 'simple' intervention. Key areas of contribution will now be considered:

i. The completion of a scoping review to identify the key strands of evidence that inform the current measures and treatment for PFPS in clinical practice, locating the key professional responsibilities and roles, as well as patient contingencies.

This was accomplished by screening in depth both the literature but also the local physiotherapy practice in order to learn the conditions, the barriers and the patients' characteristics that the local physiotherapists have to confront when dealing with PFPS. Additionally, a second aim included the recognition of the methods that the clinical physiotherapists use to identify and treat a PFPS case and to assess them in order to provide best-practice clinical tools. This was to be achieved through investigating actual clinical practice and would be tested in both physiology labs and clinics. The research question sought to identify key factors that operated in applied practice to potentially influence patient outcomes. Furthermore the research question attempted to identify areas for improvement and possible remedial strategies for implementing best practice. In this stage key components that could influence patient outcomes had already started to be formed. The in-depth screening of the literature revealed the evidence context whilst the conditions, the barriers and the patients' characteristics that the local physiotherapists have to confront started to form the practitioner, patient and organisational context which will be supplemented by the next studies and will develop the PFPS model.

ii. The examination of contextual factors that mediated, mitigated or facilitated improved utility of treatment and measures in applied physiotherapy practice, focusing particularly on the role of interpretation and implementation of evidence and their use by physiotherapy professionals, operating within particular organisational environments.

After a comprehensive series of reliability, validity and differentiation tests on common clinical outcome measures, it was observed that although most of the tests were reliable, only the iliopsoas muscle flexibility (as measured by a goniometer) was found to be reliable and to differentiate PFPS from other groups. This test has been previously reported in several studies (e.g. Tyler et al., 2006; Waryasz & McDermott, 2008), although not often measured with a goniometer and always tested by physiotherapists for PFPS (see Chapter 8). Also the 'clam' test, which has been used as a concentric exercise to diagnose hip weakness and tiredness (Distefano et al., 2009), was generally observed to be able to differentiate PFPS from that of other conditions and healthy people. However, as with the above outcome measure, testing hip weakness is time consuming and not always regarded as the most common/important area to focus on in PFPS (Chapter 4 and 8) maybe because there remains controversy in the literature as to the importance of hip muscle strengthening for PFPS (Collins et al., 2012; Bolgla and Malone, 2005). This above findings showed that the PFPS assessment and treatment could be improved however problematic interactions between contexts (practitioner-evidence) have already started to emerge since physiotherapists do not use outcomes all the time whilst the assessment of the iliopsoas and hip muscles is also suggested by the literature. Although most of the physiotherapists did not use validated questionnaires for PFPS, they did know about them (Chapter 4) and this thesis was able to determine that most were reliable and that patients showed improvements in most following treatment (Chapters 5 and 7). However, the current questionnaires that can be used for PFPS are perhaps still not as appropriate to PFPS as they could be, which was highlighted by Chapter 6, where many questions within two common questionnaires used for PFPS in the literature (Howe, et al., 2012; Esculier et al., 2013), demonstrated that they had less 'meaningfulness' than others. The use of VAS for usual pain was found to be reliable for PFPS, and although may not differentiate between other patients. The fact that this is a quick outcome measure to administer could make it useful to physiotherapists once a diagnosis is made. Outcome measures that are quick to administer would be of most use to physiotherapists working in

NHS settings, as they reported lack of time with their patients as one of the key issues for effective treatment (Chapters 4 and 8). The previous comment shows the interaction between patient and organisational contexts but also the detachment of the evidence which requires the usage of outcome measures because of this interaction. What also has been highlighted from this thesis is that the strong focus in the literature prior to 2008 in trying to determine 'goal-standard' outcome measures for PFPS (Fredericson and Yoon, 2006) has been largely superseded by a stronger requirement to determine the most appropriate functional and pain release measures (Chapter 8 and Chapter 3), better patient education and compliance (Chapter 8). Physiotherapists appeared to achieve this (Chapter 7) through detachment and surfacing of the knowledge probably because they had no other choice since they could not improve strengthening and length of the muscles because of the problematic interaction between patient and organisational contexts with the practitioner context. However, in this case they are a step ahead from the literature which has now started to determine functional and pain measures for patients with PFPS.

iii. The study 'unpacked' the research question as part of a review of evidence and empirical data in order to develop recommendations for improved implementation of PFPS as a complex intervention. The recommendations focus on a context-orientated approach to guide clinical treatment and measures in PFPS.

Such an example is the fact that PFPS should not be considered as a condition appearing in predominantly athletic patients. The patients that physiotherapists see in the clinics are mostly non-athletic, therefore physiotherapists have to confront their reluctance in performing any kind of exercise, let alone precise exercises for strength and flexibility that literature suggests for treatment (predominantly based on research from athletic/military participants; see Chapter 3). In the light of this problem, physiotherapists detached themselves from the evidence and as well as of above, physiotherapists treat pain and function by prescribing only a few generic exercises to their patients and they focus on educating patients on what the condition is and reassuring them about PFPS outcomes. The combination of low patient compliance, few exercises prescribed and limited time to treat and re-assess PFPS patients in NHS settings synthesises another interactional relationship between the contextual factors and results in a short-term positive solution of the problem (Chapter 7: patients observing decreased pain after 6-weeks physiotherapy treatment). However, in the long term, physiotherapists reported in Chapter 8 that patients return with the same symptoms after a short period of time something which is in line with the research literature (Noehren, Scholz, & Davis (2011). The above results shows the poor bridging opportunities between practice and evidence leading to difficulties in physiotherapy practice, attempts to modify evidence but with limited durability and effectiveness. The contribution and impact of the above statement must lead future research to address such bridging deficits. Additionally, most of the exercise-based interventions come from research studies conducted in research laboratories where non-portable dynamometers are available for strength assessment (see Chapter 3). The same equipment is not available in NHS clinics. Because of this, and because they only have a limited time to take such measures, they do not include strength assessment in their typical practice. Therefore, the above observation shows again the poor bridging between what literature suggests and what clinical physiotherapists can use. Additionally, the short-term results of the physiotherapy treatment make the syndrome become chronic and add strain on the already stretched physiotherapy waiting list. This shows the dynamic process the complexity of interactions within the wider context beyond the intra-physiotherapy practice.

iv. In this way the research question underpins a thesis that has focused on comprehending the applied context of PFPS and builds on the strengths of current approaches to implementation of complex interventions that focus on understanding context. As such, the thesis develops a model of PFPS as an applied intervention and embeds the results in a wider argument regarding challenges to implementation of best practice in clinical environments where practitioners act within boundaries of autonomous practice.

The thesis provides an account that identifies the relevance of the present study within the field of healthcare sciences and particularly physiotherapy practice,

- It evidences and identifies the range of factors that underpin the complexity of Patellofemoral Pain Syndrome (PFPS) as an area of practice for physiotherapist in the applied context of practice;
- It examines the utility of clinical measures and treatment within the context of applied practice, and generates a greater understanding of the mitigating factors that influence these in the work of physiotherapist with PFPS, suggesting impacts on patient outcomes;
- It develops a model based on a multi-phased study that examines the area of applied practice in PFPS management in physiotherapy that account for PFPS as a complex intervention;
- Based on the overall results the thesis challenges the current understanding of PFPS as an area for innovation and change in physiotherapy practice and suggests the utility of a revised and context-focused model of implementation for improvements centred on the PARIHS framework.

10.2.1 Important / novel outcomes from this PhD

This thesis untangled many interesting observations that came to light only after a combination of different research techniques that not only focused on in-depth literature searching and quantitative analysis, but by also probing the actual treatment/assessment used by physiotherapists in a clinical setting. The main novel outcomes revealed from the current thesis are:

a) Current PFPS research regarding the evidence base of exercise treatment, outcome measures, risk factors and diagnostic tests has changed and that focus in future should be more on adopting functional measures and improving treatment through a variety of different ways such as patient education/assurance and compliance. Clinical tests are not regarded by physiotherapists as their main priority; they find that their patients are too variable in both symptoms and causes and they have limited time with their PFPS patients.

b) Physiotherapists treat patients and not syndromes. The thesis has shown that because of the poor bridging between evidence and clinical practice physiotherapists have modified their approaches by treating patients' needs. However, this concluded in a total surfacing of knowledge about PFPS and adopted modified interventions to assess and manage the individual patients' condition.

c) The focus on athletic/military populations (Lankhorst et al., 2012) in the PFPS literature has not necessarily assisted physiotherapists working in general practice, such as the NHS, with how best to treat and test non-athletic patients, which is their most common patient group, i.e. that they do not necessarily fit into the literatures' definition of a PFPS patient.

d) The reliability and validity of strength testing, including that of a portable dynamometer for the lower limb strength assessment that can be used in clinical settings (Appendix 9) is generally good. However, although muscle strengthening is deemed important in the treatment of PFPS by physiotherapists, the term 'strengthening' is perhaps used differently to that of researchers. Physiotherapists' perception about 'strengthening' is based more on improving patients function and quality of movement than actually seeing improvements in strength.

e) Although many common outcome measures and scales used in the assessment of PFPS are reliable their 'usefulness' in differentiating between other patient groups is less clear. The questionnaires (AKPS and LEFS) used for PFPS were reliable and valid but not useful for diagnosis. This could be due to the questionnaires not being good enough for PFPS. This could in part be due to particular questions within each questionnaire not being as meaningful to PFPS as they could be (Chapter 6). Initial investigation into these questionnaires could be very useful for future questionnaire validation and may support the use for a new Modified AKPS without the meaningless and less reliable questions (as has been piloted within this thesis).

f) A six-week period of physiotherapy in a NHS setting does decrease patients' knee pain. However, this did not occur through increases in lower limb strength or flexibility. Physiotherapists suggest the improvement may in part be due to increased patient awareness of what is the cause of the problem with their knee and consequent self-management strategies. They also believe that education and exercises lead to improved quality of lower limb movement and that this results in better mechanical function of the limb and reduction in pain. They also felt that improvement in strength and flexibility in these patients continues for a longer period than 6 weeks. The RoR (Chapter 3) shows that significant improvement in strength and flexibility can be demonstrated within a six-week period of treatment; however the frequency and intensity of the exercise-based programme needs to be high (4-5 times per week, high loading/number of sets). The limited time that NHS physiotherapists are allowed with their patients and standard patients' inability to comply mean that it is not possible to translate such an intensive exercise programme into an NHS physiotherapy clinic.

g) A lack of fidelity between literature and clinical practice exists and this has implications for the provision of PFPS physiotherapy for patients and the NHS. The thesis has shown the poor bridging between evidence, clinical contexts and individual practice. The literature is based on the experience of very intensive exercise programmes delivered to enthusiastic athletic or military subjects, which use measuring tools to report outcomes which cannot be applied in an NHS physiotherapy clinic in a general district hospital. Therefore, physiotherapists have been detached from the evidence leading to surfacing and adopted modified interventions to assess and manage the individual patients' condition. However, this practice has implementations to both patients and NHS because patients might learn how to self-manage and deal with the pain but their condition might become chronic. In some cases it is possible that adoption of a regular exercise might prevent this happening. The fact that many of them repeatedly return for more physiotherapy treatment increases the already stretched waiting list. The above led to the development of the 'PFPS model' adopting PARIHS as a framework for addressing the deficits within PFPS practice but also for encountering and supporting the development of improved bridging for PFPS along the 'Intra', 'Inter' and 'Extra' physiotherapy continuum with facilitation of connections between macro (organizational) and micro (individual) levels by evaluation of barriers. Therefore, the model consisted of the key components that could be targeted in order to get PFPS management improved and were: practitioner, patient, evidence and organisational contexts.

10.2.2 Results in context: phases and studies

This section identifies how the data from the respective phases linked to the contemporary evidence base prior to a consideration of the overall synthesis and modelling as part of the current repositioning of PFPS in the policy and literature.

Phase 2

Every physiotherapist assessed patients from a biomechanical perspective and perceived biomechanical issues as the main cause. Physiotherapists often asked about history of low back pain as they believed that low back pain can switch off activation of GM, leading to GM wasting, bad posture and subsequently knee pain. Physiotherapists were aware of the association between weakness of GM and PFPS (Cowan, Crossley and Bennell, 2009; Ireland et al., 2003; Tyler et al., 2006; Cichanowski et al., 2007). However, only 9/24 physiotherapists mentioned GM weakness as a cause of the syndrome. There were no important differences between the survey and the interviews in terms of ranking and selection of exercises and tasks.

Physiotherapists treated patients as individuals and not the syndromes. There was a great divergence in use of, and belief in, physiotherapy interventions. There was consensus that the aim was restoration of function, but treatment choices depended more on patient factors like age, lifestyle, fitness and motivation in combination with the clinical practice of colleagues, rather than evidence-based interventions. Consequently, the treatment choices offered also depended upon which individual physiotherapist the patient was allotted to.

The results from Phase 2 of the study illustrated that physiotherapists are well informed about the different types of presentation of PFPS and the treatment possibilities, but were not perhaps fully aware of the way causes are categorized into local, proximal and distal (Davis and Powers, 2010). Therefore, they did not present them this way neither in the survey nor in the interviews. In addition, physiotherapists may confuse presenting symptoms or effects with the causes of PFPS as they did not differentiate them at any stage of this study. For example, they did not report whether the weakness or stiffness of the lower limb muscles were the cause of PFPS or the effect of it. If stiffness is an effect which stabilises the knee then stretching initially would not be the answer; at least not until the muscles are strengthened to provide more support for the knee joint (Kisner and Colby, 2012). This, along with the absence of a gold standard protocol for assessment and treatment for this condition leads each physiotherapist to confront PFPS patients in a different and mainly subjective way. However, patient education seemed to be one of the treatment components that most of physiotherapists agreed on. This was seen as being particularly important in, patients who do not have the time or enthusiasm to exercise.

A recent consensus paper suggests that the factors of PFPS should be separated into proximal distal and local (Davis and Powers, 2010); therefore, clinical practice should perhaps organise assessment and treatment according to these categories. The current study supports a recent systematic review (Collins et al., 2012) which reported multimodal physiotherapy as the most efficient. In addition, foot orthoses and acupuncture were two of the physiotherapists' preference whilst, manual therapy which was not found to be significant in Collins et al. (2012) was not reported at all in current study.

As in the Cochrane reviews (Heintjes et al., 2009; Callaghan and Selfe, 2012; Hossain et al., 2010), physiotherapists in NWW identified the VAS as the primary patient reported outcome measure for pain. For secondary outcomes such as function, quality of life and activity levels, physiotherapists know about, but rarely use, particular measures such as the Anterior Knee Pain Questionnaire (Kujala et al., 1993), the Modified Functional Index Questionnaire (Harrison, et al., 1995), the SF-36 (Ware and Sherbourne, 1992) and the WOMAC OA Index (Bellamy and Buchanan, 1988). The last two outcome measures are generic questionnaires, not designed for PFPS.

Published guidelines for non-operative treatment (Witvrouw et al., 2005; Fredericson and Yoon; 2006, Houghton, 2007; Dixit and Difiori, 2007; Juhn, 1999) support the views of the physiotherapists that the term PFPS comprises many different entities. Physiotherapy practice in this study did not consistently align with a published clinical examination protocol (Witvrouw et al., 2005) which recommended a lengthy and comprehensive assessment of symptoms such as pain and instability; alignment of the entire lower extremity such as altered q-angle, squinting patella, genu valgus, genu recuvatum and pronation of the subtalar joint; patellar position e.g. patella alta, baja, glide, tilt and rotation; muscles and soft tissues, such as hypotrophy of VMO, imbalance between VMO and VL, weakness of knee extensors, hip flexors and/or hip abductors, tightness of the medial retinaculum and tightness of lateral muscle structures, hamstrings and rectus femoris, and, finally examination of the knee function under different activities such as walking, step-up/down and one leg squats. The limited time available in NHS appointments would not allow such a lengthy assessment. Thus, the finding of a quick evidence-based tool such as 5 repetitions of a single-leg squat (Crossley et al., 2011) can make a difference in clinical practice, however, these tests have to be tested in PFPS people first. Such studies should consider the fact that many people with PFPS find that even one legged squat provokes the pain and the deterrent effect this might have on their ability to complete the test. So there are doubts about whether the use of this test can be generalised to the NHS population.

A similar approach with more precise exercises is suggested in an unpublished Anterior Knee Pain manual (Herrington, 2009 unpublished manual 'Anterior Knee Pain: Differential Diagnosis & Treatment'). According to this manual, physiotherapists are advised to categorise their patients in terms of the potential cause (abnormal biomechanics, soft tissue, muscle imbalance, training/environmental, or patellofemoral stress). The protocol then recommends assessing patients by testing lower limb alignment (including pelvis, hip, femur, knee, tibia and foot), whilst completing static and dynamic movements relating to their posture, e.g. one leg squats and gait procedures. The muscle strength of quadriceps, tibialis posterior/flexor hallucis longus, gluteus maximus and hip lateral rotator muscles should be assessed. The same muscles should be then tested regarding their flexibility. Finally, patella glide, tilt and rotation should also be assessed.

Both published and unpublished guidelines reported a long catalogue of tests in order to assess all these parameters. Moreover, they recommended many and very precise exercises that patients should do at home. The findings of this study show that NWW physiotherapists were generally aware of assessment tests and outcome measures as well as the exercises that they could use, but generally they did not use them because they did not have time and felt restricted by their schedule. If more time and more sessions per week with the same patient were available physiotherapists would probably assess and measure outcomes differently. The inconsistent use of objective patient reported outcome measures in routine practice is identified in a recent Medical Research Council report (2009) as an issue to be addressed through further research and practice development. In addition, physiotherapists knew that if they prescribed precise and complex exercises, most of their patients (e.g. case studies 2 and 3) would not comply. Consequently, they advise this group of patients to perform a very limited number of simple functional exercises which they consider to be achievable rather than the unrealistically complex and demanding exercises recommended in guidelines and manuals.

The physiotherapists claimed they used a great variety of sources to inform their knowledge. However, they admitted that their practice was mostly influenced by colleagues rather than the evidence base. A recent study (Barton, et al., 2011) supports this evidence by revealing that the barriers for inhibiting the use of evidence based practice in PFPS were the limited knowledge of current evidence, the variable access to published research, the little time for professional development allowed in the NHS and the limited external validity of research to apply to clinical patients. Knowing where physiotherapists obtain information, knowledge and skills to develop their practice is important contextual information when considering implementing new evidence-based physiotherapy interventions and processes.

Phase 3

Literature has changed over the last years. Back when this PhD study was designed, there was a trend for clinical guidelines in different syndromes and conditions. Such examples include protocols for Low Back Pain (LBP), frozen shoulder and impingement syndrome. PFPS was one of those syndromes that needed guidelines. That was also mentioned by the physiotherapists in phase 2 where they reported that because of the lack of protocol, treatment depends on the physiotherapist. However, earlier studies have shown that this is not possible with PFPS due to its nebulous pathophysiology (Cook et al., 2010).

That was also found in phase 3 where numerous clinical tests and techniques were assessed about their reliability, validity and ability to differentiate PFPS patients from healthy controls and from patients with other conditions of the lower limb. This phase of a thesis agrees with previous ones (Piva et al., 2006; Bennell et al., 2000; Loudon et al.,2002) which reported high reliability on clinical tests and outcome measures for in PFPS. However, a great disagreement of this study was with those reported in Barton's (2013) review and concluded that patients with PFPS have weak gluts. This muscle problem was not found in this study, however; hip external rotation weakness was found to be more prevalent in PFPS patients compared to controls. That is also explained by the effectiveness that the tiring clam (which is a combination of hip abduction and external rotation) was found to have in PFPS patients along with the iliopsoas muscle tightness that PFPS patients had compared to the healthy controls (iliopsoas muscle also reported as secondary external rotator of the hip) (Tyler, 2006). Literature has not shown previous studies which compared clinical tests for the differentiation of PFPS from other conditions of the lower limb. However the results of this phase have shown that among a numerous tests, only the iliopsoas component of the modified Thomas test along with tiring clam can differentiate the two groups. This comes to agree with Cook et al. (2010) who reported that PFPS should be a diagnosis of exclusion

Phase 4

This phase was important to show the lack of evidence regarding the outcome measures recommended for PFPS cases. The RoR in phase 1 showed that there was only limited evidence up to 2004 (Selfe, 2004). This phase reported a different kind of analysis measuring not just the reliability and validity of the total scores of two of the most usual scales, but also the reliability and meaningfulness. Previous scales reported high reliability of those scales (Watson et al., 2005; Paxton et al., 2003) however they questioned the usefulness of those scales in PFPS conditions. This phase showed that there are many items in each scale that could be modified or changed to other items in order the scales to better assess a PFPS case. This phase also shows the lack of literature transferability to clinical practice not only because physiotherapists reported that they do not have time to use any scales (phase 2) but also because of the lack of specificity too.

Phase 5

This phase does not question the effectiveness of physiotherapy treatment but the effectiveness of treatment as physiotherapists believe it happens. As mentioned in phase 2 physiotherapists reported to use a lot of strengthening and stretching components in PFPS treatment. However, without using any outcomes they could not realize that what they achieved after a six-week treatment was a pain reduction and function improvement and not the improvement of strength and flexibility. To our knowledge there are no previous studies which report the effectiveness of a six-week PFPS treatment, however; physiologists (Brooks et al., 2006) reported that six weeks is enough time to achieve strength and flexibility. Therefore, the question was whether physiotherapists and physiologists mean the same thing when they are referred to these 2 muscle characteristics. This phase also shows the lack of fidelity between what literature suggests (strengthening and stretching of several muscles) and what physiotherapists perform in the clinic.

Phase 6

This phase aimed to identify why a six-week treatment improved pain and function but not strength and flexibility. The focus group study was a great opportunity for physiotherapists to talk about their clinical practice since they were surprised with the results of their treatment. However; after a little time they realized that the above results could not be any different. The explanation was not simple but complex.

Physiotherapists agreed that they aimed to improve strength and flexibility but their patients are not keen on exercising and the times they see them are not enough for significant improvement. Although they knew the terms of strength and flexibility, what they actually meant behind these words were muscle coordination. In addition, the reason they did not measure strength was because they thought that would not be typical practice although this comes to a contradiction with the regulations of the Health and Care Professions Council (HCPC) standards of physiotherapy proficiency which suggest the use of appropriate outcome measures on every occasion (HCPC, 2013).

Since their patients are non-athletic and do not comply easily with exercises, physiotherapists only give simple exercises which does not lead to muscle strength. Since there is no protocol to guide PFPS physiotherapy practice, and no guidelines force physiotherapy practice to strengthening and flexibility physiotherapists use their own techniques which in some case work.

Physiotherapy practice is patient-dependent and aims to improve pain and function which enhance quality of life. Education also plays an important role and is widely suggested by the Health and Care Professions Council (HCPC) standards of physiotherapy proficiency (HCPC

2013). Physiotherapists believe that their treatment is effective although the functional exercises they prescribe are not enough. However, they would not change their practice since there is no evidence base to the patients and the working conditions (limited time per patient) they experience

Phase 7: Reflection on the Synthesis of results

The results of the previous studies showed that the PFPS physiotherapy practice was characterised as isolated by possible opportunities for knowledge translation in practice. This put physiotherapist practice as a variable which was compounded by the patient, organisational and regional variables.

Gwyn Owen (2013) the Chartered Society of Physiotherapy's (CSP) professional officer for Continuing Professional Development (CPD) reported that the principle of involving service users in the design, planning and implementation of services has been a key strand in government policy since the late 1990s in all four UK countries. She also reported that if clinical practitioners want to put patients into the centre of their practice, it is important the service users to be involved in the design, planning and implementation of their treatment. Despite the policy drivers, there are still cases in which service users have had little or no involvement in decisions about their care.

The above statement seems to agree with the results of this thesis which has explored the clinical physiotherapy practice and the barriers that clinical physiotherapists face when treating a complex syndrome such as PFPS. NHS physiotherapists reported in phase 2 that their treatment depends on their patient and on what their patient wants to achieve. This is probably because they realized that there is a poor bridging between evidence base and applied physiotherapy. Having identified little relationship between the NHS and athletic constituency physiotherapists modified their practice by treating people's needs and not syndromes. This is in line with the government policy about putting the patients in to the centre of the treatment. However, it is a typical example of surfacing of the evidence since this practice (as phase 5 has shown), has limited durability and effectiveness and does not have the results that literature suggests (i.e. strengthening and stretching of several muscles). If patients did not have to choose about their treatment they would probably get other home exercises which they would have different effect in muscles. On the other hand, Owen's statement (2013) about patients being involved in the design, planning and implementation of their treatment shows that although physiotherapists perform a person-centred decision making (treatment according to what patients want to achieve) this does not apply to the kind of exercises prescribed to them. If physiotherapists planned the treatment with patients, the latter would probably conform or would not lie about having done their home exercises (phase 2). As a result physiotherapists prescribe only a few and easy exercises (detachment from evidence base) in order to get compliance. Owen (2013) also quotes that 'Adopting patients being involved in their treatment may require us to think critically about power and relationship dynamics in practice'. This relation dynamic does not seem to be on track according to this thesis since physiotherapists cannot persuade patients to perform the exercises that the former would decide (patient context plays an important role). Although they reported that they use a lot of education regarding what deteriorates and what decreases the symptoms, (education probably helped to decrease the pain and increase the function) this education does not go far enough to exercises.

Another important issue that is emerged from the thesis and is discussed by the CSP is the patients' characteristics. Owen (2013) quotes: 'A truly person-centred approach to decision making recognises that someone's experience is socially constructed – it depends on who they are, their personal history and context'. This shows that every patient has their own characteristics and that treatment should depend on that. Physiotherapists showed that they knew that their approach to the non-athletic patients should be different to those the literature suggests. Therefore, the physiotherapists were detached from the patient contexts surfacing of knowledge about PFPS focused on athletic patients in response to poor bridging. Patient compliance was a major problem that is not mentioned in any guidelines and physiotherapists had to face it themselves. As reported in phase 5 the few and easy exercises physiotherapists prescribed did not have the outcome that physiotherapists would prefer. Group classes could be suggested to enhance compliance, however; there is a need for further guidelines regarding how physiotherapists should approach those patients.

The same CSP article (Owen, 2013) also includes that physiotherapists should: 'focus their attention towards collecting objective data, and assumes that a person's issues are predictable, measurable and generalisable. This perception about measuring objective data is also supported by the Australian guidelines (Australian Standards for Physiotherapy, 2006) for physiotherapy practice (determine a plan of evaluation that uses valid and reliable outcome measures). This thesis has shown that there a reliable and valid outcome measures in PFPS, however; physiotherapists do not use them in their typical clinical practice although they know they should which shows another detachment from the evidence base. The reason is that they claim they have no time for them and they prefer to use this time in other treatment components such as education. This reveals that the organizational and regional contexts along with the policies physiotherapists have to follow play an important role and possibly determine physiotherapy outcome.

10.2.3 Overall strengths and limitations

Phase 1

The major strength of this phase is that it presents the first RoR in PFPS searching the most important components of the syndromes such as the risk factors, outcome measures, exercise treatment and clinical tests. This phase was the foundation of the thesis since it provided with the entire evidence base that was compared with what physiotherapists knew about the syndrome and used in the clinic. Additionally, this phase helped in the identification of the secondary questions of the thesis by searching the primary studies of the reviews. Some of these questions (athletic/military patients used by the reviews) played an important role in the thesis and displayed the lack of implementation between literature and applied physiotherapy. On the other hand, no statistical analysis was performed between the results of the primary studies because such an attempt would be impossible because of the different methods and outcome measures that each study used.

Phase 2

A major strength of this phase is that it reflects the physiotherapy practice in a rural part of the United Kingdom with no physiotherapy school. To the author's knowledge a study of such a service has not been previously conducted. However, the small sample from one area within the UK means we should be cautious about generalising these findings. Another advantage of the study is the mixed method design and the triangulation of findings using different types of evidence. Altrichter et al. (2008) contend that triangulation "gives a more detailed and balanced picture of the situation." This study has used methodological triangulation which involves using more than one method to gather data (interviews and survey) and investigator triangulation which involves multiple researchers in an investigation (principal investigator and a member of PFPS group) (Denzin, 2006).

On the other hand analysis of qualitative interviews was only performed at a basic level in order to develop categories and compare findings with questionnaire data. This was because further analysis would add nothing to the scope of this research project study which is to identify the clinical assessments and treatments used by physiotherapists and not to analyse them. However, the findings do resonate with our clinical knowledge of treating PFPS in a

UK context. Another limitation is that the physiotherapists were not asked to discriminate which of the factors they believed were the cause of PFPS and which were the effects.

Phase 3

One limitation of the study was that although the study was intended to be blinded, in some cases the participants with PFPS would walk into the laboratory with a limp or revealed where they had pain by their facial expressions especially when performing the tests. Additionally, besides the 'clam' test, other clinical tests such as the squat and stair descent were also reported as preferred methods by the physiotherapists (Chapter 7) which were not assessed in this study. The feasibility of using these tests was investigated; however, they were not used in this study because standardization was found to be very difficult. These tests were assessed using motion analysis techniques. These results are not reported in this thesis.

Phase 4

Previous literature review has not shown relative evidence regarding this way of analysis. Previous researchers analysed the reliability of the final scores of the scales and not of each question separately. On the other hand, a limitation of the phase could be the small number of patients included in this study because the district general hospital could not provide us with more patients during that period of recruitment. Additionally, although physiotherapists in phase 2 said that they would use these scales in their assessment, it is not known whether they thought that these scales were not the most appropriate for PFPS. That would complement the phase 4 even more. In addition, the patients of this study were asked to complete the scales only twice. If they participated more times the analysis would probably provide us with stronger results. The reason for this decision was that all patients were recruited from the waiting list and if they were asked to participate longer in this study they would probably have started their physiotherapy treatment. If this happened, the above analysis of the scales would not be possible as the parameters would not be the same between sessions. Finally, the analysis would be complemented if a control group was included. If participants with no PFPS reported a question as a 'problem' this question should also be ruled out from a PFPS scale

Phase 5

This phase was important because it revealed the effectiveness of a six-week programme of applied physiotherapy in PFPS patients. A limitation of this phase was that the sample size was calculated according to the needs of a comparison study. However, significant results in function and pain were found when the pre-and post-treatment results were compared. On the other hand, there was no monitoring to what treatment components each physiotherapist used in this 6 weeks while no control group was included either.

In addition, the modified AKPS was not validated before or implemented to a large number o patients. However, it was designed carefully by finding the limitations of the AKPS and by consulting other authors regarding what questions and design a new AKP questionnaire should have.

Phase 6

The strength of this phase was that two focus groups were conducted which included most of the physiotherapists employed by the local NHS physiotherapy department; the same physiotherapists who were questioned and interviewed in the mixed-method study and the same physiotherapists whose effectiveness of treatment was monitored in the previous phase. The use of an assistant moderator was another advantage of this phase because a consensus i several matters was reached by the majority of the focus groups. On the other hand, not all physiotherapists gave as much information as others however all physiotherapists participate in the consensus procedure.

10.3 RECOMMENDATIONS

The studies documented in the thesis highlight a number of key areas that require further consideration in the sphere of policy, research and practice in PFPS area.

10.3.1 Policy

This PhD study has shown that further consideration in the area of policy is required. There is a need of a clear understanding of PFPS decision-making intentions and decision making possibilities. Physiotherapists showed (Chapter 4 and 8) that they make decisions according to the circumstances (patient, evidence, practitioner and organizational contexts) whilst there is 'detachment' from the evidence base and a 'surfacing' of knowledge about PFPS focused on athletic patients that need to be considered. The patient variable seems to be very important, since physiotherapists reported to treat patients and not syndromes. However, this attitude may have negative consequences to patients who primarily want to get rid of the pain and bad function without considering about the continuity of wellbeing. Therefore, education about the persistence of good condition and even the improvement of it by adding specific exercises is highly recommended. In addition, a clear understanding of the key contexts in PFPS is also required. There is a need to consider the additional factors of organisational and regional processes that exacerbated the poor 'Bridging' of evidence and practice, focused on the athletic parameters for treatment and approaches compared to the physiotherapists constituency of NHS non-athletic patients. Also, the organisational and regional 'Ambiguity' concerning the physiotherapist role in aligning practice to appropriate benchmarks for PFPS is required consideration in the sphere of policy, research and practice in PFPS area .

10.3.2 Research

Research has started to explore PFPS in depth in the last two decades. So far, there is a sufficient progress with regards to the biomechanical changes of the lower limb, the risk factors and the exercises that physiotherapists should subscribe. Research has given a lot and valid information to physiotherapists who have to face PFPS patients with overused knees. However, the research focus has to change on different population than what has been focused until now. Non-athletic populations appear to have the same symptoms and the reason is not the overuse. The literature does not provide with evidence base for non-athletic patients who according to clinical physiotherapists have different risk factors, needs, and difficulty in compliance to precise exercises. This thesis developed the PFPS model in the applied physiotherapy practice which was based on the PARIHS framework. This model identified the areas that require bridging in PFPS such as the evidence, practitioner, patient and organizational contexts. However it is recommended that further development of the current model and contexts is required to develop evidence base even further. Such a development would include the exploration of more areas that need better development e.g. (patient needs), would enhance the implementation of applied physiotherapy practice and would improve the effectiveness of PFPS treatment. Additionally, it is recommended that more implementation models (e.g. PARIHS) is required in the field of PFPS and physiotherapy in general which will create a range of contexts and therefore a whole arena for research development.

10.3.3 Practice

Taking into consideration the gap between what literature suggests and what clinical physiotherapists can use, physiotherapists appeared to do their best by treating the patients' needs and not the syndrome. Therefore, a lot of function exercises are prescribed to patients who are not keen on doing any exercises while education seems to play an important role too. As a result their six-week treatment appears to work with regards to pain and function. However, since it is appeared that no strength or length changes are occurred during these 6 weeks, it is questionable whether many of these patients return to the physiotherapy department having the same symptoms because of the lack of strength and length restoration.

It is recommended that physiotherapists should focus more on these two treatment components educating their patients about the need to exercise and including group classes in their treatment. In addition, a better bridging of evidence into practice is required considering the key components of the PFPS applied physiotherapy practice model that could be targeted to address improved management. These components include the practitioner, patient, evidence and organizational contexts. Since the context-focused model of implementation for improvements centred on the PARIHS framework highlighted the challenges and barriers of implementation in PFPS the use of models of implementation that work with the applied context of physiotherapy is highly recommended.

10.4 PHD FUTURE IMPLEMENTATIONS

Having identified the problem of research applicability to clinical practice, future studies should take into consideration the limitations of NHS clinical environments such as the limited time for assessment and treatment and the mainly-non-athletic patient characteristics, when suggesting treatment options. Additionally, unlike what previous research suggests (Chapter 3) about the need for more research in athletic and military populations, there is a high need for research in non-athletic patients. Since education was deemed to play an important role in NHS physiotherapy treatment, future research should appraise the role of education alone compared to education and function exercises and education and supervised strengthening exercises. Education of patients' needs to cover a variety of aspects including education about the nature of PFPS, reassurance of patients in terms of their prognosis and education of the correct way for the patients to complete their exercise-based treatment. Further, research should aim to identify ways of long-term physiotherapy effect to incorporate the effectiveness and maintenance of the current physiotherapy practice after a six and 12 month time and how these would change if strength and flexibility issues were properly addressed. If this can be achieved, it will be revealed whether the reason that 80% of the

PFPS patients still reported pain 5 years after rehabilitation (Noehren, Scholz, & Davis 2011) was because their strength and flexibility components were not achieved. Such a result would refrain patients from returning to the physiotherapy clinic having the same symptoms a few months after treatment. Finally, to achieve patients' compliance, group classes have been proved to be beneficial in patients with other syndromes and might be helpful for patients with PFPS as well. Patients who are not keen on exercising or cannot find time would probably find group classes compulsory compared to the non-supervised exercises at home. On a wider theoretical level there is a need to further develop the initial theoretical modelling completed in this study, focusing on perhaps the implementation of best practice in applied physiotherapy, addressing deficits such as poor bridging, ambiguity and separation operating within particular organisational environments.

10.5 CONCLUDING REMARKS

This thesis has detailed the outcomes from a series of studies which documented PFPS as a complex rather than a 'simple' intervention in applied physiotherapy practice. The 'surfacing of the evidence' was that physiotherapists identified little relationship between the NHS and athletic constituency and this resulted in modified treatments according to patients' needs, with implications for durability and effectiveness of outcomes. The thesis has developed a model as part of the synthesis that identified the dynamics of practice environments and accounted for the influence of different variables that impacted on the outcomes of physiotherapy practice. The sequential methods of different designs enabled the researcher to include a range of data using qualitative, quantitative and mixed methods, to address complex research questions and to understand the phenomenon. Overall the thesis offers a more comprehensive representation of the phenomenon of PFPS management in applied physiotherapy practice and the reasons for the 'poor bridging' between physiotherapy practice and the key contexts. A better bridging is required between physiotherapy practice and evidence base, patient variables, organisational and regional contexts.

REFERENCES

Australian Physiotherapy Council (2006) "Australian Standards for Physiotherapy"

Agre, J.C. Magness, J.L. Hull, S.Z. Wright, K.C. Baxter, T.L. Patterson, R. Stradel, L. (1987) "Strength testing with a portable dynamometer: reliability for upper and lower extremities", Archives of Physical Medicine and Rehabilitation, Vol 68 pp454-8.

Altrichter, H., Feldman, A., Posch, P. & Somekh, B. (2008). "Teachers investigate their work: An introduction to action research across the professions", Routledge. p. 147. (2nd edition).

Aminaka, N. Gribble, P.A. (2005) "A systematic review of the effects of therapeutic taping on patellofemoral pain syndome", Journal of athletic Training, Vol 40 pp341-351.

Arroll, B. Ellis-Pegler, E. Edwards, A. Sutcliffe, G. (1997) "Patellofemoral pain syndrome. A critical review of the clinical trials on nonoperative therapy", Am J Sports Med, Vol 25 pp207-12

Aune, A.K. Holm, I. Risberg, M.A. et al. (2001) "Four-strand hamstring tendon autograft compared with patellar tendon-bone autograft for anterior cruciate ligament reconstruction: A randomised study with two year follow-up", American Journal of Sports Medicine, Vol 29 pp722-28.

Baker, M.M. Juhn. M.S. (2000) "Patellofemoral pain syndrome in the female athlete", Clin Sports Med, Vol 19 pp315-29

Barton, C. Hemmings, S. Morrissey, D. (2011) "The influence of published evidence on physiotherapists' clinical reasoning when treating patellofemoral pain syndrome: a mixed methods study", http://www.revaki.ugent.be/sites/default/files/CJBarton1.pdf (accessed 30 January 2012).

Barton, C.J. Menz, H.B. Crossley, K.M. (2010) "Effects of prefabricated foot orthoses on pain and function in individuals with patellofemoral pain syndrome: A cohort study", Physical Therapy in Sport, Vol 12 pp70-75.

Barton, C.J. Lack, S. Malliaras, P. et al. (2013) "Gluteal muscle activity and patellofemoral pain syndrome: a systematic review", Br J Sports Med, Vol 47 pp207–14.

Barton, C.J Webster, K.E. Menz, H.B. (2008) "Evaluation of the scope and quality of systematic reviews on nonpharmacological conservative treatment for patellofemoral pain syndrome", J Orthop Sports Phys Ther, Vol 38 pp529-41.

Bastian, H. Glasziou, P. Chalmers, I. (2010) "Seventy-five trials and eleven systematic reviews a day: how will we ever keep up", PLoS Medicine, Vol 7 DOI: 10.1371/journal.pmed.1000326

Baxter, P. Jack, S. (2008) "Qualitative Case Study Methodology: Study Design and Implementation for Novice Researchers", The Qualitative Report, Vol 13 pp544-558.

Bazett-Jones, D.M. Cobb, S.C. Joshi, M.N. et al (2011) "Normalizing hip muscle strength: Establishing body-size-independent measurements", Archives of Physical Medicine and Rehabilitation, Vol 92 pp76-82.

Bellamy, N. Buchanan, W.W. Goldsmith, C.H. Campbell, J. Stitt, L.W. (1988) "Validation study of WOMAC: a health status instrument for measuring clinically important patient relevant outcomes to an heumatic drug therapy in patients with osteoarthritis of the hip or knee", Journal of Rheumatology, Vol 15 pp1833–40.

Bent, P.N. Wright, C.C. Rushton, B.A. Batt, E. (2009) "Selecting Outcome Measures in Sports Medicine: A guide for practitioners using the example of anterior cruciate ligament rehabilitation", British Journal of Sports Medicine, Vol 43 pp1006-12.

Bennell, K. Bartam, S. Crossley, K. Green, S. (2000) "Outcome measures in patellofemoral pain syndrome: test retest reliability and inter-relationships", Physical Therapy in Sport, Vol 1 pp22-41.

Bennell, K. Hodges, P. Mellor, R. Bexander, C. Souvlis, T. (2004) "The nature of anterior knee pain following injection of hypertonic saline into the infrapatellar fat pad", Journal of Orthopaedic Research, Vol22 pp116-121.

Bennett, J.G. Stauber, W.T. (1986) "Evaluation and treatment of anterior knee pain using eccentric exercise", Medicine and Science in Sports and Exercise, Vol 18 pp526-530.

Binkley, J.A. Stratford, P.W. Lott, S.A. Riddle, D.L. (1999) "The Lower Extremity Functional Scale (LEFS): Scale Development, Measurement Properties, and Clinical Application", Physical Therapy, Vol 79 pp371-383.

Bland, J.M. Altman, D.G. (1987) "Statistical methods for assessing agreement between measurement", The Lancet, Vol 327 pp307-10.

Blazina, M.E. Fox, J.M. Del Pizzo, W. Broukhim, B. Ivey, F.M. (1979) "Patellofemoral replacement", Clin Orthop, Vol 144 pp98-102.

Bohannon. R.W. (1986) "Test-retest reliability of handheld dynamometry during a single session of strength assessment", Physical Therapy, Vol 66 pp206-209.

Bolgla, L.A Boling, M.C. (2011) "An update for the conservative management of patellofemoral pain syndrome: A systematic review of the literature from 2000 to 2010", International Journal of Sports and Physical Therapy, Vol 6 pp113-125.

Bolgla, L.A. Malone, T.R. (2005) "Exercise prescription and patellofemoral pain: evidence for rehabilitation" Journal of Sports Rehabilitation, Vol 14 pp72-88.

Bolgla, L.A. Malone, T.R. Umberger, B.R. Uhl, T.L. (2008) "Hip strength and hip and knee kinematics during stair descent in females with and without patellofemoral pain syndrome", Journal of Orthopaedics Sports and Physical Therapy, Vol 38 pp12-18.

Boling, M. Padua, D. Marshall, S. Guskiewicz, K. Pyne, S. Beutler, A. (2010) "Gender differences in the incidence and the prevalence of patellofemoral pain syndrome", Scandinavian Journal of Medicine and Science in Sports, Vol 20 pp725-30.

Britten, N (1995) "Qualitative interviews in medical research", British Medical Journal Vol 311 pp251-3

Brooks, G.A. Fahey, T.D. White, T.P. (1996) "Exercise Physiology: Human Bioenergetics and its Applications", Mayfield Publishing Co. ISBN 0072556420.

Burnard, P. (1991) "A method of analysing interview transcripts in qualitative research", Nurse Education Today, Vol 11 pp461–466.

Callaghan, M. J. Oldham, J.A. (2004) "Quadriceps atrophy: to what extend does it exist in patellofemoral pain syndrome?", British Journal of Sports medicine, Vol 38 pp295-299.

Callaghan, M. J. Selfe, J. Dey, P. (2009) "Activity-associated pain in patellofemoral pain syndrome: How does it inform research and practice?", Physiotherapy, Vol 95 pp321-322.

Callaghan, M.J. Selfe, J. (2007) "Has the incidence of prevalence of patellofemoral pain syndrome in the general population of the United Kingdom been properly evaluated?", Physical Therapy in Sport, Vol 8 pp37-43.

Callaghan, M.J. Selfe, J. (2012) "Patellar taping for patellofemoral pain syndrome in adults (protocol)", Cochrane Database of Systematic Reviews, Vol 4. Art No.: CD006717. DOI: 10.1002/14651858.

Campbell, M. Fitzpatrick, R Haines, A. Kinmonth, A. Sandercock, P. Spiegelhalter, D. Tyrer, P. (2000) "Framework for design and evaluation of complex interventions to improve health", British Medical Journal, Vol 321 pp694.

Carr, A. Hewlett, S. Hughes, R. et al. (2003) "Rheumatology outcomes: the patient's perspective", Journal of Rheumatology, Vol 30 pp880–3.

Caylor, D. Fites, R. Worrell, T.W. (1993) "The relationship between quadriceps angle and anterior knee pain syndrome", Journal of orthopaedics and Sports Physical Medicine, Vol 17pp11-16.

Charmaz, K. (2006) "Constructing grounded theory: A practical guide through qualitative analysis", London: Sage Publications Limited.

Cherryholmes, C. H. (1992). "Notes on pragmatism and scientific realism", Educational Researcher, Vol 14 pp13-17.

Chesworth, B.M. Culham, E. Tata, G.E. Peat, M. (1989) "Validation of outcome measurements in patients with patellofmoral pain syndrome", The journal of Orthopaedic and Sport Physical Therapy, Vol 10 pp302-8.

Cichanowski, H.R. Schmitt, J.S. Johnson, R.J. Niemuth, P.E. (2007) "Hip strength in collegiate female athletes with patellofemoral pain", Medicine and Science in Sports and Exercise, Vol 39 pp1227-32.

Clarke, M. (2008) "Interpreting the results of systematic reviews", Semin Hematol, Vol 45 pp176-180.

Clarke, M. Hopewell, S. Chalmers, Iain. (2010) "Clinical trial should begin and end with systematic reviews of relevant evidence: 12 years and waiting", The Lancet, Vol 376 pp20-21

Clarkson, H.M (2000) "Musculoskeletal Assessment: Joint Range of Motion and Manual Muscle Strength" 2nd Ed, Lippincott Williams & Wilkins,

Cleland, J. McRae, M. (2002) "Patellofemoral Pain Syndrome: A Critical Analysis of Current Concepts", Physical Therapy Reviews, Vol 7 pp152-161.

Cohen, J. (1988) "Statistical power analysis for the behavioural sciences", 2nd Edition, Erlbaum, Hillsdale, New York.

Collins, N.J. Bierma- Zeinstra, S.M.A. Crossley, K.M. et al. (2013) "Prognostic factors for patellofemoral pain: a multicentre observational analysis", Br J Sports Med, Vol 47 pp227–33.

Collins, N.J. Bisset, L.M. Crossley, K.M. Vicenzino, B. (2012) "Efficacy of nonsurgical interventions for anterior knee pain: Systematic review and metaanalysis of randomised trials", Sports Medicine, Vol 42 pp31-49.

Collins, N.J. Crossley, K.M. Beller, E. Darnell, R. McPoil, T. Vicenzino, B. (2008) "Foot orthoses and physiotherapy in the treatment of patellofemoral pain syndrome: randomised clinical trial", British Medical Journal, Vol 337 doi: 10.1136/bmj.a1735

Collins, N.J. Crossley, K.M. Darnell, R. Vicenzino, B. (2010) "Predictors of short and long term outocome in patellofemoral pain syndrome: a prospective longitudinal study", BMC Musculoskeletal Disorders, Vol 11 doi: 10.1186/1471-2474-11-11.

Conn, V.S. Valentine, J.C. Cooper, H.M. (2003) "Grey literature in meta-analyses", Nursing Research, Vol 52 pp256-261.

Cook, C. Hegedus, E.J. Hawkins, R. Scovell, F. Wyland, D. (2010) "Diagnostic accuracy and association to disability of clinical test findings associated with patellofemoral pain syndrome", Physiotherapy Canada, Vol 62 pp17-24.

Cook, C. Mabry, L. Reiman, M.P. Hegedus, E.J. (2012) "Best tests/clinical findings for screening and diagnosis of patellofemoral pain syndrome: a systematic review", Physiotherapy, Vol 98 pp93-100.

Cooper, H. (1998) "Synthesizing research: A guide for literature reviews" 3rd Edition, Sage Publications, Thousand Oaks, CA.

Cowan, SM. Crossley, K. Bennell, K. (2009) "Altered hip and trunk muscle function in individuals with patellofemoral pain", British Journal of Sports Medicine, Vol 43 pp584-588.

Cowan, SM. Bennell, K.L. Hodges, P.W. Crossley, K.M. McConnell, J. (2001) "Delayed onset of electromyographic activity of vastus medialis obliquus relative to vastus lateralis in subjects with patellofemoral pain syndrome", Archives of Physical Medicine and Rehabilitation, Vol 82 pp183-189.

Cowan, SM. Hodges, P.W. Bennell, K.L. Crossley K.M. (2002) "Altered vastii recruitment when people with patellofemoral pain syndrome complete a postural task", Archives of Physical Medicine and Rehabilitation, Vol 83 pp989-995.

Craig, N. Dieppe, P. Macintyre, S. Michie, S. Nazareth, I. Petticrew, M. (2008) "Developing and evaluating complex interventions: the new Medical Research Council guidance", British Medical Journal, Vol 337 pp1655.

Creswell, J.W. Plano Clark, V.L. Gutmann, M.L. Hanson, W.E. (2003) "Advanced mixed methods research designs". In A. Tashakkori & B. Teddlie (Eds.), Handbook of mixed methods in social & behavioural research Thousand Oaks, Sage Publications, CA pp209-240.

Creswell, J.W. (1994). "Research design: Qualitative and quantitative approaches". Thousand Oaks, CA: Sage.

Creswell, J.W. (1998). "Qualitative Inquiry and Research Design: Choosing Among Five Traditions". Thousand Oaks, CA: Sage.

Christopher, N.C. Congeni, J. (2002) "Overuse injuries in the pediatric athlete: evaluation, initial management, and strategies for prevention", Clinical Pediatric Emergency Medline, Vol 3 pp118–28.

Crossley, K.M. Bennell, K.L. Cowan, S.M. Green, S. (2004b) "Analysis of outcome measures for persons with patellofemoral pain: which are reliable and valid?", Archives of Physical Medicine and Rehabilitation, Vol 85 pp815-22.

Crossley, K. Bennell, K.L. Green, S. McConnell, J. (2001) "A systematic review of physical interventions for patellofemoral pain syndrome", Clin J Sport Med, Vol 11 pp103-10

Crossley, K. Bennell, K.L. Green, S. Cowan, S. McConnell, J. (2002) "Physical therapy for patellofemoral pain: a randomized, double blinded, placebo-controlled trial", The American Journal of Sports Medicine, Vol 30 pp857-865.

Crossley, K.M. Cowan, S.M. Bennell, K.L. McConnell, J (2004a) "Knee flexion during stair ambulation is altered in individuals with patellofemoral pain", Journal of Orthopaedic Research, Vol 22 pp267-274.

Crossley, K.M. Zhang, W.J. Schache, A.G. Bryant, A. Cowan, S.M. (2011) "Performance on the single-leg squat task indicates hip abductor muscle function", American Journal of Sports Medicine, Vol 39 pp866-873.

Culvenor, A.G. Belinda, C.C.H. Lai. Makdissi, M. Collins, N.J. Vicenzino, B. Morris, H.G Crossley, K.M. (2014) "Patellofemoral Osteoarthritis is Prevalent and Associated With Worse Symptoms and Function After Hamstring Tendon Autograft ACL Reconstruction", British Journal of Sports Medicine, Vol 48 pp435-439

Cutbill, J.W. Ladly, K.O. Bray, R.C. Thorne, P. Verhoef, M. (1997) "Anterior knee pain: A review", Clinical Journal of Sport Medicine, Vol 7 pp40-45.

Davis, I.S. Powers, C.M. (2010) "Patellofemoral Pain Syndrome: Proximal Distal, and Local Factors, An International Retreat, April 30-May 2, 2009, Fells Point, Baltimore, MD", Journal of Orthopaedic & Sports Physical Therapy, Vol 40 ppA3-A9.

Denzin, N. (2006). "Sociological Methods: A Sourcebook. Aldine Transaction". ISBN 978-0-202-30840-1. (5th edition).

Derasari, A. Brindle, T.J. Alter, K.E. Sheehan, F.T. (2010) "McConnell Taping Shifts the Patella Inferiorly in Patients With Patellofemoral Pain: A Dynamic Magnetic Resonance Imaging Study", Physical Therapy, Vol 90 pp411-419.

Devereaux, M.D. Lachmann, S.M. (1984) "Patello-femoral arthralgia in athletes attending a sports injury clinic", British Journal of Sports Medicine, Vol 18 pp18-21.

Dierks, T.A. Mana, K.T. Hamill, J. Davis, I.S. (2008) "Proximal and distal influences on hip and knee kinematics in runners with patellofemoral pain during a prolonged run", Journal of orthopaedic and Sports Physical Theory, Vol 38 pp448-56.

Distefano, J.D. Blackburn, T.J. Marshall, W.S. Padua, A.D. (2009) "Gluteal Muscle Activation During Common Therapeutic Exercises", Journal of Orthopaedic & Sports Physical Therapy, Vol 29 pp7.

Dixit, S. Difiori, J.P. (2007) "Management of patellofemoral pain syndrome", American Family Physician, Vol75 pp194-202.

Doward, L.C. McKenna, S.P. (2004) "Defining Patient-Reported Outcomes" Value in Health, Vol 7 ppS4-S8.

Dragoo, J.L. Johnson, C. McConnell, J. (2012) "Evaluation and treatment of disorders of the infrapatellar fat pad", Sports Medicine, Vol 42 pp51-67.

Duffey, M.J. Martin, D.F. Cannon, D.W. et al. (2000) "Etiologic factors associated with anterior knee pain in distance runners", Medicine and Science in Sports and Exercise, Vol 32 pp1825-1832.

Dumas, J.E. Lynch, A.M. Laughlin, J.E. Phillips Smith, E. Prinz, R.J. (2001) "Promoting intervention fidelity. Conceptual issues, methods, and preliminary results from the early alliance prevention trial", American Journal of Prevention Medicine, Vol 20 pp38-47.

Duncan, R. Peat, G. Thomas, e. Wood, L. Hay, E. Croft, P. (2009) "Does isolated patellofemoral osteoarthritis matter? ", Osteoarthritis Cartilage, Vol 2009 pp1151-5.

Duri, Z.A. Aichroth, P.M. Wilkins, R. Jones, J. (1999) "Patellar tendonitis and anterior knee pain", American Journal of Knee Surgery, Vol 12 pp99-108.

Dursun, N, Dursun, E. Kilic, Z. (2001) "Electromyografic biofeedback-controlled exercise versus conservative care for patellofemoral pain syndrome", Archives of Physical Medicine and Rehabilitation, Vol 82 pp1692-5.

Dutton, R.A. Khadavi, M.J. Fredericson, M. (2014) "Update on rehabilitation of patellofemoral pain", Current Sports Medicine Reports, Vol 13 pp172-178.

Ellen, M.I. Jackson, H.B. Dibiase, S.J. (1999) "Uncommon causes of Anterior Knee Pain: A Case Report of Infrapatellar Constracture Syndrome", American Journal of Physical Medicine and Rehabilitation, Vol 78 pp376-380.

Esculier, J.F. Roy, J.S. Bouyer, L.J. (2013) "Psychometric evidence of self-reported questionnaires for patellofemoral pain syndrome: a systematic review", Disability and Rehabilitation, online early submission DOI: 10.3109/09638288.2013.774061

Fagan, D. Delahunt, E. (2008) "Patellofemoral pain syndrome: a review on the associated neuromuscular dificits and the current treatment options", British Journal of Sports Medicine Vol 42 pp789-785.

Fern, E.F. (2001) "Advanced Focus Group Research". Thousand Oaks, Calif: Sage.

Ficat, R. P. Ficat, C. Gedeon, P. Toussaint, J.B. (1979) "Spongialization. A new treatment for diseased patellae", Clinical Orthopaedics and related research, Vol 144 pp74-83.

Fredericson, M. Cookingham, C.L. Chaudhari, A.M. Dowdell, B.C. Oestreicher, N. Sahrmann, S.A. (2000) "Hip abductor weakness in distance runners with iliotibial band syndrome", Clinical Journal of Sports Medicine, Vol 10 pp169-175.

Fredericson, M. Yoon, K. (2006) "Physical Examination and Patellofemoral Pain Syndrome", American Journal of Physical Medicine & Rehabilitation, Vol 85 pp234-243.

Frye, J.L. Ramey, L.N. Hart, J.M. (2012) "The effects of exercise on decreasing pain and increasing function in patients with patellofemoral pain syndrome: A systematic review", Sports Health, Vol 4 pp205-210.

Fu, F.H Bennett, C.H. Ma, C.B. et al. (2000) "Current trends in anterior cruciate ligament reconstruction. Part 2: Operative procedures and clinical correlations", American Journal of Sports Medicine, Vol 28 pp124-130.

Fulkerson, J.P. (2002) "Diagnosis and Treatment of Patients with Patellofemoral Pain", American Journal of Sports Medicine, Vol 30 pp447-56

Fulkerson, J.P. Arendt, E.A. (2000) "Anterior knee pain in females", Clinical orthopaedics, Vol 372 pp69-73.

Gajdosik, R. Lusin, G (1983) "Hamstring muscle tightness: Reliability of an active knee-extension test", Physical Therapy, Vol 63 pp1085-1088.

Galanty, H. Matthews, C. Hergenroeder, A. (1994) "Anterior knee pain in adolescents", Clinical Journal of Sport Medicine Vol 4 pp176-181.

Gannan, R. Ciliska, D. Thomas, H. (2010) "Expediating systematic reviews: methods and implications of rapid reviews", Implementation Science, Vol 5 pp56-66.

Gerbino, P.G. (2006) "Adolescent Anterior Knee Pain", Operative Techniques in Sports Medicine, Vol 14 pp203-211.

Ghersi, D. Pang, T. (2009) "From Mexico to Mali: four years in the history of clinical trial registration", .Journal of Evidence-Based Medicine, Vol2 pp1-7.

Gholve, P.A. Scher, D.M. Khakharia, S. et al. (2007) "Osgood Schlatter syndrome", Current Opinion in Pediatrics, Vol 19 pp44-50.

Glaser, B.G. (1978) "Theoretical Sensitivity", Mill Valley, CA: Sociology Press.

Glaser, B.G. & Strauss, A.L. (1967) "The Discovery of Grounded Theory: Strategies for Qualitative Research", Chicago: Aldine Pub. Co.

Green, S. (2003) "Clinical management: Patellofemoral Syndrome", Journal of Bodywork and Movement Therapies, Vol 9 pp16-26.

Haim, A. Yaniv, M. Dekel, S. Amir, H. (2006) "Patellofemoral pain syndrome: validity of clinical and radiological features", Clinical Orthopaedics and Related Research, Vol 451 pp223–8.

Halabchi, F. Mazaheri, R. Seif-Barghi, T. (2013) "Patellofemoral Pain Syndrome and modifiable intrinsic Risk Factors; How to Assess and Address? ", Asian Journal of Sports Medicine, Vol 4 pp85-100

Harrison, E. Quinney, H. Magee, D. Sheppard, M.S. McQuarrie, A. (1995) "Analysis of outcome measures used in the study of patellofemoral pain syndrome", Physiotherapy Canada, Vol 47 pp264-72.

Harvie, D. O'leary, T. Kumar, S. (2011) "A systematic review of randomized controlled trials on exercise parameters in the treatment of patellofemoral pain: what works? " Journal of Multidisciplinary Healthcare, Vol 4 pp383-92.

Harvey, D. (1998). "Assessment of the flexibility of elite athletes using the modified Thomas test". Br J Sports Med Vol22 pp68–70.

Health & Care Professions Council. (2013) "Standards of proficiency-physiotherapists" Publication code: 20130301jPOLPUB (printed May 2013)

Herrington, L. (2009) "Anterior Knee Pain: Differential Diagnosis and Treatment", Health Education Seminars, April 2009, Glan Clwyd, Rhyl, UK.

Heidegger, M. (1962) "Being and time", London: SCM Press Ltd.

Heintjes, E.M. Berger, M. Bierma-Zeinstra, S.M.A. Bernsen, R.M.D. Verhaar, J.A.N. Koes, B.W. (2009) "Exercise therapy for patellofemoral pain syndrome", Cochrane Database of Systematic Reviews, Vol 4. CD003472.

Herrington, L. Rivett, N. Munro, S. (2006) "The relationship between patella position and length of the iliotibial band as assessed using Ober's test", Manual Therapy, Vol 11 pp182-186.

Ho, K.Y. Hu, H.H. Colletti, P.M. Powers, C.M. (2014) "Running-induced patellofemoral pain fluctuates with changes in patella water content", European Journal of Sports Science, Vol 14 pp628-34.

Hossain, M. Alexander, P. Burls, A. Jobanputra, P. (2010) "Foot orthoses for patellofemoral pain in adults", Cochrane Database Systematic Reviews, Vol 3, CD008402

Houghton, K.M. (2007) "Review for the generalist: evaluation of anterior knee pain", Pediatric Rheumatology, Vol 4 pp8.

Howe, T.E. Dawson, L.J. Syme, G. Duncan, L. Reid, J. (2012) "Evaluation of outcome measures for use in clinical practice for adults with musculoskeletal conditions of the knee: A systematic review", Manual Therapy, Vol 17 pp100-118.

Hudson, Z. Darthuy, E. (2007) "Iliotibial band tightness and patellofemoral pain syndrome: A case-control study", Manual Therapy, Vol 14 pp147-151.

Hughston, J. C. Walsh, W.M. Puddy, G. (1984) "Patellar subluxation and dislocation. Saunders monographs in clinical orthopaedics", W.B. Saunders Company, Philadelphia, Vol 5.

Humac/Norm, Testing and Rehabilitation System, Computer Sports Medicine, Inc., MA, USA ADInstruments Pty Ltd Unit 6, 4 Gladstone Rd Castle Hill, NSW 2154 Australia.

Ireland, M.L. Wilson, J.D. Ballantyne, B.T. Davis, I.M. (2003) "Hip strength in females with and without patellofemoral pain", Journal Orthopaedics and Sports Physical Therapy, Vol 22 pp671-676.

Irha, E. Vrdoljak, J. (2003) "Medial synovial plica syndrome of the knee: a diagnostic pitfall in adolescent athletes", Journal of Pediatric Orthopaedics B, Vol 12 pp44–48.

Jackson, A.M. (2001) "Anterior Knee Pain", The Journal of Bone and Joint Surgery, Vol 83-b pp937-48.

Jacobs, C.A. Uhl, T..L. Mattacola, C.G. Shapiro, R. Rayens, W.S. (2007) "Hip abductor Function and Lower Extremity Landing Kinematics: Sex Differences", Journal of Athletic Training, Vol 42 pp76-82.

Johnson, R.B. & Christensen, L.B. (2004) "Educational research: Quantitative, qualitative, and mixed approaches", Boston: Allyn and Bacon

Johnson, R.P. (1997) "Anterior knee pain in adolescents and young adults", Curr Opin Rheumatol, Vol 9 pp159-64.

Jones, J.G. (2004) "Unpublished data from an audit of the casemix of musculoskeletal referrals to the TEAMS programme".

Juhn, M.S. (1999) "Patellofemoral pain syndrome: a review and guidelines for treatment", American Family Physician, Vol 60 pp2012.

Kendall, N.A. Linton, S.J., Main, C.J. (1997) "Guide to Assessing Psychosocial Yellow Flags in Acute Low Back Pain: Risk Factors for Long-Term Disability and Work Loss", Wellington, New Zealand: Accident Rehabilitation and Compensation Insurance Corporation of New Zealand and the National Health Committee, New Zealand.

Kibler, W.B. (1987) "Strength and flexibility findings in anterior knee pain syndrome in athletes", Americal Journal of Sports Medicine, Vol 15.

Kottner, J. Audige, L. Bronson, S. et al. (2010) "Guidelines for reporting reliability agreement studies (GRRAS) were proposed", Journal of Clinical Epidemiology, Vol 64 pp96-106.

Kisner, C. Colby, A.L (2012) "Therapeutic exercise: foundations and techniques", sixth edition. Philadelphia: F.A. Davis Company.

Kitzinger, J (1995) "Qualitative research: Introducing focus groups". British Medical Journal, Vol 29 pp299-302.

Knapik, J.J. Wright, J.E. Mawdsley, R.H. Braun, J.M. (1991) "Preseason strength and flexibility imbalances associated with athletic injuries in female collegiate athletes", American Journal of Sports Medicine, Vol 19 pp76-81.

Kramer, M.S. Feinstein, A.R. (1981) "Clinical Biostatistics 54. The Biostatistics of Concordance", Clinical Pharmacology and Therapeutics, Vol 29 pp111-3.

Kroemer, K.H.E. (1970) "Terminology measurement and interpretation of data", Human Factors, Vol 12 pp297-313.

Krouwer, J.S. (2008) "Why Bland-Altman plots should use X, not (Y+X)/2 when X is a reference method", Statistics in Medicine, Vol 27 pp778-780.

Krueger, R.A. (1994). "The methodology of focus groups: The importance of interaction between research participants". Sociology of Health and Illness, Vol 18, pp103-121.

Krueger, R.A. Casey, M.A. (2000) "Focus groups; a practical guide for applied research", 3rd edition. London: Sage Publications Inc.

Kujala, U.M. Jaakkola, L.H. Koskinen, S.K. Taimela, S. Hurme, M. Nelimarkka, O. (1993) "Scoring for Patellofemoral Disorders". Arthroscopy, Vol 9 pp159-163.

Lancaster, R. (2007) "To determine reliable functional hip muscle weakness tests for patients with anterior knee pain and to compare with healthy controls", Unpublished data: BSc University of Wales Bangor.

Lankhorst, N.E. Bierma-Zeinstra, S.M.A. Van Middlekoop, M (2012) "Risk factors for patellofemoral pain syndrome: A systematic review", Journal of Orthopaedic & Sports Physical Therapy, Vol 42 pp81-95.

Lankhorst, N.E. Bierma-Zeinstra, S.M.A. Van Middlekoop, M (2013) "Factors associated with patellofemoral pain syndrome: A systematic review", British Journal of Sports Medicine, Vol 47 pp193-206.

Lichtenstein, A. Yetley, E. Lau, J. (2008) "Application of systematic review methodology to the field of nutrition" Journal of Nutrition, Vol 138, pp2297-2306.

Long-Rossi, F. Salsich, S.B. (2010) "Pain and Hip Lateral Rotator Muscle Strength Contribute to Functional Status in Females with Patellofemoral Pain", Physiotherapy Research International, Vol 15 pp57-60.

Loudon, J.K. Wiesner, D. Goist-Foley, H.L. Asjes, C. Loudon, K.L. (2002) "Intrarater reliability of functional performance tests for subjects with patellofemoral pain syndrome". Journal of Athletic Training, Vol *37 pp*256-261.

Lowry, C.D. Cleland, J.A. Dyke, K. (2008) "Management of patients with patellofemoral pain syndrome using a multi-modal approach: a case series", Journal of Orthopaedics and Sports Physical Therapy, Vol 33 pp647-660.

Lu, Y.M. Lin, J.H. Hsiao, S.F. Liu, M.F. Chen, S.M., Lue, Y.J. (2011) "The relative and absolute reliability of leg muscle strength testing by a handheld dynamometer", Journal of Strength and Conditioning Research, Vol 25 pp1065-1071

Lubinus, H.H. (1979) "Patella glide bearing total replacement", Orthopaedics, Vol 2 pp119-27.

MacIntyre, D.L. Robertson, D.G. (1992) "Quadriceps muscle activity in women runners with and without patellofemoral pain syndrome", Archives of Physical Medicine and Rehabilitation, Vol 73 pp10-4.

Malanga, G.A. Andrus, S. Nadler, S.F. McLean, J. (2003) "Physical examination of the knee: A review of the original test description and scientific validity of common orthopedic tests", Achieves of Physical Medicine and Rehabilitation, Vol 84 pp592-603

Marshall, J.W. Bangert, K.S (2008) "Clinical Biochemistry: Metabolic and clinical aspects", Churcill Livingstone, New York.

Mascal, C.L. Landel, R. Powers, C. (2003) "Management of patellofemoral pain targeting hip, pelvis, and trunk muscle function: 2 case reports, Journal of Orthopaedic and Sports Physical Therapy, Vol 33 pp642-660.

Mayring, P. (2000) "Qualitative Content Analysis", Forum Qualitative Sozialforschung / Forum: Qualitative Social Research [On-line Journal], Vol 1. Available at: http://qualitative-research.net/fqs/fqs-e/2-00inhalt-e.htm [Date of access: 31 January, 2012]

McConnell, J. (1996) "Management of patellofemoral problems", Manual Therapy, Vol 1 pp60-66.

McNeill, J. Lynn, F. Alderdice, F. (2012) "Public health interventions in midwifery: a systematic review of systematic reviews", BMC Public Health, Vol 12-955

Mensch, G. Ellis, P.E. (1986) "Running Patterns of Transfemoral Amputees: A Clinical Analysis", Prosthetics and Orthotics International, Vol 10 pp129-134.

Messier, S.P. Davis, S.E. Curl, W.W. Lowery, R.B. Pack, R.J. (1991) "Etiologic factors associated with patellofemoral pain in runners", Medicine and Science in Sports and Exercise, Vol 23 pp1008-1015.

Micheo, W. Baerga, L. Miranda, G (2012) "Basic principles regarding strength, flexibility and stability exercises". PM R: the journal of injury, function and rehabilitation, Vol 4 pp805-11.

Milgrom, C. Finestone, A. Eldad, A. Shlamkovitch, N. (1991) "Patellofemoral pain caused by overactivity. A prospective study of risk factors in infantry recruits", Journal of Bone and Joint Surgery-American Volume, Vol 73 pp1041-1043.

Moher, D. et al. (2007) "Epidemiology and reporting characteristics of systematic reviews", PLoS Medicine, Vol 4 DOI: 10.1371/journal.pmed.0040078

Moher, D. Liberati, A. Tetzlaff, J. Altman, D.G. (2009) "The PRISMA Group: Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement", BMJ, 339:b2535.

Mollenkopf, G.W. (1949) "Variation of the standard error of measurement". Psychometrika, Vol 14 pp189-229.

Mølgaard, C. Rathleff, M.S. Simonsen, O. (2011) "Patellofemoral pain syndrome and its association with hip, ankle, and foot function in 16- to 18-year-old high school students: a single-blind case-control study", Journal of American Podiatric Medical Association, Vol 101 pp215-22.

Morrison-Beedy D, Côté-Arsenault D, Feinstein NF (2001) "Maximising results with focus groups: Moderator and issues". Applied Nursing Research, Vol 14, pp48-53

Murphy, J.P. (1990). "Pragmatism: From Peirce to Davidson". Boulder, CO: Westview.

Nakagawa, T.H. Moriya, E.T.U. Maciel, C.D. Serrao, F.V. (2012) "Trunk, Pelvis, Hip, and Knee Kinematics, Hip Strength, and Gluteal Muscle Activation During a Single-Leg Squat in Males and Females With and Without Patellofemoral Pain Syndrome", Journal of Orthopaedics & Sports Physical Therapy,Vol 42 pp491-501.

Naslund, J. Naslund, U.B. Odenbring, S. Lundenberg, T. (2006) "Comparison of symptoms and clinical findings in subgroups of individuals with patellofemoral pain syndrome", Physiotherapy Theory and Practice, Vol 22 pp105-18.

Nijs, J. Geel, V.C. Van der auwera, C. Van de Velde, B. (2005) "Diagnostic value of five clinical tests in patellofemoral pain syndrome", Manual therapy, Vol 11 pp69-77.

Nimon, G. Murray, D. Sandow, M. Goodfellow, J.W. (1998) "Natural history of anterior knee pain: A 14- to 20-year follow-up of nonoperative management", Journal of Paediatric Orthopaedics, Vol 18 pp118-122.

Niskanen, R.O. Paavilainen, P.J. Jaakkola, M. Korkala, O.L. (2001) "Poor correlation of clinical signs with patellar cartilaginous changes", Arthroscopy, Vol 17 pp307.

Noblit, G.W. Hare, D. (1988) "Meta-ethnography: Synthesizing qualitative studies", Sage, Newbury Park.

Noehren, B Pohl, M.B. Sanchez, Z. Cunningham, T. Latterman, C. (2012) "Proximal and Distal Kinematics in Female Runners with Patellofemoral Pain". Clinical Biomechanics, Vol 27 pp366-371.

Noehren, B. Scholz, J. Davis, I. (2011) "The effect of real-time gait retraining on hip kinematics, pain and function in subjects with patellofemoral pain syndrome", British Journal of Sports Medicine, Vol 45 pp691-696.

Nunes, G.S. Luiz Stapait, E. Hors Kirsten, M. de Noronha, M. Moraes Santos, G. (2013) "Clinical test for diagnosis of patellofemoral pain syndrome: Systematic review with meta-analysis", Physical Therapy in Sport, Vol 14 pp54-59

Oliveira, V.C. and Henschke, N. (2012) "Multimodal physiotherapy is effective for anterior knee pain relief", Br J Sports Med, Vol 47 pp245-6.

Onwuegbuzie, A.J. Dickinson, W.B. Leech, N.L. Zoran, A.G. (2009) "A Qualitative Framework for Collecting and Analyzing Data in Focus Group Research", International Journal of Qualitative Methods, Vol 8 pp 1-21.

Owen, G. (2013) "Patient Centred Practice" Chartered Society of Physiotherapy, Vol 19

Oxman, A.D. Guyatt, G.H. (1993). "The science ofreviewing research", Annals of the New York Academy of Sciences, Vol 703 pp125-34.

Pallant, J. (2007) "SPSS survival manual: a step by step guide to data analysis using SPSS for Windows", Open University Press, Maidenhead.

Papadopoulos, K. Noyes, J. Barnes, M. Jones, G. J. Thom, M.J. (2012) "How do physiotherapists assess and treat patellofemoral pain syndrome in North Wales? A mixed method study", International Journal of Therapy and Rehabilitation, Vol 19 pp261-72

Pappas, E. Wong-Tom, W.M. (2012) "Prospective predictors of patellofemoral pain syndrome: a systematic review with meta-analysis", Sports Health, Vol 4 pp115-120.

Patton, M.Q. (2002) "Qualitative research and evaluation methods" London: Sage Publications Inc.

Paxton, E.W. Fithian, D.C. Stone, M.L. Silva, P. (2003) "The reliability and validity of knee specific and general health instruments in assessing acute patellar dislocation outcomes", American Journal of Sports Medicine, Vol 31 pp487-92.

Piva, R.S. Fitzgerald, G.K. Wisniewski, S. Delitto, A. (2009) "Predictors of pain and function outcome measures after rehabilitation in patients with patellofemoral pain syndrome", Journal of Rehabilitation Medicine, Vol 41 pp604-612.

Piva, R.S. Goodnight, E.A. Childs, J.D. (2005) "Strength around the hip and flexibility of soft tissues in individuals with and without patellofemoral pain syndrome", Journal of Orthopaedic and Sports Physical Therapy, Vol 35 pp793-801.

Piva, S.R. Fitzgerald, G.K. Irrgang, J.J. Jones, S. Hando, B. Childs, J.D. (2006) "Reliability of measures of impairments associated with patellofemoral pain syndrome", BMC Musculoskeletal Disorders, Vol 7 pp33.

Powers, C.M. (1998) "Rehabilitation of patellofemoral joint disorders: a critical review", Journal of Orthopaedics and Sports Physical Therapy, Vol 28 pp345-54

Powers, C.M. Mortenson, S. Nishimoto, D. Simon, D. (1999) "Criterion-related validity of a clinical measurement to determine the medial/lateral component of patellar orientation", Journal of Orthopaedics and Sports Physical Therapy, Vol 29 pp372-377

Presser, S. Couper, P.M. Lessler, T.J. Martin, E. Martin, J. Rothgeb, M.J. Singer, E. (2004) "Methods for testing and evaluating survey questions", Public Opinion Quarterly, Vol 68 pp109-130.

Prins, M.R. van der Wurff, P. (2009) "Females with patellofemoral pain syndrome have weak hip muscles: a systematic review", Australian Journal of Physiotherapy, Vol 55 pp9-15.

Puniello, M.S. (1993) "Iliotibial band tightness and medial patellar glide in patients with patellofemoral dysfunction", Journal of Orthopaedic and Sport Physical Therapy, Vol 17 pp144-148.

Rattray, J. Jones, C.M. (2005) "Essential elements of questionnaire design and development". Journal of Clinical Nursing, Vol 16 pp234-43.

Reid, D.C. Burnham, R.S. Saboe, L.A. Kushner, S.F. (1987) "Lower extremity flexibility patterns in classical ballet dancers and their correlation to lateral hip and knee injuries", American Journal of Sports Medicine, Vol 15 pp347–352.

Reiman, M.P Bolgla, L.A. Loudon, J.K. (2011) "A literature review of studies evaluating gluteus maximus and gluteus medius activation during rehabilitation exercises", Physiotherapy Theory and Practice, DOI: 10.3109.09593985.2011.604981.

Reynaldo, J Santos, A. (1999) "Cronabach's alpha: A tool for assessing the reliability of scales". Journal of Extension, Vol 37. Available from: http://www.joe.org/joe/1999april/tt3.html [cited: 8th May 2013].

Ritchie, J and Spencer, L (1994), "Qualitative data analysis for applied policy research", in Bryman and Burgess, eds., Analysing Qualitative Data, London: Routledge, p173-194.

Rittel, H.W. Webber, M.M. (1973), "Dilemmas in a general theory of planning", Policy Sciences, Vol 4, pp155-169.

Robinson, R.L. Nee, R.J. (2007) "Analysis of hip strength in females seeking physical therapy treatment for unilateral patellofemoral pain syndrome", Journal of Orthopaedic and Sports Physical Therapy, Vol 37 pp232-238.

Rodrigues, P. TenBroek, T. Hamill, J. (2013) "Runners with anterior knee pain use a greater percentage of their available pronation range of motion", Journal of Applied Biomechanics, Vol 29 pp141-146.

Roux, L. (2011) "Exercise therapy for patellofemoral pain syndrome costs society less than usual care", Clinical Journal of Sport Medicine, Vol 21 pp275-276.

RS® Components Ltd. Birchington Road, Corby, Northants, NN17 9RS, UK

Rycroft-Malone, J. Seers, K. Chandler, J. Hawkes, C.A. Crichton, N. Allen, C. Bullock, I. Strunin, L. (2013) "The role of evidence, context, and facilitation in an implementation trial: implications for the development of the PARIHS framework", Implementation Science, Vol 8 doi:10.1186/1748-5908-8-28.

Salsich, G.B. Brechter, J.H. Farwell, D. Powers, C.M. (2002) "The effects of patellar taping on knee kinetics, kinematics, and vastus lateralis muscle activity during stair ambulation in individuals with patellofemoral pain", Journal of Orthopaedic and Sports Physical Therapy, Vol 32 pp3-10.

Sandow, M.J. Goodfellow, J.W. (1985) "The natural history of anterior knee pain in adolescents", The journal of Bone and Joint Surgery, Vol 67 pp36-8.

Scottish Intercollegiate Guidelines Network: Systematic literature review. (2008).Available at: http://www.sign.ac.uk/guidelines/fulltext/50/ webcite section6.htm. Accessed 24 May 2013

Sharif, M.O. Janjua-Sharif, F.N.Ali, H. Ahmed, F. (2013). "Systematic Reviews Explained: AMSTAR-How to Tell the Good From the Bad and the Ugly", Oral Health Dent Manag Vol 12 pp9-16

Selfe, J. (2004) "The patellofemoral Joint: A review of primary research", Critical reviews in Physical and Rehabilitation Medicine, Vol 16 pp1-30

Servi, T.J. (2011) "Patellofemoral Joint Syndromes", http://www.emedicine.com/sports/topic96.htm, (accessed 05 February, 2012).

Shea, B.J. Grimshaw, J.M. Wells, G.A. Boers, M. Andersson, N. Hamel, C. & Bouter, L.M. (2007) "Development of AMSTAR: A measurement tool to assess the methodological quality of systematic reviews", BMC Medical Research Methodology, Vol 7:10

Shea, B.J. Hamel, C. Wells, G.A. Bouter, L.M. Kristjansson, E. Grimshaw, J. Boers, M. (2009) "AMSTAR is a reliable and valid measurement tool to assess the methodological quality of systematic reviews", Journal of Clinical Epidemiology, Vol 62 pp1013-1020.

Smith, A.D. Stroud, L. McQueen, C. (1991) "Flexibility and anterior knee pain in adolescent elite figure skaters", Journal of Pediatric Orthopaedics, Vol 11 pp77-82.

Smith, T.O. Davies, L. O'Driscoll, M-L. Donell, S.T. (2008) "An evaluation of the clinical tests and outcome measures used to assess patellar instability", Knee Vol 15 pp255-262.

Smith, V. Devane, D. Begley, C. & Clarke, M. (2011) "Methodology in conducting a systematic review of systematic reviews of healthcare interventions" BMC Medical Research Methodology, Vol 11 pp15.

Souza, R.B. Powers, C.M. (2009a) "Predictors of hip internal rotation during running: an evaluation of hip strength and femoral structure in women with and without patellofemoral pain", American Journal of Sports Medicine, Vol 37 pp579-587.

Souza, R.B. Powers, C.M. (2009b) "Differences in hip kinematics, muscle strength and muscle activation between subjects with and without patellofemoral pain", Journal Orthopaedic & Sports Physical Therapy, Vol 39 pp12-19.

Stake, R.E. (2000) "The case study method in social inquiry". In R. Gomm, M. Hammersley, & P. Foster (Eds.), Case study method: Key issues, key texts (pp. 20-26). London: Sage.

Stake, R.E. (1995) "The art of case study research", Thousand Oaks, CA: Sage

Stake, R.E. (1988) "Case studies methods in educational research: seeking sweet water". In R.M Jaeger (Ed.) Complementary methods for research in education (pp253-278) Washington, DC: American Educational Research Association

Stedman, L.T. (1990) "Stedman's medical dictionary", 25th Edition, Williams and Wilkins, Baltimore.

Stefanik, J.J. Zhu, Y. Zumwalt, A.C. Gross, K.D. Clancy, M. et al. (2010) "The association between patella alta and the prevalence and worsening of structural features of patellofemoral joint osteoarthritis: The Multicenter Osteoarthritis Study", Arthritis Care Research, Vol 62 pp1258-1265.

Stockton, K.A. Wrigley, T.V. Mengersen, K.A. Kandiah, D.A. Paratz, J.D. Bennell, K.L. (2011) "Test-retest reliability of hand-held dynamometry and functional tests in systemic lupus erythematosus", Lupus, Vol 20 pp144-50.

SurveyMonket™, http://www.surveymonkey.com/, (accessed 18 May 2008).

Tan, S.S. Van Linschoten, R.L. Van Middelkoop, M. Koes, B.W. Bierma-Zeinstra, S.M. Koopmanschap, M.A. (2010) "Cost-utility of exercise Therapy in adolescents and young adults suffering from the patellofemoral pain syndrome", Scandinavian Journal of Medicine & Science in Sports, Vol 20 pp568-579.

Tavakol, M. Dennick, R. (2011) "Making sense of Chronbach's alpha", International Journal of Medical Education, Vol 2 pp53-55.

Taunton, J.E. Wilkinson, M. (2001) "Rheumatology: 14. Diagnosis and management of anterior knee pain" Canadian Medical Association Journal, Vol 29 pp1595-601.

Tegner, Y. Lysholm, J. (1985) "Rating systems in the evaluation of knee ligament injuries", Clinical Orthopaedics and Related Research, Vol198 pp43-9.

Thalheimer, W. Cook, S. (2002) "How to calculate effect sizes from published research: A simplified methodology", A Work-Learning Research Publication, Retrieved May 30, 2014 from http://work-learning.com/effect_sizes.htm.

Thomee, R. Augustsson, J. Karlsson, J. (1999) "Patellofemoral Pain Syndrome: A review of current issues", Sports Medicine, Vol 28 pp245-262.

Thomee, R. Renstrom, P. Karsson, J. Grimby, G. (1995) "Patellofemoral pain syndrome in young women", Scandinavian Journal of Medical Sciences in sports, Vol 5 pp245-251.

Tobin, R. Robinson, G (2000) "The effect of McConnell's vastus lateralis inhibition taping technique on vastus lateralis and vastus medialis obliquus activity", Physiotherapy, Vol 86 pp173-183.

Tumia, N. Maffulli, N. (2002) "Patellofemoral Pain in female athletes", Sports Medicine and Arthroscopy Review, Vol10 pp69-75.

Tyler, T.F. Nicholas, S.J. Mullaney, M.J. McHugh, M.P. (2006) "The role of hip muscle function in the treatment of patellofemoral pain syndrome", American Journal of Sports Medicine, Vol 34 pp630-636.

Van Linschoten, R. van Middelkoop, M. Berger, M.Y. et al. (2009) "Supervised exercise therapy versus usual care for patellofemoral pain syndrome: an open label randomised controlled trial", British Medical Journal, Vol 339 doi: 10.1136/bmj.b4074

Van Tiggelen, D. Witvrouw, E. Roget, P. Cambier, D. Danneels, L. Verdonk, R. (2004) "Effect of bracing on the prevention of anterior knee pain-a prospective randomized study", Knee Surgery, Sports Traumatology, Arthroscopy, Vol 12 pp434-439.

Vicente, S.A. (2006) "Anterior knee pain and patellar instability", 1st edition, Springer, London

Ware, J.E. Sherbourne, C.D. (1992) "The MOS 36-Item Short Form Health Survey (SF-36), A Conceptual framework and item selection", Medical Care, Vol 30 pp473-83.

Waryasz, G. McDermott, A. (2008) "Patellofemoral pain syndrome (PFPS): a systematic review of anatomy and potential risk factors" Dynamic Medicine, Vol 7 pp9.

Watson, C.J. Propps, M. Ratner, J. Zeigler, D.L. Horton, P. Smith, S.S. (2005) "Reliability and responsiveness of the lower extremity functional scale and the anterior knee pain scale in patients with anterior knee pain", Journal of Orthopaedic and Sports Physical Therapy, Vol35 pp136–146.

Welsch, M.A. Williams, P.A. Pollock, M.L. Graves, J.E. Foster, D.N. Fulton, M.N. (1998) "Quantification of full-range-of-motion unilateral and bilateral knee flexion and extension torque ratios", Archives of Physical Medicine and Rehabilitation, Vol 79 pp971-978.

White, L.C. Dolphin, P. Dixon, J. (2009) "Hamstring length in patellofemoral pain syndrome", Physiotherapy, Vol 95 pp24-28.

Whittemore, R. Knafl, K. (2005) "The integrated review: updated methodology", Journal of Advanced Nursing. Chapter in: Methodological issues in nursing research. Blackwell Publishing Ltd pp546-553.

Willson, J.D. Binder-Macleod, S. Davis, I.S. (2008) "Lower extremity jumping mechanics of female athletes with and without patellofemoral pain before and after exertion", American Journal of Sports Medicine, Vol 36 pp1587-96.

Willson J.D. Davis, I.S. (2009) "Lower extremity strength and mechanics during jumping in women with patellofemoral pain", Journal of Sport Rehabilitation, Vol 18 pp76-90.

Winslow, J. Yoder. (1995) "Patellofemoral pain in female ballet dancers:correlation with iliotibial band tightness and tibial external rotation", Journal of Orthopaedic and Sports Physical Therapy, Vol 22 pp18-21.

Witvrouw, E. Callaghan, M.J. Stefanik, J.J. et al. (2014) "Patellofemoral pain: consensus statement from the 3rd International Patellofemoral Pain Research Retreat held in Vancouver, September 2013", British Journal of Sports Medicine, Vol 48 pp411-414

Witvrouw, E. Lysens, R. Bellemans, J. Cambier, D. Vanderstraeten, G. (2000) "Intrinsic risk factors for the development of anterior knee pain in an athletic population. A two-year prospective study", The American Journal of Sports Medicine, Vol 28 pp480-89.

Witvrouw, E. Sneyers, C. Lysens, R. Victor, J. Bellemans, J. (1996) "Reflex response times of vastus medialis oblique and vastus lateralis in normal subjects and in subjects with patellofemoral pain syndrome", The Journal of Orthopaedic and Sports Physical Therapy, Vol 24 pp160-5.

Witvrouw, E. Werner, S. Mikkelsen, C. Van Tiggelen, D. Vanden Berghe, L. Cerulli, G. (2005) "Clinical classification of patellofemoral syndrome: guidelines for non-operative treatment", Knee Surgery, Sports Traumatology, Arthroscopy, Vol 13 pp122 -130.

Wojtys, E.M. Beaman, D.N. Glover, R.A. Janda, D. (1990) "Innervation of the human knee joint by substance-P fibers", Arthroscopy, Vol 6 pp254-63.

Wood, L. Muller, S. Peat, G. (2011) "The epidemiology of Patellofemoral disorder in adulthood: a review of routine general practice morbidity recording", Primary Health Care Research and Development, Vol 12 pp157-164.

Yin, R. K. (2003). "Case study research: Design and methods" (3rd ed.). Thousand Oaks, CA: Sage.

APPENDIX ONE: THE MULTI-STRAND SEARCH STRATEGY FOR THE RoR

Keywords		Number of published studies
Patellofemoral pain syndrome*Review*	1. risk factors	25
	2. exercise treatment	45
	3. diagnostic clinical tests	7
	4. psychometric outcome measurements	46
#1 OR #2 OR #3 OR #4		123
Anterior Knee Pain*Review*	1. risk factors	21
	2. exercise treatment	33
	3. diagnostic clinical tests	3
	4. psychometric outcome measurements	44
#1 OR #2 OR #3 OR #4		101
Chondromalacia patella*Review*	1. risk factors	2
	2. exercise treatment	8
	3. diagnostic clinical tests	7
	1. psychometric outcome measurements	5
#1 OR #2 OR #3 OR #4		22

APPENDIX TWO: SURVEY QUESTIONNAIRE

1.The 'PFPS' Questionnaire Project

Thank you for choosing to complete the Patellofemoral Pain Syndrome Questionnaire Survey for Physiotherapists. An information leaflet about the survey is also attached and available to you. Please read the survey information sheet and if you are interested in taking part in this project proceed to the next page. If you have any queries and would like to talk to a member of the survey please, do not hesitate to contact Konstantinos Papadopoulos, e-mail: pepa01@bangor.ac.uk, Tel (01248) 383132 Mrs Moyra Barnes, moyra.barnes@nww-tr.wales.nhs.uk, Tel (01248) 384384 and Dr Jeremy Jones, e-mail: pesc03@bangor.ac.uk, Tel (01248) 388261

Questionnaire version 2, 19/04/09

2. Participant's details

Questionnaire survey and selected follow-up qualitative interviews of how Physiotherapists assess and their rehabilitation practice for patients with Patellofemoral Pain Syndrome.

The 'PFPS Questionnaire' survey

Name of researcher: Kostas Papadopoulos

We would like to be able to contact you in order to inform you about the £50 prize draw and a likely interview, therefore, please enter your e-mail address.

1) E-mail address: [ ]

2) Are you also willing to be interviewed at a later date? Please insert a Y or N as appropriate. ☐

3. A Little Bit About You

Please insert a 'Y' in one choice.

1) How many new patients with Patellofemoral Pain Syndrome (PFPS) do you treat per month?

0	1-2	3-5	6-10	10-20	20+
☐	☐	☐	☐	☐	☐

Please insert a 'Y' in one choice

2) How long have you been practising as a physiotherapist (Years)?

1	2	3	4-5	6-10	11-20	21
☐	☐	☐	☐	☐	☐	☐

Please insert a 'Y' in one choice.

3) How confident are you in dealing with PFPS?

1. Not at all confident	2.	3.	4.	5. Very confident
☐	☐	☐	☐	☐

4) Please insert a 'Y' in one choice.

In which organization do you work?

NHS Trust ☐ Other ☐ NHS & Private Practice ☐

Private practice ☐ LHB ☐

4. The 'PFPS Questionnaire' survey: Treatment

Although Patellofemoral Pain Syndrome is very common there is not a gold standard treatment, therefore, physiotherapists treat the syndrome in a number of different ways.

For the following questions please insert a 'Y' in one choice.

How often do you use the following when treating PFPS?

1) McConnell's Taping Technique.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

2) McConnell's Vastus Lateralis Inhibition Taping Technique.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

3) Foot Orthotics.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

4) Muscle strengthening.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

Please give more details about the muscles you usually strengthen.

5) Stretching.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

Please give more details about the muscles you usually stretch.

6) Acupuncture.

1. Never 2. 3. 4. 5. Always

☐ ☐ ☐ ☐ ☐

7) Orthotic brace.

1. Never 2. 3. 4. 5. Always

☐ ☐ ☐ ☐ ☐

8) Patients' education.

1. Never 2. 3. 4. 5. Always

☐ ☐ ☐ ☐ ☐

9) Open chain exercises.

1. Never 2. 3. 4. 5. Always

☐ ☐ ☐ ☐ ☐

Please give more details about what kind of Open Chain exercises you use.

10) Closed chain exercises.

1. Never 2. 3. 4. 5. Always

☐ ☐ ☐ ☐ ☐

Please give more details about what kind of Closed Chain exercises you use.

11) Therapeutic ultrasound.

1. Never 2. 3. 4. 5. Always

☐ ☐ ☐ ☐ ☐

12) Electrotherapy.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

Please report the electrical modalities you use.

Please list any other methods you usually use to treat PFPS.

a)

b)

c)

d)

e)

f)

g)

assess PFPS also vary.

For the following questions please insert a 'Y' in one choice.

Questionnaires:

How often do you use the following when assessing PFPS?

1) Functional Index Questionnaire (FIQ).

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

2) Kujala Questionnaire.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

3) Western Ontario and McMaster Universities (WOMAC) Osteoarthritis Index.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

4) Visual Analogue Scale (VAS)

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

5) Hospital Anxiety and Depression Scale (HAD).

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

6) Lysholm knee scale.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

Tests:

7) The ability to perform squats.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

8) The ability to perform hopping on one leg.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

9) Ascending and descending stairs.

1. Never 2. 3. 4. 5. Always

☐ ☐ ☐ ☐ ☐

10) Running.

1. Never 2. 3. 4. 5. Always

☐ ☐ ☐ ☐ ☐

11) The 'clam' test'.

1. Never 2. 3. 4. 5. Always

☐ ☐ ☐ ☐ ☐

12) The modified Thomas test.

1. Never 2. 3. 4. 5. Always

☐ ☐ ☐ ☐ ☐

13) The Ober's Test.

1. Never	2.	3.	4.	5. Always
☐	☐	☐	☐	☐

14) Please list any other outcome measures or tests you usually use to assess PFPS condition.

a)

b)

c)

d)

e)

6. The 'PFPS Questionnaire' survey: Miscellaneous

Please answer the following questions

1) What home exercise programme do you suggest to patients with PFPS?

2) From your observations what would you say were the causes of PFPS?

3) How long after starting the treatment would it usually take to see an improvement?

4) Considering your experience of treating PFPS what percent of your patients would be:

a) Symptom free ☐ c) No better ☐

b) Much better ☐ d) Worst ☐

(This should add up to 100)

5) Do you have any further comments?

Thank you very much for completing this questionnaire. We are planning to make a presentation to the physiotherapy department at Ysbyty Gwynedd of the results of this survey. Please return it to Kostas Papadopoulos via e-mail, ***E-mail address:*** pepa01@bangor.ac.uk *or post it to this address: (addressed removed to assure anonymity)*

APPENDIX THREE: SURVEY INVITATION LETTER

► The School of Sport, Health and Exercise Sciences, Bangor University,

► The Department of Physiotherapy, (department deleted to assure anonymity)

Study title: Questionnaire survey and selective follow-up qualitative interviews of how Physiotherapists assess and their rehabilitation practice for patients with Patellofemoral Pain Syndrome.

Dear colleague,

We are doing some research into the Patellofemoral Pain Syndrome and we are interested in finding out how you assess and treat your patients with PFPS. (Please see the attached information sheet for full details). We would be grateful if you would complete our questionnaire. You can do this simply by clicking the link below.

https://www.surveymonkey.com/s.aspx?sm=C1neDbvHr3kAT63FTq_2bX1w_3d_3d

If you wish to fill in a paper version print off the attached questionnaire, complete it and return it to Moyra Barnes, (address deleted to assure anonymity).

It should only take 15-20 minutes and will give you the chance to win £50 in High Street Vouchers after a draw.

We are planning to interview a selection of ten physiotherapists. There is a question relating to this in the questionnaire. This will enable us to explore questionnaire findings in more detail. The interviews will take 30 minutes and can be carried out at your place of work, at a time convenient for you.

The study has been approved by NWW NHS Trust Ethics Committee.

Thank you very much for reading this. We hope you will complete the questionnaire. It will help our understanding of PFPS as well as helping us plan our future research into the condition.

Good luck in the £50 draw.

Regards,

Kostas Papadopoulos, PhD student, Bangor University,

Moyra Barnes, Physiotherapist,

Dr Jeremy Jones, Consultant Rheumatologist, Senior Clinical Lecturer.

Appendix Four: Interview Topic Guide

Questions that were covered during the interviews

1) How do you diagnose PFPS?

2) What is the first thing you are checking on your PFPS patient during the first session?

3) What function tests do you mostly use to assess the syndrome?

4) Could you please perform them?

5) Do you think these tests are valid?

6) How long does each test need to be performed?

7) How often do you use the outcome measures mentioned in the questionnaire?

8) Which outcome measures do you mostly use?

9) How long does each outcome measure need to be performed?

10) Which is the most common cause of the syndrome?

11) Do you apply a specific treatment for each cause?

12) How would you approach these 3 cases?

13) What treatment do you usually use?

14) Could you please demonstrate some of the exercise programmes you use?

15) What home exercise programs do you ask your patient to follow for each cause of PFPS?

16) How many of your patients do you think they really perform the home exercise program?

17) When do you discharge a PFPS patient?

Appendix Five: The Anterior Knee Pain Questionnaire

Participant ID:

Session:

Anterior Knee Pain Questionnaire

Which knee is affected? Left Right Both

How long have you had the problem? …….Years …….. Months

For each question, circle the letter, which best corresponds to the problems you have with your knee.

1. Limp

   A. None (5)

   B. Slight/Occasional (3)

   C. Constant (0)

2. Taking weight on your leg

   A. Full weight on leg without pain (5)

   B. Painful on weight bearing (3)

   C. Unable to fully weight bear on leg (0)

3. Walking

   A. Unlimited (5)

B. More than one mile (3)

C. Between ½ to 1 mile (2)

D. Unable to walk any distance (0)

4. Stairs

A. No problems (10)

B. Slight pain going down (7)

C. Pain going up and down (3)

D. Unable to go up or down stairs without pain (0)

5 Squatting

A. No difficulty (5)

B. Repeated squatting is painful (4)

C. Painful each time (3)

D. Possible, but not taking full weight (2)

E. Unable to squat (0)

6. Running

A. No problems (10)

B. Pain after greater than 1 mile (8)

C. Slight pain from the start, but able to run (6)

D. Painful to run (3)

E. Unable to run (0)

7. Jumping

A. No difficulty (10)

B. Slight discomfort (7)

C. Constant pain (3)

D. Unable to jump (0)

8. Prolonged sitting with knee bent

A. No problems (10)

B. Pain/stiffness after exercises (8)

C. Constantly painful (6)

D. Pain forces you to regularly straighten knee (4)

E. Unable to sit with knee bent (0)

9. Pain

A. None (10)

B. Slight and occasional (8)

C. Interferes with sleep (6)

D. Occasionally severe (3)

E. Constant and severe (0)

10. Swelling

A. None (10)

B. After severe exertion (8)

C. After daily activities (6)

D. Every evening (4)

E. Constantly present (0)

11. Feeling of instability giving way in the knee cap.

A. None (10)

B. Occasionally with sporting or high load activities (6)

C. Occasionally in daily activities (4)

D. At least 1 dislocation of knee cap (2)

E. More than 1 dislocation (0)

12. Wasting of thigh muscles

A. None (5)

B. Noticeable compared to other leg (3)

C. Greatly reduced thigh muscle size compared to the other leg (0)

13. Loss of knee bend

A. None (5)

B. Slight at the end of movement (3)

C. Severe limitation of movement (0)

Score = /100

The reference for the questionnaire is Kujala, U. R., Jaakkola, L. H., Koskinen, S. K., Taimela, S., Hurme, M. and Nelimarkka, O. (1993). Scoring of Patellofemoral Disorders. Journal of Arthroscopy and Related Surgery, 9(2), 159-16

APPENDIX SIX: THE LOWER EXTREMITY FUNCTIONAL SCALE

"THE LOWER EXTREMITY FUNCTIONAL SCALE"

Name:____ Date:____________________

We are interested in knowing whether you are having any difficulty at all with the activities listed below because of your lower limb problem for which you are currently seeking attention. Please provide an answer for each activity.

Today, do you, or would you have any difficulty at all with:

	Activities	**Extreme Difficulty or Unable to Perform Activity**	**Quite a Bit of Difficulty**	**Moderate Difficulty**	**A Little Bit of Difficulty**	**No Difficulty**
1	Any of your usual work, housework or school activities	0	1	2	3	4
2	Your usual hobbies, recreational or sporting activities	0	1	2	3	4
3	Getting into or out of the bath	0	1	2	3	4
4	Walking between rooms	0	1	2	3	4
5	Putting on your shoes or socks	0	1	2	3	4
6	Squatting	0	1	2	3	4
7	Lifting an object, like a bag of groceries, from the floor	0	1	2	3	4

8	Performing light activities around your home	0	1	2	3	4
9	Performing heavy activities around your home	0	1	2	3	4
10	Getting into or out of a car	0	1	2	3	4
11	Walking 2 blocks	0	1	2	3	4
12	Walking a mile	0	1	2	3	4
13	Going up or down 10 stairs (about 1 flight of stairs)	0	1	2	3	4
14	Standing for 1 hour	0	1	2	3	4
15	Sitting for 1 hour	0	1	2	3	4
16	Running on even ground	0	1	2	3	4
17	Running on uneven ground	0	1	2	3	4
18	Making sharp turns while running fast	0	1	2	3	4
19	Hopping	0	1	2	3	4
20	Rolling over in bed	0	1	2	3	4
	Column Totals:					

Minimum Level of Detectable Change (90% Confidence): 9 points **SCORE: _______/80**

Reprinted from Brinkley, J.Stafford, P., Lott, S., Ridle, D., & The North American Orthopaedic Rehabilitation Research Network, The Lower Extremity Functional Scale: Scale development, measurement properties, and clinical application, Physical Therapy, 1999, 79, 4371-383, with permission of the American Physical Therapy Association

Signature:____

APPENDIX SEVEN: THE VISUAL ANALOGUE SCALE (VAS)

The Vas for Usual Pain is provided as an example. All VAS looked the same but measured different components

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Prifysgol Bangor
Adeilad y George
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Fton: (01248) 388256 Swyddfa Gyffredinol
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e-mail: shes@bangor.ac.uk
http://www.shes.bangor.ac.uk

Participant ID:
Session:

Date:

Usual pain

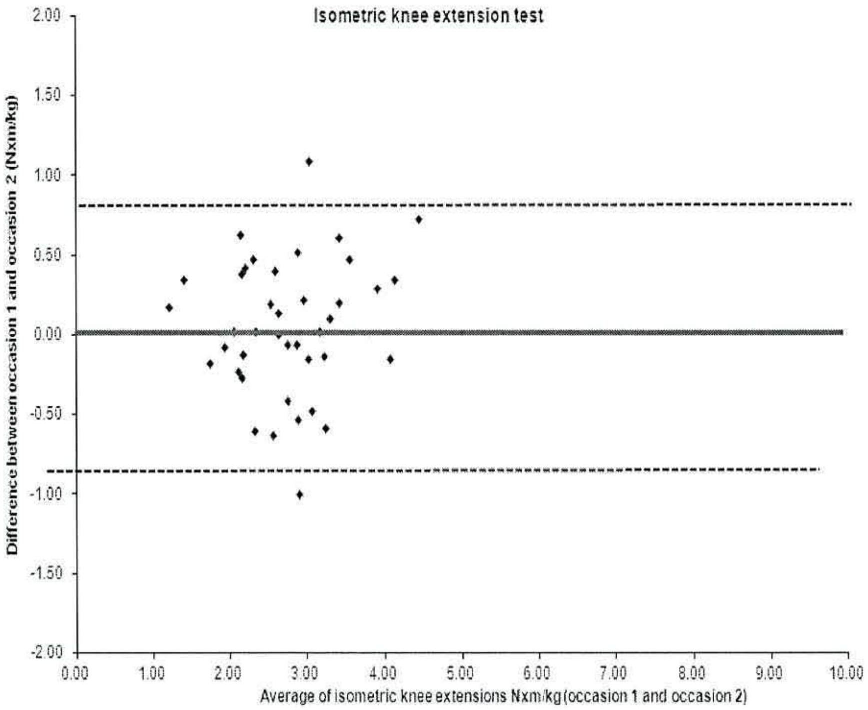
Visual Analogue Scale (VAS)

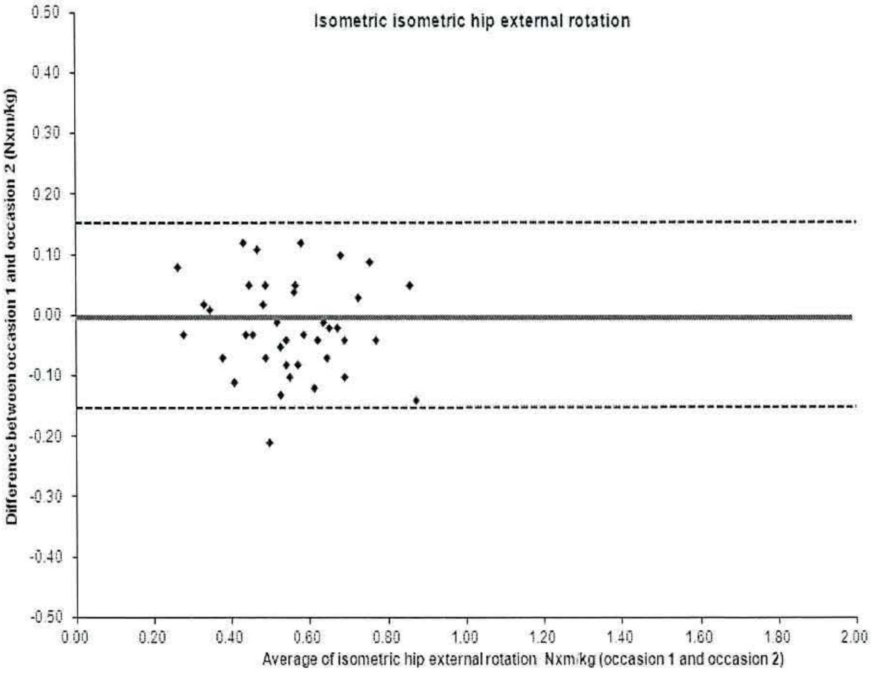
____

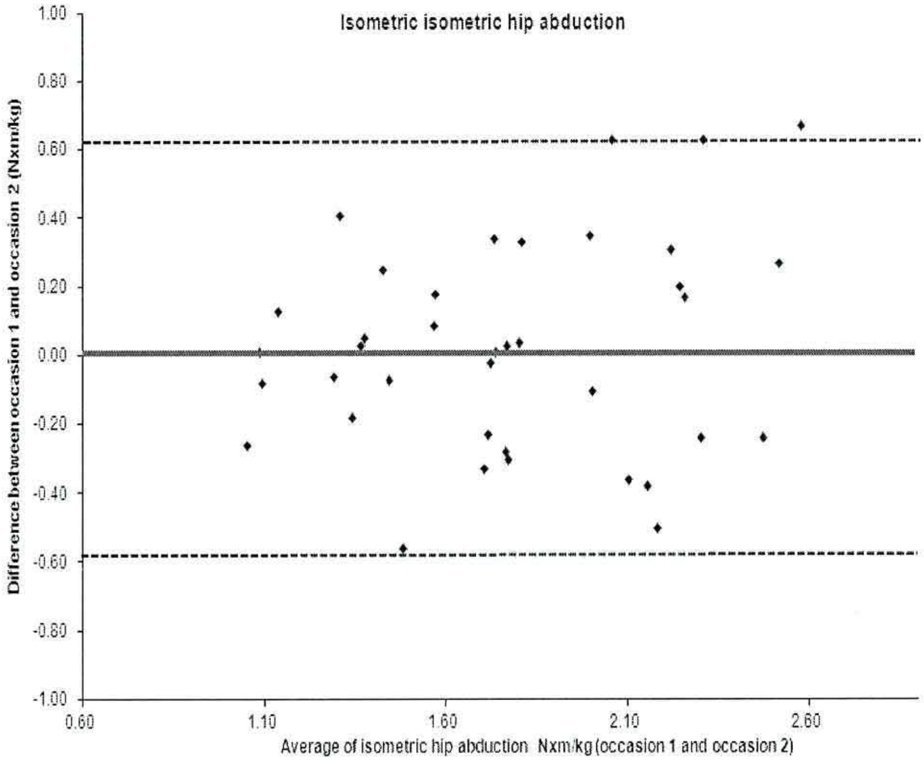
No pain — Pain as bad as it could possibly be

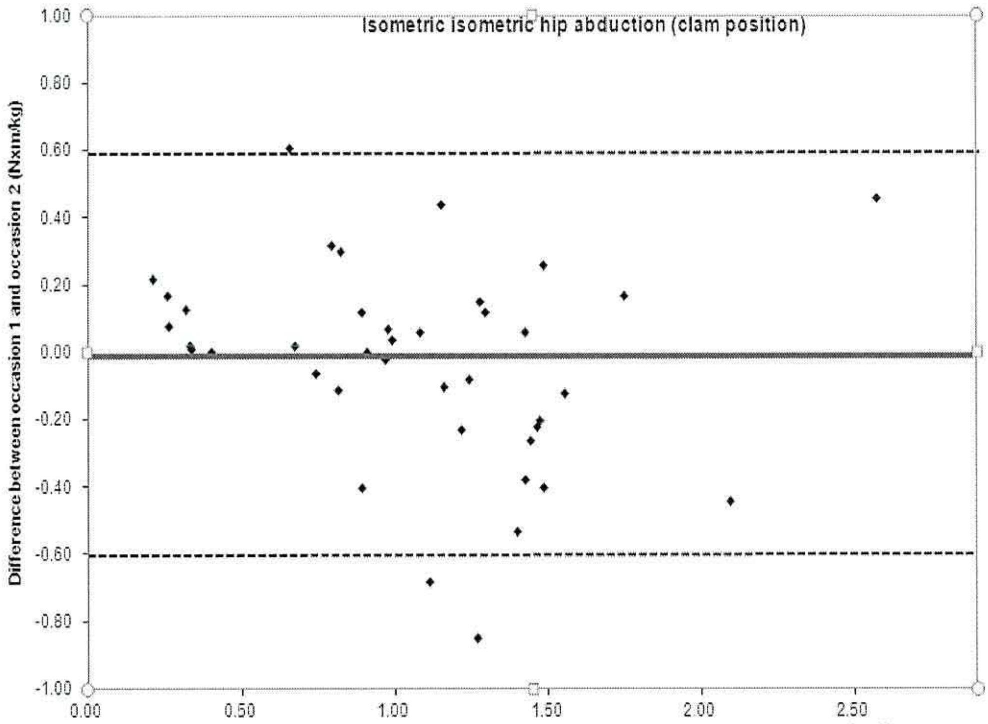
A 10-cm baseline is recommended for VAS scales. From Stratton Hill C. Guidelines for Treatment of Cancer Pain: The Revis Edition of the Final Report of the Texas Cancer Council's Workgroup on Pain Control in Cancer Patients, 2nd Edition; pages

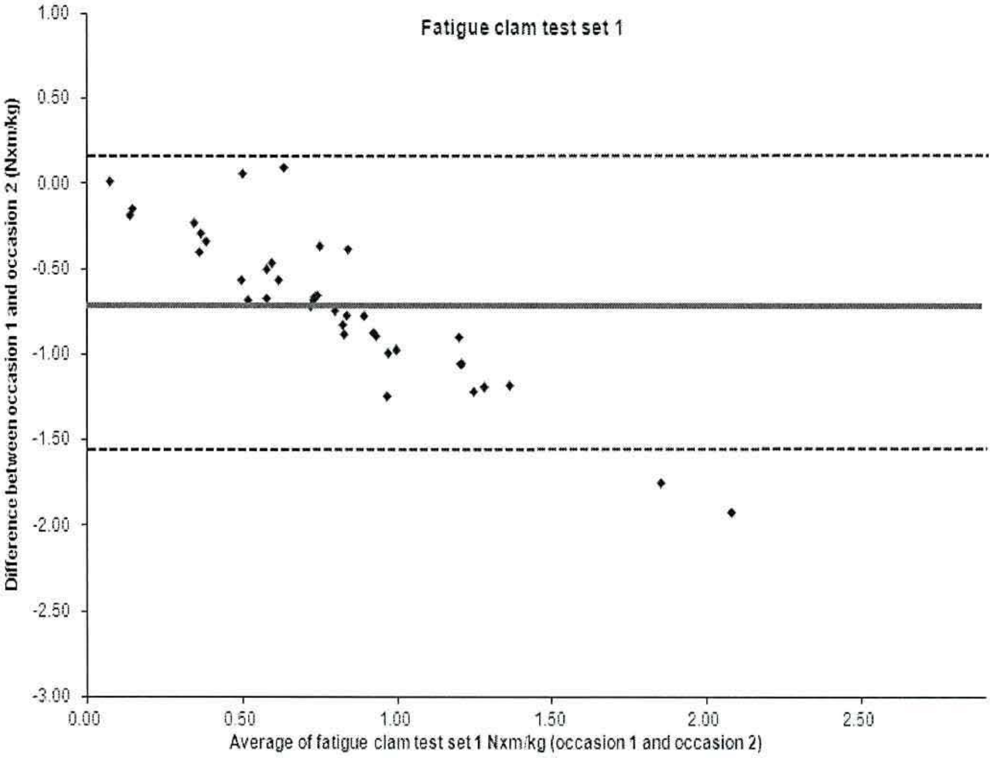
APPENDIX EIGHT: BLAND AND ALTMAN PLOTS TO SUPPORT RELIABILITY AND VALIDITY OF THE TESTS AND OUTCOME MEASURES.

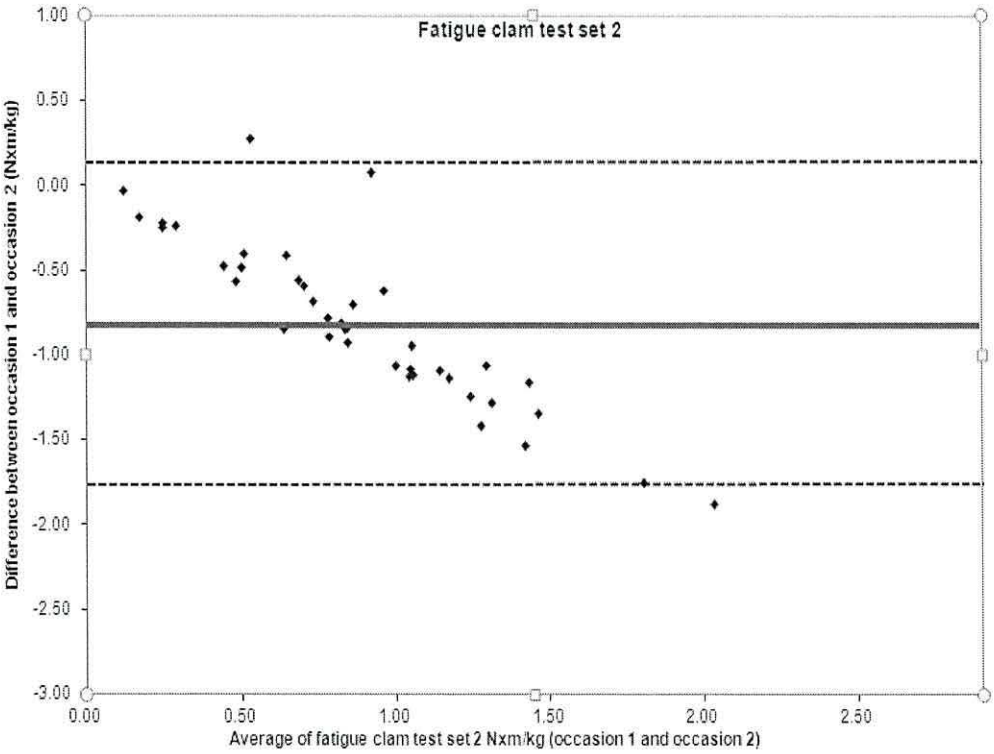


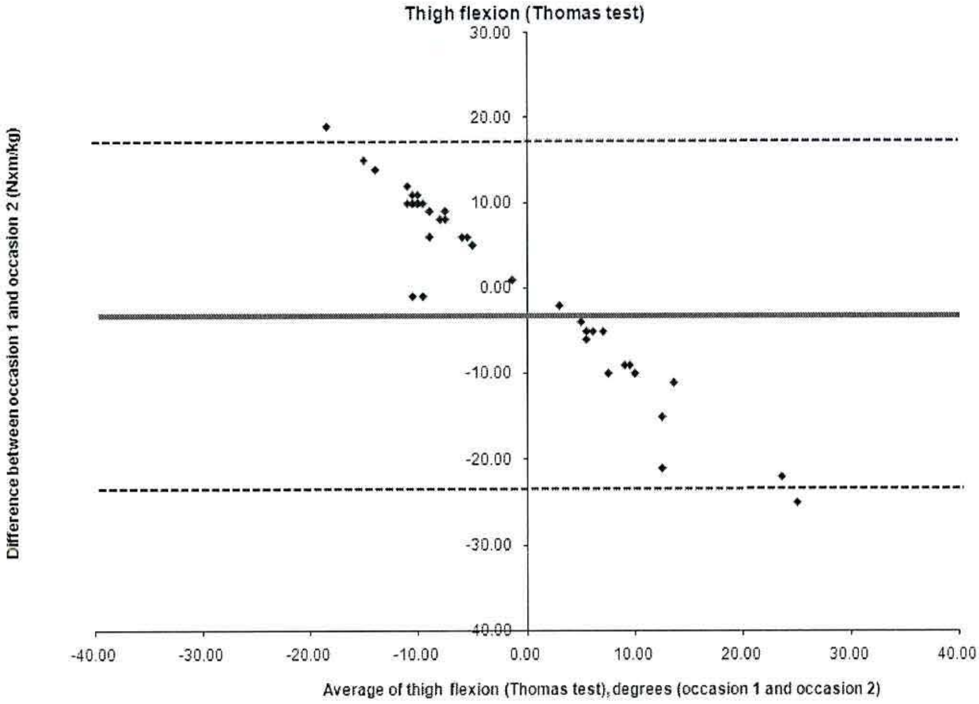


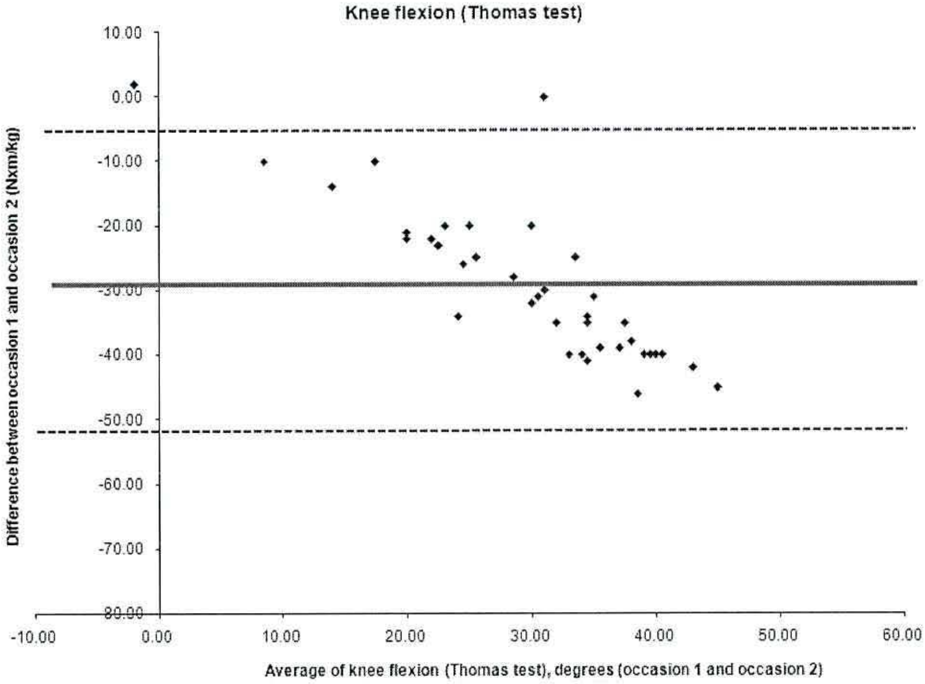

Isometric isometric hip abduction
Difference between occasion 1 and occasion 2 (Nxm/kg)
Average of isometric hip abduction Nxm/kg (occasion 1 and occasion 2)
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
0.60
1.10
1.60
2.10
2.60

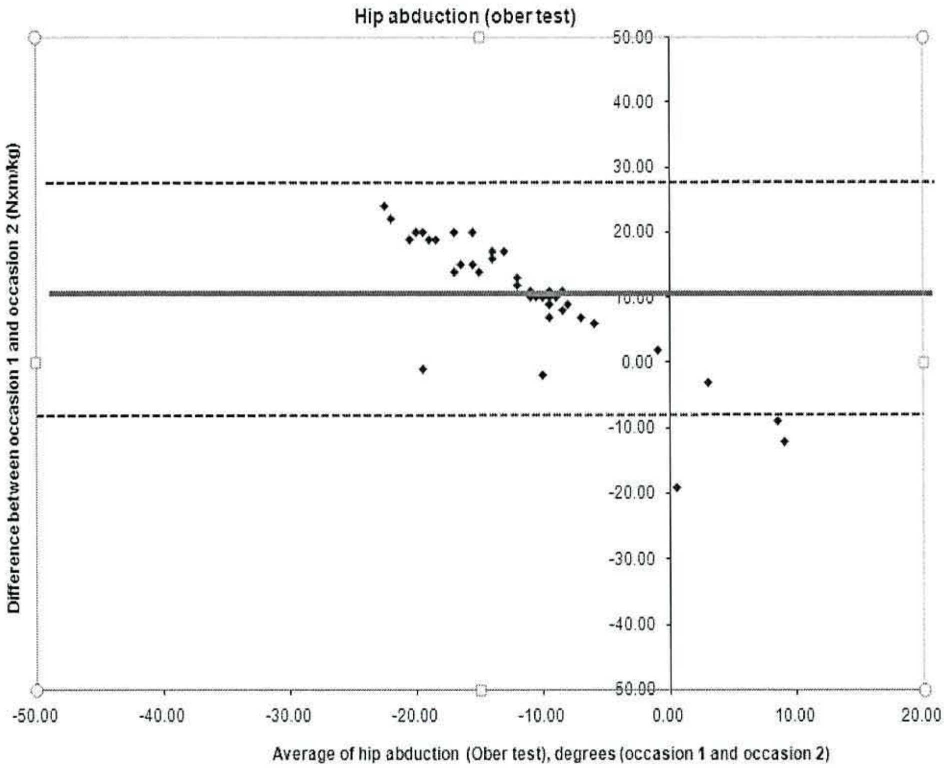

Isometric isometric hip abduction (clam position)
Difference between occasion 1 and occasion 2 (Nxm/kg)
Average of isometric hip abduction (clam position) Nxm/kg (occasion 1 and occasion 2)
1.00
0.80
0.60
0.40
0.20
0.00
-0.20
-0.40
-0.60
-0.80
-1.00
0.00
0.50
1.00
1.50
2.00
2.50


Fatigue clam test set 1
Difference between occasion 1 and occasion 2 (Nxm/kg)
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
0.00
0.50
1.00
1.50
2.00
2.50
Average of fatigue clam test set 1 Nxm/kg (occasion 1 and occasion 2)

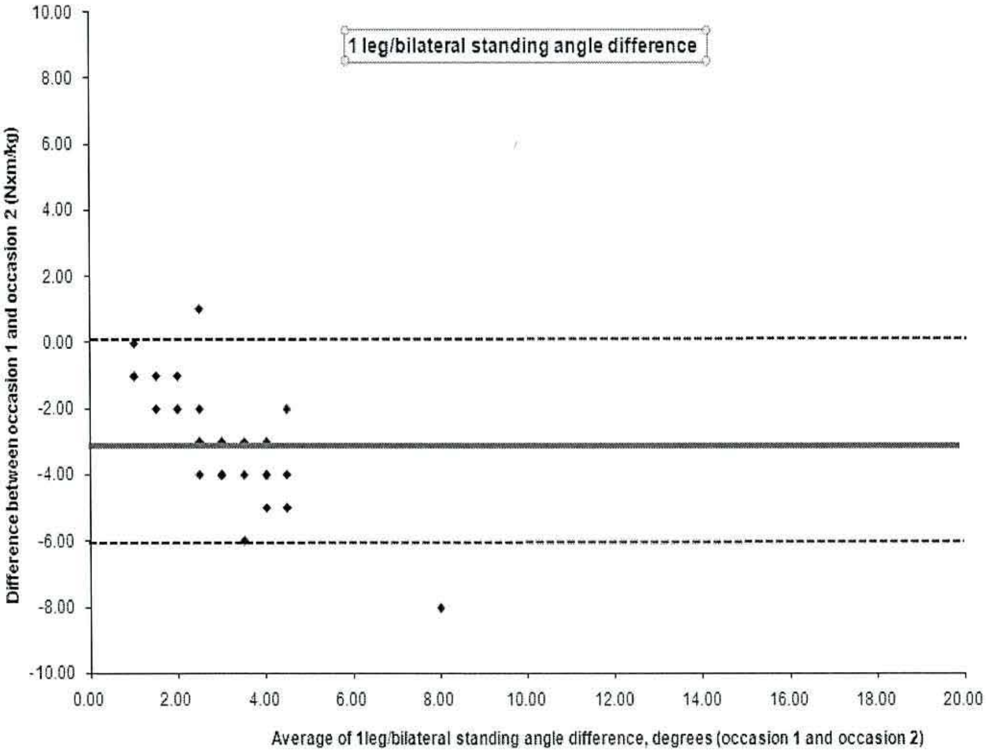

Fatigue clam test set 2
Difference between occasion 1 and occasion 2 (Nxm/kg)
1.00
0.50
0.00
-0.50
-1.00
-1.50
-2.00
-2.50
-3.00
0.00
0.50
1.00
1.50
2.00
2.50
Average of fatigue clam test set 2 Nxm/kg (occasion 1 and occasion 2)


Thigh flexion (Thomas test)
Difference between occasion 1 and occasion 2 (Nxm/kg)
30.00
20.00
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-40.00
-30.00
-20.00
-10.00
0.00
10.00
20.00
30.00
40.00
Average of thigh flexion (Thomas test), degrees (occasion 1 and occasion 2)

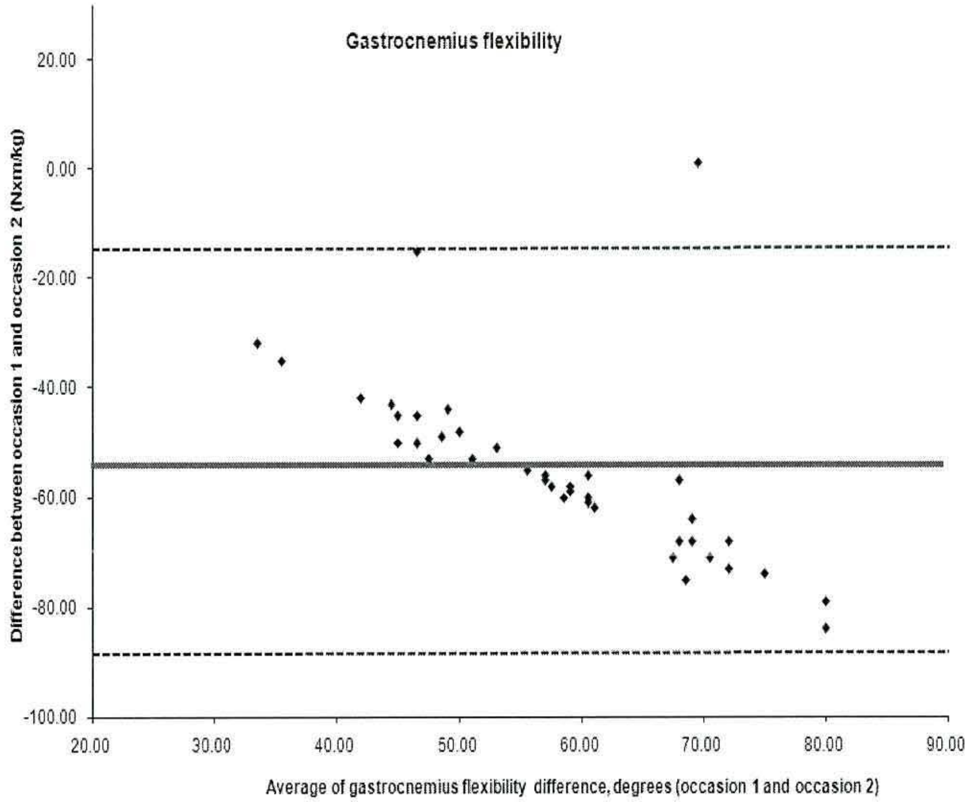

Knee flexion (Thomas test)
Difference between occasion 1 and occasion 2 (Nxm/kg)
10.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-60.00
-70.00
-80.00
-10.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
Average of knee flexion (Thomas test), degrees (occasion 1 and occasion 2)

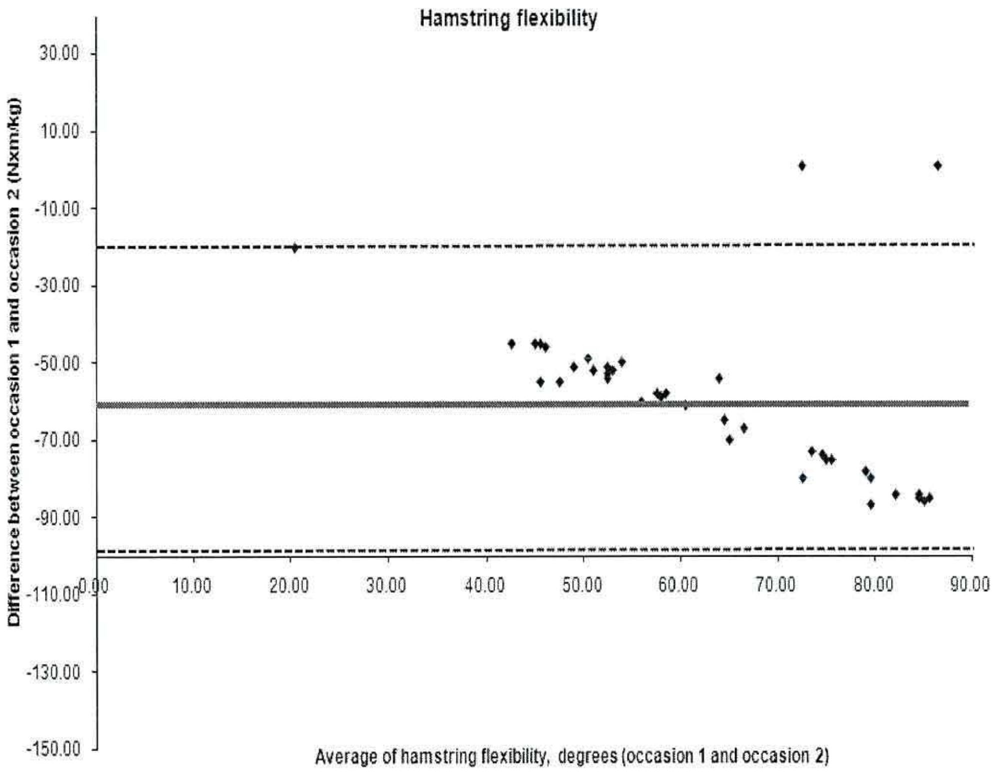


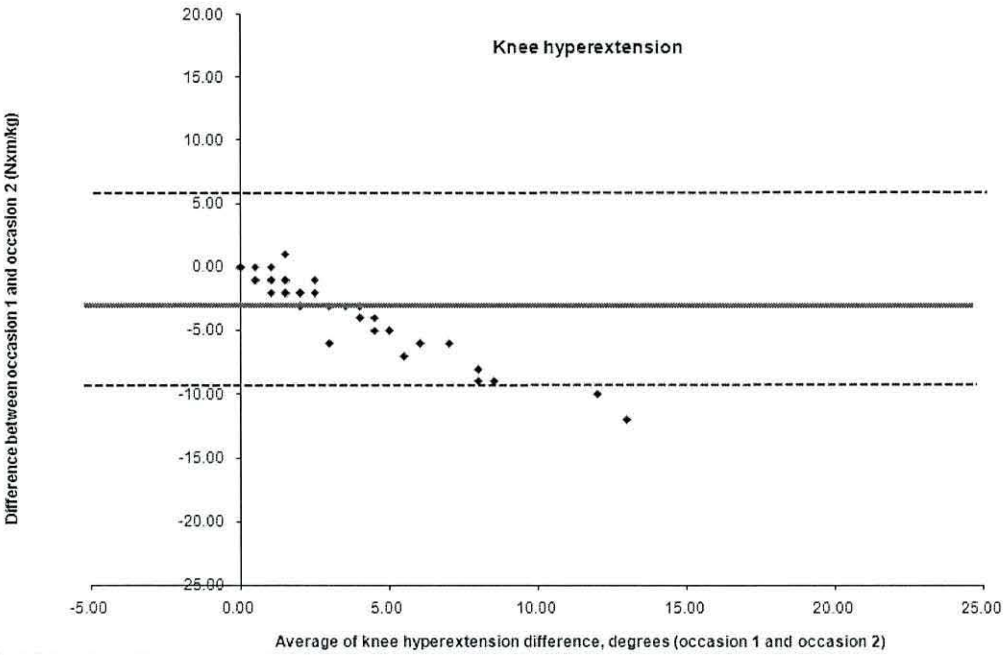
Hip abduction (ober test)
Difference between occasion 1 and occasion 2 (Nxm/kg)
50.00
40.00
30.00
20.00
0.00
-10.00
-20.00
-30.00
-40.00
-50.00
-50.00
-40.00
-30.00
-20.00
-10.00
0.00
10.00
20.00
Average of hip abduction (Ober test), degrees (occasion 1 and occasion 2)

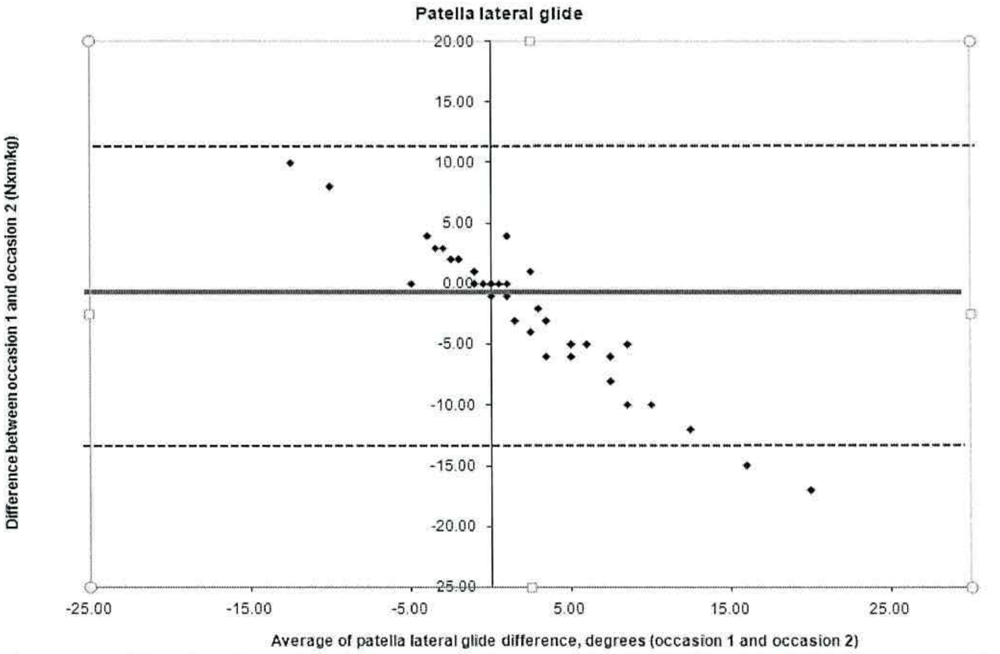


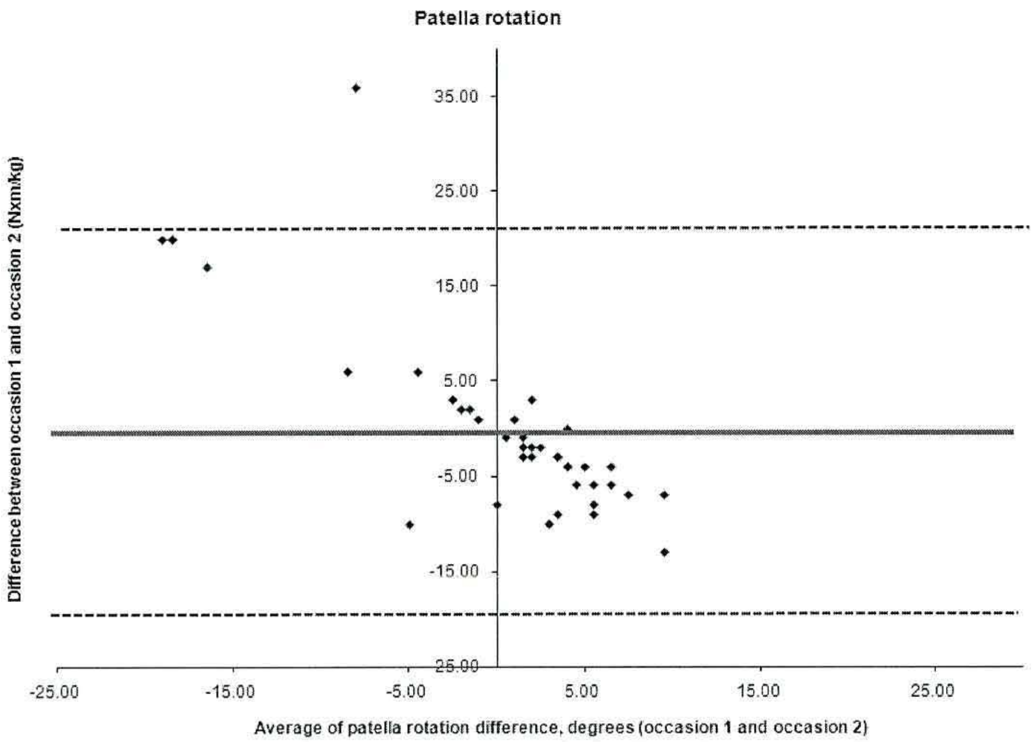
1 leg/bilateral standing angle difference
Difference between occasion 1 and occasion 2 (Nxm/kg)
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00
14.00
16.00
18.00
20.00
Average of 1leg/bilateral standing angle difference, degrees (occasion 1 and occasion 2)


Gastrocnemius flexibility
Difference between occasion 1 and occasion 2 (Nxm/kg)
Average of gastrocnemius flexibility difference, degrees (occasion 1 and occasion 2)
20.00
0.00
-20.00
-40.00
-60.00
-80.00
-100.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00

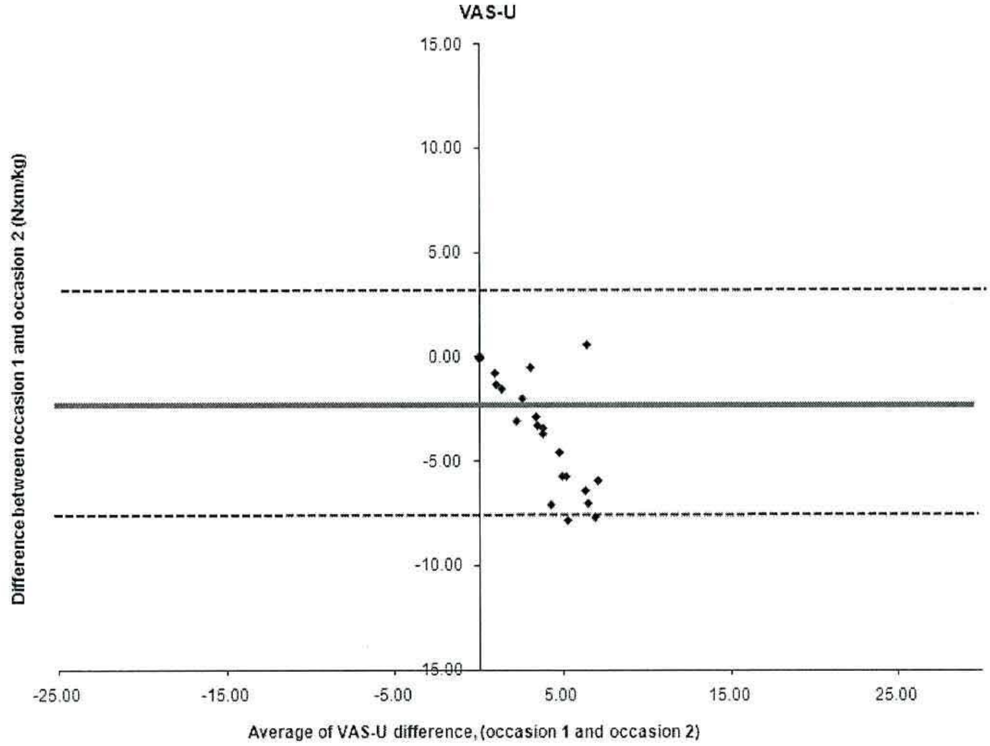

Hamstring flexibility
Difference between occasion 1 and occasion 2 (Nxm/kg)
Average of hamstring flexibility, degrees (occasion 1 and occasion 2)
30.00
10.00
-10.00
-30.00
-50.00
-70.00
-90.00
-110.00
-130.00
-150.00
0.00
10.00
20.00
30.00
40.00
50.00
60.00
70.00
80.00
90.00


Knee hyperextension
Difference between occasion 1 and occasion 2 (Nxm/kg)
Average of knee hyperextension difference, degrees (occasion 1 and occasion 2)

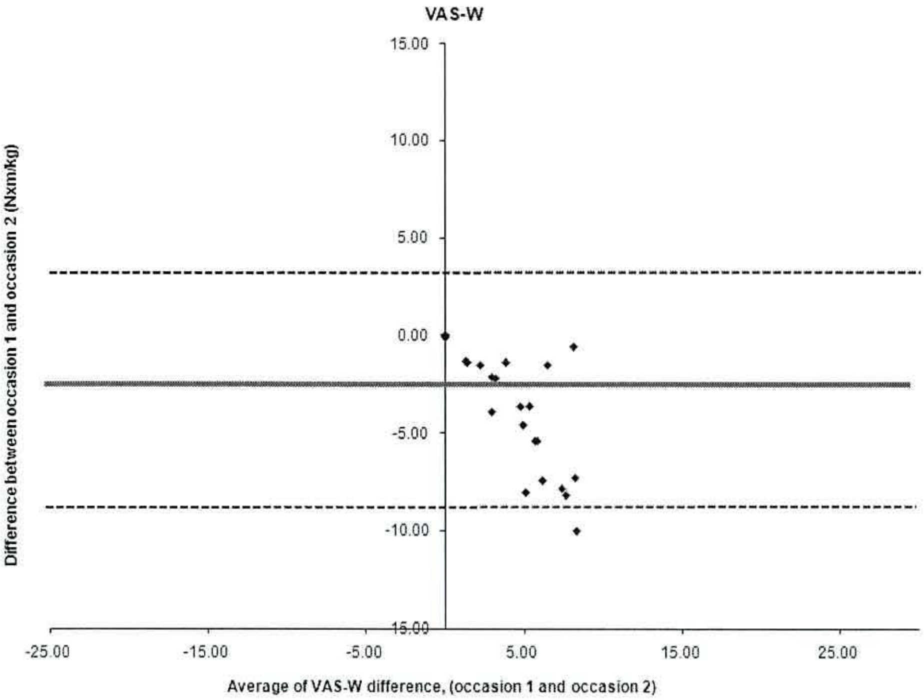

Patella lateral glide
Difference between occasion 1 and occasion 2 (Nxm/kg)
Average of patella lateral glide difference, degrees (occasion 1 and occasion 2)

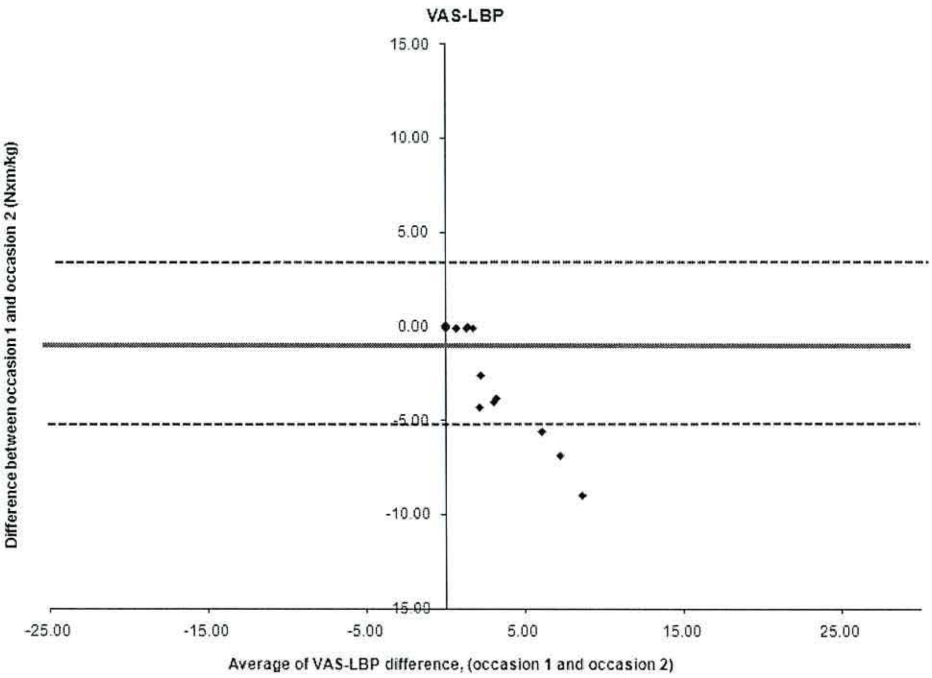


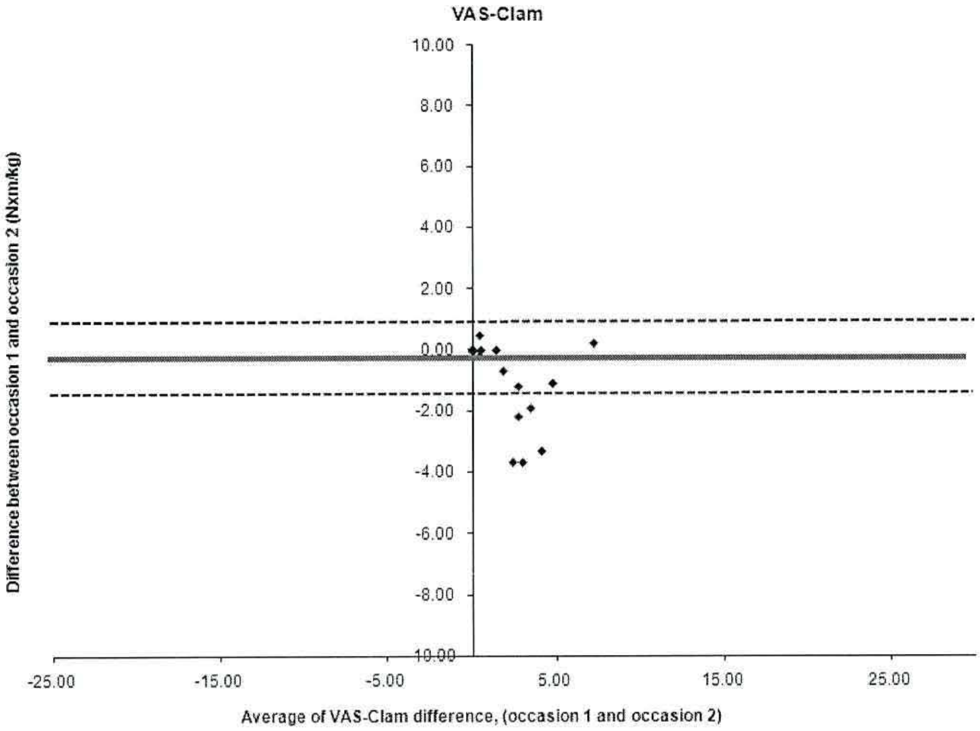
Patella rotation
35.00
25.00
15.00
5.00
-5.00
-15.00
-25.00
-25.00
-15.00
-5.00
5.00
15.00
25.00
Difference between occasion 1 and occasion 2 (Nxm/kg)
Average of patella rotation difference, degrees (occasion 1 and occasion 2)

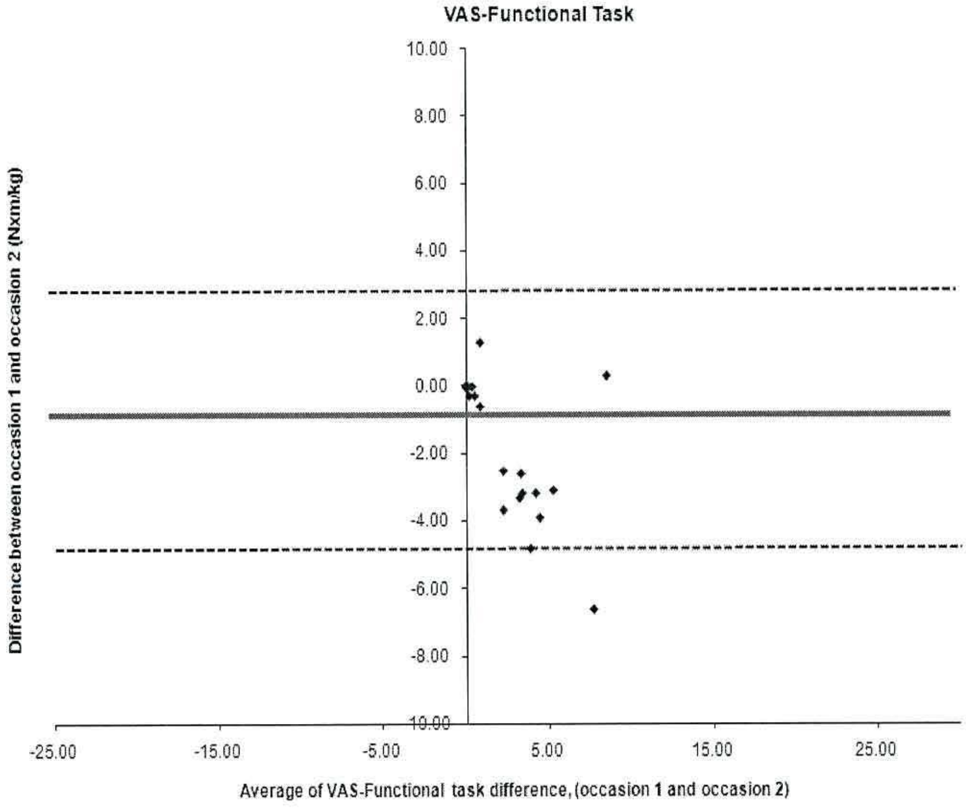


VAS-U
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-25.00
-15.00
-5.00
5.00
15.00
25.00
Difference between occasion 1 and occasion 2 (Nxm/kg)
Average of VAS-U difference, (occasion 1 and occasion 2)


VAS-W
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-25.00
-15.00
-5.00
5.00
15.00
25.00
Difference between occasion 1 and occasion 2 (Nxm/kg)
Average of VAS-W difference, (occasion 1 and occasion 2)


VAS-LBP
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
-25.00
-15.00
-5.00
5.00
15.00
25.00
Difference between occasion 1 and occasion 2 (Nxm/kg)
Average of VAS-LBP difference, (occasion 1 and occasion 2)


VAS-Clam
Difference between occasion 1 and occasion 2 (Nxm/kg)
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
-25.00
-15.00
-5.00
5.00
15.00
25.00
Average of VAS-Clam difference, (occasion 1 and occasion 2)


VAS-Functional Task
Difference between occasion 1 and occasion 2 (Nxm/kg)
10.00
8.00
6.00
4.00
2.00
0.00
-2.00
-4.00
-6.00
-8.00
-10.00
-25.00
-15.00
-5.00
5.00
15.00
25.00
Average of VAS-Functional task difference, (occasion 1 and occasion 2)

APPENDIX NINE: A STUDY TO IDENTIFY THE REPRODUCIBILITY OF STRENGTH TESTS USING A PORTABLE DYNAMOMETER. MEASUREMENT COMPARISONS WITH A NON-PORTABLE DYNAMOMETER.

INTRODUCTION

Chapter 5 of this thesis reported a series of assessment tests to be reliable, valid and able to differentiate PFPS people from healthy controls. In order to check whether the same tests can also differentiate PFPS patients from patients with other lower limb conditions, there was a need to transfer those tests from the physiology lab to the physiotherapy clinic. Additionally, since NWW physiotherapists reported in Chapter 4 that they use muscle strengthening to treat PFPS patients, it was important to investigate the muscle strength output that physiotherapy treatment had. The technical difficulties (inability to transfer to the clinic) did not allow the use of the same equipment (Humac Norm Testing and Rehabilitation System) in order to assess muscle strength. For this reason, the involvement of new portable equipment was necessary [ADInstruments (Pty Ltd Unit 6)]. The backtracking search of the systematic review of reviews (Chapter 3) revealed 43 primary studies which used dynamometers for strength assessment. However, only 14 studies used hand-held dynamometers, probably because most of the studies took place in physiology labs where isokinetic dynamometers are available. Additionally, the reliability and validity of the hand-held dynamometers were not reported in those studies.

Further research, revealed a number of reasons which discouraged the use of hand-held dynamometers in the assessment of the lower limb muscles. These were their low reliability when used on the lower limb (Agre et al., 1987), the absence of comparisons with other gold standard dynamometers and the question about the number of trials needed to decrease the systematic bias (Stockton et al., 2011). A recent study reports high reliability (ICCs = 0.83-0.92) when testing different groups of the lower limb (Lu et al., 2011) however, they reveal low reliability for knee extensors (ICC = 0.60). The reason is the one mentioned in the literature review (Chapter 3). Knee extensors can produce intense contractions and their inter-rater reliability in MVCs depends on the examiner. For the above reasons a new method to assess muscle strength was designed using a load cell and two chains attached from both sides to assess lower limb muscle strenth. Because this innovative way of assessing muscle strength had not been used in other studies, the reproducibility and validity of the new portable dynamometer in particular tasks had first to be ascertained.

Aims

The aim of this study was to investigate whether a portable dynamometer (load cell plus Power lab© software) could be used as a reliable way of measuring lower limb strength. Thus it was decided that reliability (test re-test, intra-rater), and reproducibility of the portable dynamometer would be assessed along with the validity when the portable dynamometer was compared with (a gold standard) non-portable dynamometer Humac Norm© (criterion validity) in four isometric lower limb tests.

METHODOLOGY

Twenty individuals (9 males and 11 females) different from those described in previous chapters were asked to participate in this study. All participants were healthy people with no lower limb conditions and were students or staff of Bangor University. They were asked to visit the physiology laboratories of the School of Sport, Health and Exercise Sciences on two occasions. The second session was at least a week after the first session. During the first session, participants performed strength tests using their dominant leg measured by the portable dynamometer and later they performed the same tests measured by the non-portable Humac Norm©. In the second session they performed strength tests measured by the portable dynamometer only.

The study was approved by the School of Sport, Health & Exercise Sciences ethics committee of Bangor University.

Before testing took place, both portable and non-portable dynamometers were calibrated. In order to maintain data integrity technicians from the School of Sports, Health and Exercise Sciences calibrated the Humac Norm© according to the manual of the isokinetic dynamometer. Same technicians also calibrated the load cell of the portable dynamometer. A 5 kilogram free hand weight was attached to the load cell with a chain and the load cell was then set to show 5 kilogram push force.

There was a familiarization session a day before the first trial where participants were told what they had to perform the next day. In addition, they performed a series of MVCs of all the strength tests on both isokinetic and portable dynamometer.

-The portable dynamometer (ADInstuments PowerLab/16SP©, Australia) was attached to ADInstuments Bridge Amp FE221 and the latter was then attached to an ©RS load cell, model 615 (©RS Components Ltd, UK). Two metal chains were connected from both sides of the load cell. One chain was stabilised to the bars that the physiotherapy couch had underneath, and the other chain was attached to the load cell ended in a loop shape. This loop was covered by soft material (pipe insulation material). Participants were asked to put their leg into the loop and push away. The leg tested was the one that participants considered as their 'strong' one. The direction participants had to push was always vertical to the load cell. Participants put their leg into the loop and the examiner passively stretched the chain to its end. Then the examiner set all measurements to zero. This had to be done before every single trial.

Performing this, the examiner achieved to exclude the confounding factor of the chain weight or chain noise. There was no force caused by the examiner because when the participants were asked to push, the examiner got his hands off the chain. All participants were measured in the morning and both measurements were done at the same time of the day. Participants were asked whether they performed any exercises the day before and whether they felt weak or had any residual pain at the day of the examination. Participants who did not comply with those requirements were excluded from the study.

During the trials, participants had no visual feedback as the monitors were out of their sight. Before they performed the tests the investigator provided them with clear instructions regarding how long they had to push for, in what direction and how hard. The only verbal instruction participants received by the investigator was the word 'go' just at the time they had to perform the strength tests.

The four isometric tests participants were asked to perform were the same tests described in Chapter 5. Same positions were used whilst the angles of their tested were measured by a goniometer. The tests performed in the portable dynamometer are described below:

Test 1)

Isometric knee extension from sitting position with the knee extended to 60° from leg extension (Welsh et al., 1998). Participants were placed in a sitting position on the physiotherapy couch with their knees off the edge of the bed. A soft cylinder shaped material was placed under their knees, so that there was no pain during the contractions. Seven trials were performed on each participant. The first three were a warm up of approximately 25, 50 and 75 percent of the participant's maximum strength activity, whilst, the last 4 were 100% o MVC. Participants placed their hands behind their back to hold the end of couch. The loop with the force transducer was placed around the distal tibia, just above the ankle.

Test 2)

Isometric hip abduction with the tested knee extended and the hip abducted to 30° (Distefano et al., 2009). Participants were lying on the side with the tested hip on the top. Trunk, pelvis and the top lower limb were in alignment, whilst the other leg was flexed to support participant stability during contractions. The loop was then placed around the distal portion of the top of the thigh, just above the knee. The same warm up was conducted as with the previous test and 4 MVCs were then performed.

Test 3)

Isometric hip abduction ('clam' position) with hips flexed to 60° and knees to 90° and the hip abducted to 30° (Distefano et al., 2009). Participants from side lying position performed 7 isometric contractions (3 warm ups and 4 MVSs) with the tested leg on the top. The researcher stabilised the pelvis in order to inhibit any backwards movement. The loop was placed in the same position as in the previous test.

Test 4)

Isometric hip external rotation with the tested leg fully extended and rotated to 5° from supine position. Participants were placed in supine position with the heel of the tested leg in a hole provided by the physiotherapy couch (Lancaster, 2007; Jacobs et al., 2007; Ireland et al., 2003). The chain was attached tight around the training shoe whilst, the pelvis and the tested leg thigh was strapped to the couch to inhibit any movement or flexion. When participants rotated their hip to 5° the chain was tight. Warm up and 4 MVSs were then performed.

All angles were measured with a goniometer (Absolute Axis, Baseline, New York, USA). Between contractions there was 1 minute rest. Figure 26a and 26b show the position participants had to take in both portable and non-portable dynamometers for the above four tests.

Figure 26a. Isometric torque testing position comparisons of knee extension and hip abduction between portable and non-portable dynamometers.

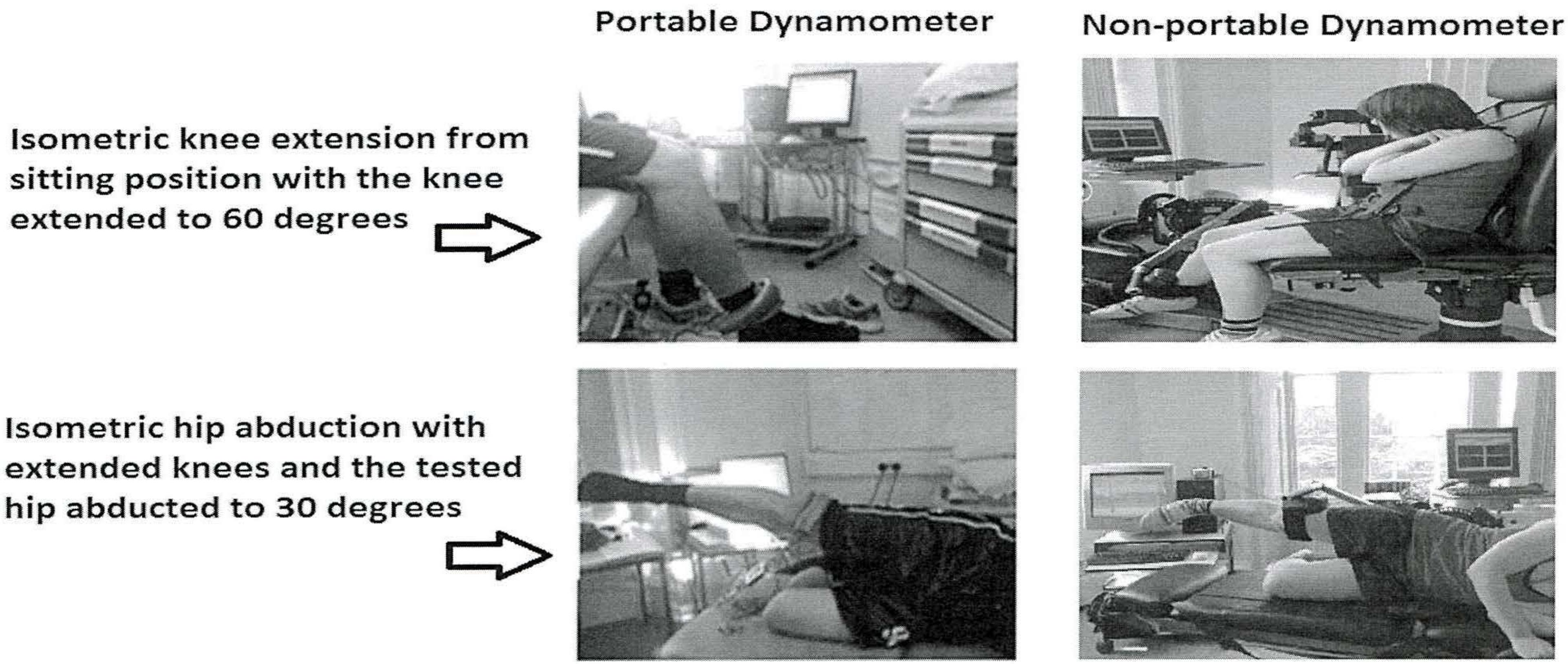
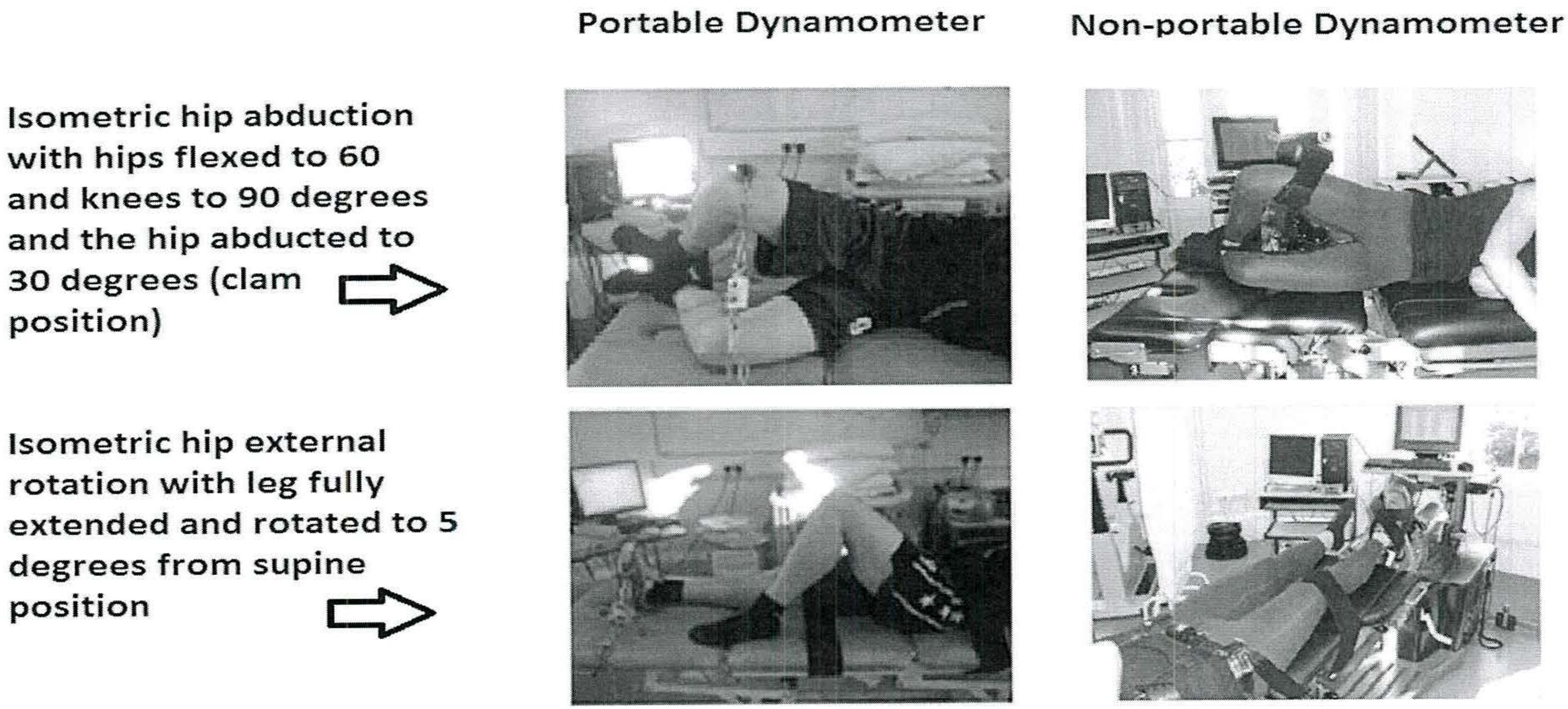


Figure 26b. Isometric torque testing position comparisons of the clam and hip external rotation between portable and non-portable dynamometers.



Statistical analysis

Independent t-Tests were conducted between contractions measured by the portable and non-portable dynamometers to identify any differences between participants' performance. To measure the ability of the portable dynamometer to report similar results under the same conditions, intra-class correlations coefficient (ICC) was conducted between the results of the first and second session to test reliability. Finally, to assess criterion validity of the new dynamometer, 4 Bland and Altman plots were created to show correlation of performance with the non-portable dynamometer.

The Bland and Altman plot is a statistical method for assessing agreement between measurements (Bland and Altman, 1987). The measurements can be plotted against one of the two methods (Krouwer, 2008) (gold standard method); in this case the non-portable (Humac Norm©) isokinetic dynamometer results. Each plot is comprised of an x axis which reports the average MVCs measured by the two dynamometers and a y axis which shows the differences between the MVCs. Each plot has 3 lines; one for mean (red middle line), and two discontinuous lines which are defined as the mean difference plus and minus 1.96 times the standard deviation (± 95% limits of agreement) (see Results: Figures 27-30).

Measurements gained from the non-portable dynamometer were reported automatically in N/m (Newtons/meter) whereas; measurements from the portable dynamometer were in N (Newtons). Therefore, the distance between the joint which produced the force and the position of the loop of the lower limp was measured for all tests in order to convert measurements to N/m (torque).

RESULTS

Twenty healthy controls took part in this study (11 females and 9 males). Their age was 22.60 ± 3 years, height 1.72 ± 0.11 m and weight 73.78 ± 13.18 kg. There was no differences ($p<0.05$) between the performances of any of the strength tests measured by the two dynamometers. Table 19 presents the lower and upper bound, T values, means ± SDs and p values for both dynamometers in the tests measured.

Outcome measures	Lower bound	Upper bound	T	Mean ± SD PD	Mean ± SD ND	t-Test (p Value)
Knee extension	-13.90	1.61	1.65	227±78	220±75	0.80
Hip external rotation	-3.16	4.16	0.29	44.70±12	44.30±14	0.90
Hip abduction	-1.47	11.82	1.62	139±50	145±49	0.68
Hip abduction ('clam' test position)	-2.92	9.43	1.10	127±50	129±51	0.99

Table 19. Independent t-Tests between the portable (PD) and non-portable (ND) dynamometer.

Outcome measures show the mean maximal isometric torque for each test; values are expressed in Nm; $p\leq0.05$

Reliability analysis revealed strong ICC (above 0.9) (Table 20) whilst the correlation between the new portable method and the non-portable isokinetic dynamometer showed strong correlations for all four strength tests (Table 21); therefore, strong reliability and validity of the portable dynamometer was determined. Table 22 reports the confidence interval, mean bias, Standard Error (SE) of differences, whilst, one Bland and Altman plot for each test was created showing the comparison of the two techniques (Figures 27-30).

Outcome measures	Mean ± SD session 1	Mean± SD session 2	Lower bound	Upper bound	F value	ICC	Significance
Knee extension	227.00 ± 78.67	221.95 ±80.94	0.96	0.99	71.08	0.99	<0.00
Hip ext. rotation	44.75 ± 11.65	43.65± 10.43	0.93	0.99	35.35	0.97	<0.00
Hip abduction	139.33 ± 50.84	136.53 ±42.61	0.84	0.97	15.343	0.94	<0.00
Hip abduction ('clam' test position)	128.49 ± 50.91	121.28 ±50.69	0.87	0.98	19.03	0.95	<0.00

Table 20. Reliability measurements for the maximal isometric torque outcome measures tested with the portable dynamometer on two occasions.

p≤0.05, ICC= Intraclass

Correlation Coefficient. Mean ± SD values are expressed in Nm

Outcome measures	Mean ± SD PD	Mean± SD ND	Lower bound	Upper bound	F value	ICC	Significance
Knee extension	227.00 ± 78.67	220.85 ±75.72	0.97	0.99	85.55	0.99	<0.00
Hip external rotation	44.75 ± 11.65	44.25 ±14.31	0.75	0.96	10.12	0.90	<0.00
Hip abduction	139.33 ± 50.84	144.50 ±49.29	0.95	0.99	48.82	0.98	<0.00
Hip abduction ('clam' test position)	128.49 ± 50.91	131.75 ±54.27	0.96	0.99	63.08	0.98	<0.00

Table 21. Validity assessment of the portable dynamometer.

$p \leq 0.05$, ICC= Intraclass Correlation Coefficient; PD= Portable dynamometer; ND= Non-portable dynamometer

Outcome measures	Bias +/- 95% LoA is -.75 +/- (1.96x STD of difference) confidence interval	Mean Bias	SE of differences
Knee extension	±32.63	6.15	16.65
Hip external rotation	±15.34	0.50	7.83
Hip abduction	±28.04	-5.15	14.31
Hip abduction ('clam' test position)	±25.89	-3.26	13.21

Table 22. Characteristics found using the Bland and Altman plot when the measurements of the two dynamometers were compared.

Figure 27. Bland and Altman plot to assess validity of the portable dynamometer in isometric knee extension position

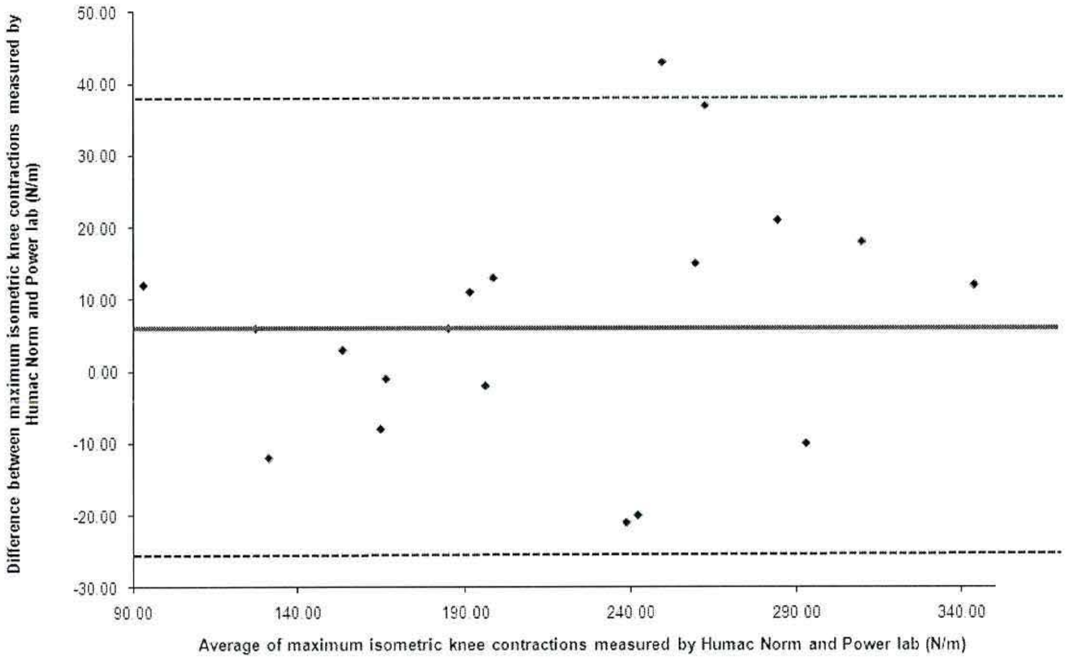


Figure 28. Bland and Altman plot to assess validity of the portable dynamometer in isometric hip external position

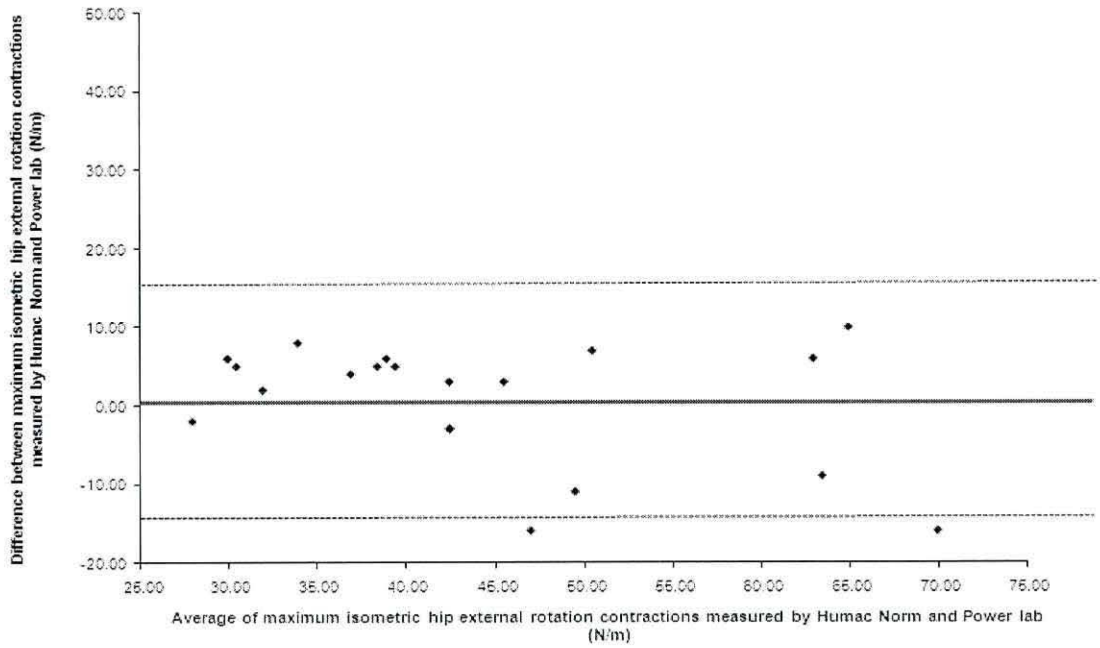


Figure 29. Bland and Altman plot to assess validity of the portable dynamometer in isometric hip abduction position

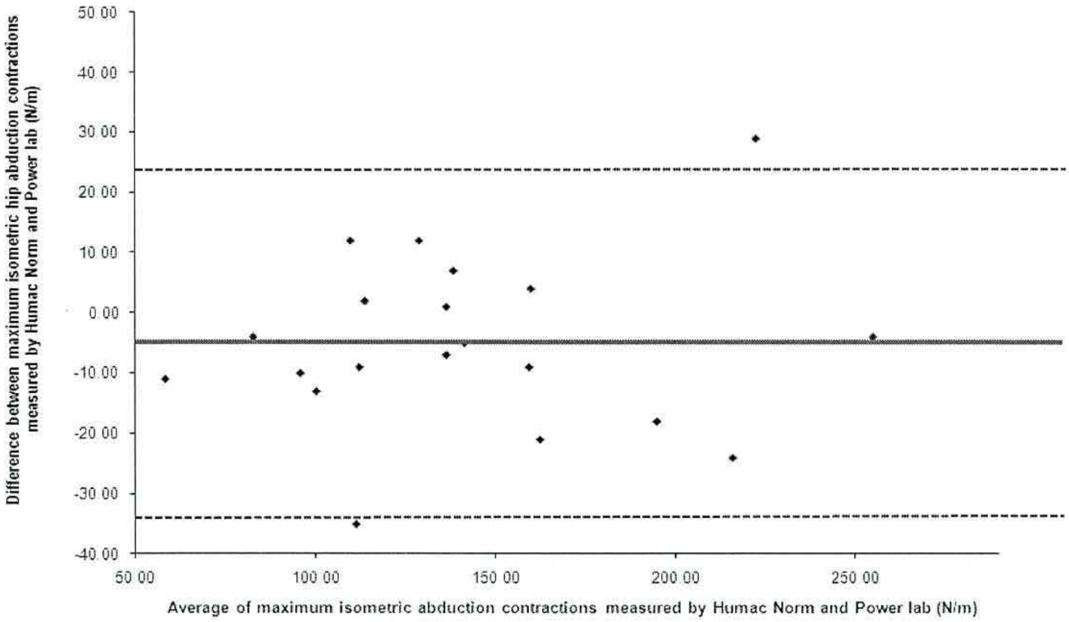
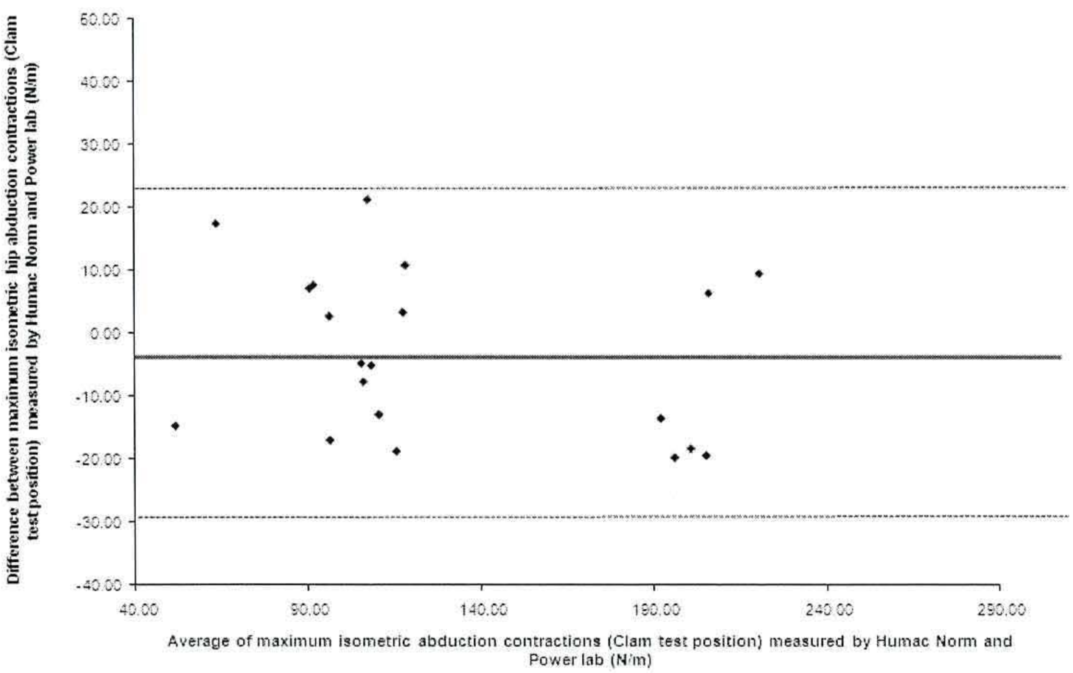


Figure 30. Bland and Altman plot to assess validity of the portable dynamometer in isometric hip abduction position ('clam' position)



DISCUSSION/IMPLICATIONS

Previous literature review did not show similar ways of measuring muscle strength in a clinical environment. Therefore, the assessment of the portable dynamometer regarding its reliability and validity was crucial but also innovative. Only a few studies on hand-held dynamometers were found in the literature to have assessed the reliability of handheld dynamometers and most of them have not been tested on PFPS patients. Hand-held dynamometers need the examiner to keep hands steady regardless of the force. This is extremely difficult especially when the participants produce high MVCs. This is probably why previous research showed that portable dynamometers revealed low reliability when testing the lower limb (Agre et al., 1987). In addition, Bohannon (1986) reported that a hand-held dynamometer is a reliable procedure but needs to be used by a clinician who is experienced with the technique. On the other hand, the use of the current portable dynamometer technique did not need any experience and enabled more precise measurements than a common hand-held device. Interestingly, results of the current study have shown that the portable method was reliable and valid enough to measure isometric muscle strength from four positions. Although the Bland and Altman plots showed scattered measurements, we cannot be secure about our results since there were measurements beyond the lines of agreement. The advantage of the portable dynamometer was that the measurements do not depend on the researcher. The disadvantage of this method was the time needed in order to set up the equipment for each test but also the increased bias that was found from the Bland and Altman plots. Although the validity of this method was assessed by comparing the results with a non-portable gold standard dynamometer (as Stockton et al. (2011) suggested) the number of trials that took place were not enough to decrease the bias. This study suggests additional trials to be performed in the future.

Limitations

A limitation of this study was the number of trials that took place in order for reliability and validity to be assessed. More trials would have perhaps provided clearer data, as any learning effect, if any, would then be excluded. In addition, only criterion validity was measured since the new portable way of assessing muscle strength was compared with the reliable and valid non-portable dynamometer. Content validity was not measured since no all important aspects of the construct were covered.

CONCLUSIONS

As the portable system was found to be reliable and valid to measure strength from all the required strength test positions, the next step of this thesis enrols the use of the portable dynamometer in the physiotherapy clinic to identify whether the above strength tests are able to differentiate PFPS patients from patients with other lower limb conditions (Chapter 5). In addition, by measuring the strength performance of PFPS patients before and after their physiotherapy treatment, it would be investigated whether a six-week physiotherapy treatment actually does strengthen the patients' muscle groups, as physiotherapists proposed that they do in the questionnaire section of Chapter 4.

APPENDIX TEN: THE MODIFIED ANTERIOR KNEE PAIN SCALE

The modified AKPS

The results of Chapter 6 and previous literature, question the full applicability of the LEFS and AKPS in patients with PFPS. These observations prompted the researcher to design a modified AKPS (MAKPS). Creating a clinical measure is a difficult and complex task. There are many steps before a questionnaire can be used clinically (Presser, et al., 2004). This questionnaire has not been validated yet; however it was decided to be used along with the AKPS and the LEFS in Chapter 7 in order to detect the physiotherapy effect of a district NHS hospital. The MAKPS is an example of what a PFPS questionnaire would look like according to the literature critics and the results of the current study. The MAKPS contains four initial questions regarding which knee is affected and how long the patients have experienced the pain (questions that are also included in the AKPS). Additionally, there are two questions about the type of the pain (on/off) and whether patients experienced any pain on the day of the assessment. PFPS usually presents with intermittent rather than continuous pain (Thomee et al., 1999) and it is very important for the clinician to know whether the patient is in pain on the day of the assessment. As neither AKPS nor LEFS set the time scale of the pain according to which questions need to be answered, the 11 questions of the MAKPS were designed to be answered to explore the pain patients experienced over the previous 7 days. The AKPS includes the pain factor in many of the 13 questions. This makes it less function-oriented and as pain is not constant in PFPS, this is probably why some of the questions were found to be less reliable. The MAKPS items do not include any questions about pain. The MAKPS has adopted the scoring method of the LEFS. The original AKPS contained different number of questions with different grades for each question with no justification as to why. The MAKPS now includes four columns across all the questions (0=no difficulty, 1=a little bit of difficulty

2=moderate difficulty, 3=quite a bit of difficulty, 4=extreme difficulty). As mentioned in the previous paragraph all people do not actually perform all the activities listed, therefore, a fifth column was available for all the questions which were not applicable to the patients.

In an attempt to rule out all the less meaningful and reliable questions (Watson et al., 2005), questions which required self-assessment such as 'wasting of thigh muscles', 'loss of knee bend' and 'swelling' were excluded. On the other hand a question regarding kneeling which has been suggested by Paxton et al. (2003) and is one of the activities that aggravates the syndrome was added.

Finally, two VASs for usual pain and for pain on the day of the assessment were also included in order to provide clinicians with all information required before treatment. The VAS for usual pain is the scale that physiotherapists reported in the interviews (Chapter 4) that they use the most. The other scale was thought to be needed because of the intermittent nature of pain in PFPS. It would be helpful for clinicians to have a record of whether the patient has pain on the day of the assessment and its severity before they ask patients to perform any exercises.

Because the modified AKPS includes different components such a number of Likert scale questions (11) from 1 to 5 and two VASs it was not possible to provide the users of the scale with just one final number. Therefore, the modified AKPS provides clinicians with three numbers. As the Likert scale questions include a 'non applicable' option different patients would be scored according to different number of questions. Thus, the total score of the questionnaire should be divided by the number of applicable questions (the non-applicable are excluded). The two other scores come from the two VASs and are calculated as per usual with a ruler in centimetres. The maximal score is 100. Below the MAKPS is presented.

<u>The Modified Anterior Knee Pain Questionnaire</u>

Participant ID:

Session:

- For the following questions circle the answer which best corresponds to you.

- Which knee is affected? **Left.... Right.... Both.....**

- How long have you had the problem? **.........Years ....Months**

- What type of pain do you have? **Permanent.... On/off......**

- Are you experiencing any pain today? **Yes.... No....**

- For each of the following 11 questions, tick the box, which best corresponds to the problems you had with your knee **<u>in the last 7 days.</u>** If you think the question is not applicable to you tick in the box to the right. For example, if you have not climbed stairs in the last 7 days.

Activities	No Difficulty (0)	A Little Bit of Difficulty (1)	Moderate Difficulty (2)	Quite a bit of Difficulty (3)	Extreme Difficulty or Unable to Perform Activities (4)	Question Not applicable
1.Kneeling	☐	☐	☐	☐	☐	☐
2.Taking weight on your leg	☐	☐	☐	☐	☐	☐
3.Walking	☐	☐	☐	☐	☐	☐
4.Going up and down stairs	☐	☐	☐	☐	☐	☐
5.Squatting	☐	☐	☐	☐	☐	☐
6.Running	☐	☐	☐	☐	☐	☐
7.Jumping	☐	☐	☐	☐	☐	☐
8.Prolonged sitting with knees bent	☐	☐	☐	☐	☐	☐
9.Pain	☐	☐	☐	☐	☐	☐
10.Feeling of instability or giving way in the knee cap	☐	☐	☐	☐	☐	☐
11. Limping	☐	☐	☐	☐	☐	☐

➢ **For the following questions please score your pain by pencilling on the straight line.**

- **How severe is the pain you are experiencing today?**

No Pain — Pain as bad as it could possibly be

- **What is your usual pain?**

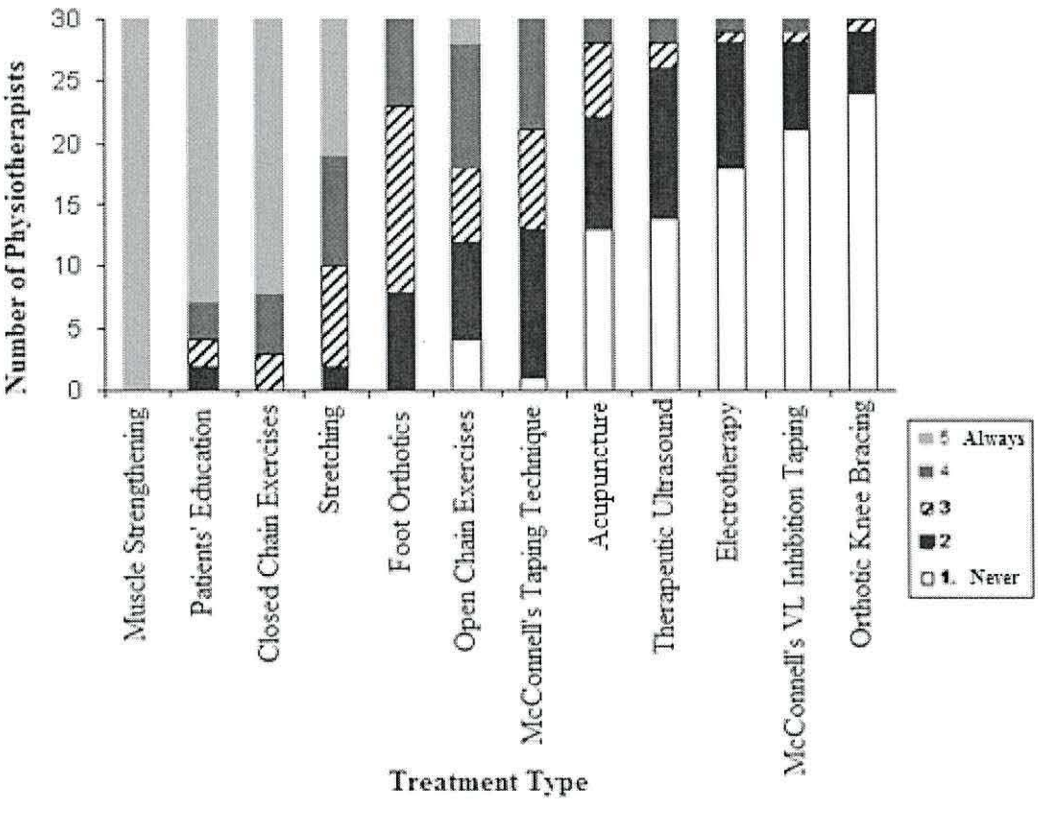
No Pain — Pain as bad as it could possibly be

Total score........./44; N/A questions........../10; VAS on the day............/10; VAS for usual pain......./10

APPENDIX ELEVEN: THE FIGURE REGARDING PHYSIOTHERAPY PRACTICE THAT WAS SHOWN TO PHYSIOTHERAPISTS DURING THE FOCUS GROUPS

Study title: **A focus group study to identify why PFPS physiotherapy has a significant effect on pain and function but not on strength and flexibility**

Figure 31. PFPS treatment methods found via the questionnaire.



APPENDIX TWELVE: THE THREE TABLES REGARDING PHYSIOTHERAPY EFFECT ON MUSCLE STRENGTH, FLEXIBILITY, PAIN AND FUNCTION THAT WERE SHOWN DURING THE FOCUS GROUPS

A focus group study to identify why PFPS physiotherapy has a significant effect on pain and function but not on strength and flexibility

Table 23. The effect of physiotherapy treatment on pain and function

Before treatment	Modified AKPS Mean±SD	VAS usual pain Mean±SD
26 PFPS patients	2.49 ± 0.74	4.32 ± 2.74
After treatment		
26 PFPS patients	2.09 ± 0.80	3.29 ± 2.33
p value from comparison between and after treatment	0.001	0.017

The above table shows that there was a significant treatment effect on the reported pain and function. The modified AKPS was chosen to measure the function and the VAS the pain

Strength tests	PFPS group Mean±SD
Before treatment isometric knee extension N/kg	5.02 ± 1.69
After treatment isometric knee extension N/kg	5.14 ± 1.42
p values following treatment	0.392
Before treatment isometric hip abduction 'clam position' N/kg	1.94 ± 0.75
After treatment isometric hip abduction 'clam position' N/kg	2.09 ± 0.75
p values following treatment	0.140
Before treatment isometric hip external rotation N/kg	1.13 ± 0.56
After treatment isometric hip external rotation N/kg	1.16 ± 0.37
p values following treatment	0.797

Table 24. The effect of physiotherapy treatment on muscle strengthening

The above table shows that there was no significant treatment effect on muscle strength.

Flexibility tests	PFPS group Mean±SD
Before treatment iliopsoas flexibility(degrees)	6.38 ± 7.31
After treatment iliopsoas flexibility (degrees)	4.24 ± 5.59
p values following treatment	**0.129**
Before treatment quadriceps flexibility (degrees)	63.96 ± 15.39
After treatment quadriceps flexibility (degrees)	64.14 ± 5.59
p values following treatment	**0.330**
Before treatment hamstrings flexibility (degrees)	33.31 ± 18.12
After treatment hamstrings flexibility(degrees)	30.84 ± 14.19
p values following treatment	**0.49**

Table 25. The effect of physiotherapy treatment on muscle flexibility.

The above table shows that there was no significant treatment effect on muscle flexibility.

APPENDIX THIRTEEN. THE TYPE OF REVIEWS ASSESSED THEIR TOPIC AND WHICH OF THEM WERE INCLUDED AND EXCLUDED.

	Authors	Included/excluded with reasons	Review topic	Reviews were entitled as:
1	Malanga et al.,2003	Included	Clinical tests	Review article
2	Nunes et al., 2013	Included	Clinical tests	Systematic with meta-analysis
3	Cook et al., 2012	Included	Clinical tests	Systematic review
4	Fredericson & Yoon, 2006	Included	Clinical tests, Risk factors	Invited review
5	Halabchi et al., 2013	**Excluded.** No methodology was reported	Risk factors	Review article
6	Waryasz & McDermott, 2008	Included	Risk factors	Systematic review
7	Pappas & and Wong-Tom, 2012	Included	Risk factors	Systematic with meta-analysis
8	Lankhorst et al., 2013	Included	Risk factors	Systematic with meta-analysis
9	Lankhorst et al., 2012	Included	Risk factors	Systematic with meta-analysis
10	Johnson, 1997	**Excluded.** No methodology was reported	Risk factors, general treatment	Review article
11	Thomee et al., 1999	**Excluded.** No methodology was reported	Risk factors, symptoms	Review article
12	Tumia & Maffulli, 2002	**Excluded.** No methodology was reported	Risk factors, Surgical treatment	Review article
13	Dixit & Difiori, 2007	**Excluded.** No methodology was reported	Risk factors. treatment	Review article
14	Heintjes et al., 2009	Included	Exercise treatment	Systematic with meta-analysis
15	Green, 2005	**Excluded.** No methodology was reported	Exercise treatment	Review article

16	Collins et al., 2012	Included	Exercise treatment	Systematic with meta-analysis
17	Bolgla & Malone, 2005	Included	Exercise treatment	Review article
18	Fagan & Delahunt, 2008	Included	Exercise treatment	Systematic review
19	Bolgla and Boling, 2011	Included	Exercise treatment	Systematic with meta-analysis
20	Harvie et al., 2011	Included	Exercise treatment	Systematic review
21	Powers, 1998	**Excluded.** No methodology was reported	Exercise treatment	Critical review
22	Frye et al., 2012	Included	Exercise treatment	Systematic review
23	Arroll et al.,1997	**Excluded.** Therapy type not suitable for this review	Exercise treatment combined with drugs	Critical review
24	Witvrouw et al., 2005	**Excluded.** No methodology was reported	Treatment	Review article
25	Crossley et al., 2001	**Excluded.** Combined methods with non-relative treatment components for this study	Several types of treatment	Systematic review
26	Juhn, 1999	**Excluded.** No methodology was reported	Several types of treatment	Review article
27	Baker & Juhn, 2000	**Excluded.** No methodology was reported	General treatment	Review article
28	Fulkerson, 2002	**Excluded.** No methodology was reported	Physical examination, Surgical treatment	Review article
29	Howe et al., 2012	Included	Outcome measures	Systematic review
30	Esculier, 2013	Included	Outcome measures	Systematic review
31	Selfe, 2004	Included	Exercise treatment, Outcome measures, Risk factors, Clinical tests	Critical Review

APPENDIX FOURTEEN. ASSESSMENT OF CLINICAL TESTS IN PFPS.

Review	Number of studies	Meta-analysis	Clinical tests in PFPS	Authors' Summary of findings	Reviewers' comments
Fredericson & Yoon, 2006	N/A	No	**Q-angle.** Low inter and intra-rater reliability was found in one study **Tilting.** Low-to moderate (0.3-0.5) Inter-tester and intra-tester coefficients **Mediolateral glide** Low Inter-tester and intra-tester coefficients <0.44 **Patellar compression** Moderate sensitivity and specificity<60% **Functional performance (lunges, step-down, single leg press, balance and reach** High reliability, ICC> 0.9 significant results.	The reliability of most tests is low or untreated. **Further research is necessary to establish a gold standard clinical test**	The methodology differs a lot across the studies. In addition, in some clinical tests, only one or two studies are reported. More studies are needed to strengthen the results.

Selfe, 2004	N/A	Without	**Q-angle**. The ICCs for intra-observer and inter-observer reliability of Q-angle were poor **Joint alignment** Poor Inter-tester and intra-tester coefficients. The measurements for patella alignment might be unreliable **Tilting** Poor Inter-tester and intra-tester coefficients The McConnell's classification of patellar orientation should not be used as measurement tool	No proper summary of findings due to great span of research questions	Evidence is based on individual studies. There is not enough evidence or the right methodology to conclude to any of this results
Nunes et al., 2013	5	Yes	**24 tests were assessed.** **The most useful reported were:** **Squatting** was the most sensitive test (91%), with the lowest LR- (0.2) and highest PV- (74%). **The vastus medialis coordination test** had the best specificity among all tests (93%) **the patellar tilt** had the highest LR+ (5.4) **the active instability** test had the highest PV+ (100%). Meta-analysis performed	Due to the multifactorial etiology of PFPS, a number of tests have been developed for its diagnosis. This review found no PFPS test with diagnostic consistency, which thus prohibits inferences about the best test to use. Future studies should	The reviewers agree that out of the 24 tests assessed in this review only the pain during squatting and the patellar tilt test have a strong tendency toward PFPS diagnosis. However, consistency of the tests was not enough to be recommended for clinical use.

			for the **patella apprehension** test. Sensitivity 15%, specificity 89%, LR+1.3, LR-1.0, PV+ 70% and PV-38%	focus on or address sample homogeneity and test standardization so that new systematic reviews with meta-analysis can more clearly determine the tests' accuracy in diagnosing PFPS.	
Cook et al., 2012	9	No	22 tests were identified. The majority of the tests were classified as patellar mobility or palpatory measures and their specificity was more that their sensitivity. The most common tests were: **Patellar apprehension (3 times)** **Clarke's sign (4 times)** **Lateral palpation (3 times)** **None of the 22 demonstrated LR+ greater than 5.0 and LR- less than 0.20** **Active instability** test had the greatest LR+ value (LR+=249)	Values diverge so significantly across the tests because different reference standards have been used among all nine papers. Until a consistent definition of PFPS is established a reference standard will be variable leading to poor methodological study quality and widely varying diagnostic statistics. **The nebulous**	The reviewers agree that the suggested tests should be used with consideration

	Pain during stair climbing (LR+=11.6) **Clarke's sign** (LR+=7.4) **Pain during prolonged sitting** (LR+=7.4) **Patellar inferior pole tilt** (LR+=5.3) Only pain during squatting demonstrated a LR-≤0.20 (LR-=0.20)	**pathology and lack of sensitive tests suggests that PFPS may be a diagnosis of exclusion.**

Abbreviations: LR=Likelihood ratio, PV= predictive value

Appendix Fifteen. Risk factors in PFPS.

Review	Number of studies	Meta-analysis	Risk factors in PFPS	Author's Summary of findings	Reviewers' comments
Fredericson & Yoon, 2006	N/A	No	**Q-angle** Contradictory results found in 5 studies **Mediolateral patellar mobility** Significant results for hypermobility of the medial glide. $p<0.05$ **General joint laxity** Contradictory results **Tight quadriceps** Significant results $p<0.05$ **Tight hamstrings** Contradictory results **Tight iliotibial band** Significant results $p<0.05$ **Quadriceps weakness** Contradictory results **Hip abductor weakness** Significant results $p<0.05$ **Functional performance (lunges, step-down, single leg press, balance and reach** Functional performance may be preferred over muscle deficits **General joint laxity** Unclear whether systematic hypermobility is correlated with PFPS	Multiple evaluations are recommended. The evaluation of generalized ligamentous laxity, a hypomobile or hypermobile patella, tenderness of the lateral patellar retinaculum patellar tilt or mediolateral displacement, decreased flexibility of the ITB and quadriceps, and weakness of the quadriceps, hip abductor, and external rotator are recommended to reveal factors contributing to PFPS and patellofemoral malalignment.	The methodology differs a lot across the studies. In addition, in some clinical tests, only one or two studies are reported. More studies are needed to strengthen the results.

Waryasz & McDermott 2008	24	No	**Electromyography (EMG) Measured Neuro-Motor Dysfunction** All 5 studies showed a significant neuro-motor dysfunction in PFPS **Foot Abnormalities** Not enough evidence. Additional research is needed **Functional Testing** Functional strength deficits can be a potential risk factor **Gastrocnemius Tightness** Two out of three studies reported significant results **Generalized Joint Laxity** Two out of three studies found significant results **Hamstring Strength** Data appears to be inconclusive. No p value was reported **Hamstring Tightness** Two out of four studies found significant results **Hip Musculature Weakness** Two out of three studies found significant results **Iliotibial Band Tightness (ITB)** Four studies reported significant results and one non-significant. **Q-angle** 3 studies reported significant results and four non-significant **Quadriceps Tightness** Six studies reported significant results $p<0.05$ **Quadriceps Weakness** Two studies reported non-significant results and three significant results **Patellar Compression** Data appears to be inconclusive **Patellar Mediolateral Glide** Data appears to be inconclusive	No summary of finding were presented	There is a little evidence and no comparisons between the presented studies that the reader cannot reach to a conclusion. This is probably the reason that even the authors did not summarize their 'evidence'

	Patellar Tilting Data appears to be inconclusive
Selfe, 2004	**Being a Woman** Significant difference p<0.05 **Military population** Significant difference p<0.05 **Chronic traumatic** anterior knee pain is resistant to treatment if symptoms persist beyond two years **ACL surgery** does not lead to PFPS p<0.05 <u>The following factors are just reported. No further evidence was provided:</u> **Shortened quadriceps** **Altered reflex response for Vastus Medialis Obliquus** **Decreased explosive strength** **Hypermobile patella** **Extension strength of the affected knee** **Pain on the patella apprehension test** **Patella crepitation, bilateral symptoms** **Body weight, Age** **Decreased arch index** **Decreased pronation** **Decreased knee extension peak torque**

	N/A	No		No proper summary of findings due to great span of research questions	Evidence is based on individual studies. There is not enough evidence or the right methodology to conclude to any of this results
Pappas and Wong-Tom, 2012	7	yes	**Anthropometrics** Data showed that height, weight, being military, leg discrepancy, thigh and calf circumference, tibial and foot length and foot width had no association with PFPS. Pooled data showed no association between leanness and PFPS **Physical fitness** Lower performance on vertical jump was associated with PFPS in one study and the number of push-up in another. **Muscle strength** The pooled analysis found that lower knee extension strength is a predictor of PFPS $p<0.01$, heterogeneity, $p=0.32$. One study also reports knee flexion and hip abduction as risk factor for PFPS **Joint laxity** Different methodology in the presented studies. **Muscle flexibility** One study reports that quadriceps and gastrocnemius flexibility was significant whilst hamstrings flexibility was not. **Lower leg alignment**	The main finding: despite the high incidence of PFPS among physically active populations and the abundance of factors that may predispose to this disorder, there are **few** prospective cohort studies, **especially among civilian populations.** In this small sample of studies, limited quadriceps and gastrocnemius flexibility, knee extension weakness, and faulty landing mechanics predict development	Agree

			Pooled analysis showed that Q-angle was not a predictor, p=0.91, heterogeneity, p=0.22 Contradictory results between genu varum and PFPS Foot posture did not show differences between PFPS and non-PFPS patients. **Biomechanical variables** Pooled analysis showed that peak valgus angle during landing tasks was not a predictive factor, p=0.40, heterogeneity, p=0.59 **Psychosocial parameters** Out of 11 psychosocial variables, seeking less social support and difficulty relaxing when confronted with the problem were predictors of PFPS	of PFPS. PFPS is a multifactorial disorder. Clinicians screening populations at high risk for PFPS should evaluate strength, flexibility, and dynamic alignment.	
Lankhorst et al., 2013	47	Yes	Static measures **Foot and ankle characteristics** Pooling was possible in 2 out of seven studies. No association between arch height index and PFPS was found. **Leg length differences** No association was found in either two studies reported. **Q-angle in weight bearing position** Pooled data of nine studies showed that PFPS patients had a Q-angle larger than 20^0. **Malalignment** Malalignment from genu valgum was not associated with PFPS in one study **Patella** Pooling was possible for three out of 39 variables. Significant differences were found for patellar tilt angle and sulcus angle. No significance was found between congruence angle in PFPS patients and controls. **Angles** Among 18 variables the only significant were the smaller	The review provides indications that PFPS is associated with a larger Q-angle, larger sulcus angle, larger patellar tilt angle, less hip abduction strength conveyed as a percentage body weight and less knee extension strength expressed by peak torque. Other factors that were statistically significant different between PFPS patients and control subjects were based on single studies, and therefore further research is required **in high-risk**	The reviewers highlight that these studies show the great span of risk factors in PFPS. However, there is no evidence regarding the populations of the studies. Only in a few occasions the authors reported military populations.

	tibial tubercle rotation angle in PFPS patients compared to controls, the greater hip external rotation angle and the smaller hip internal rotation angle in PFPS compared to controls and finally the greater knee hyperextension angle **Characteristics of Vastus Medialis Obliquus (VMO) muscle** Insertion level, fabler angle and volume of VMO muscle were evaluated and were all significantly smaller in PFPS compared to controls **Characteristics of quadriceps muscles** Quadriceps atrophy was not found significant in a cross-sectional study. <u>Kinetic measures</u> **Foot and ankle characteristics** Less foot pronation angle during first 10% of stance during running was also find significant $p<0.05$ **Ground reaction force** Only a significant lower maximum lateral force during running in PFPS group compared to the control group was found in one study. **Peak moments** Only knee flexion-extension moment during running was significantly lower in the PFPS group compared to the control group. **Peak torques** Examined in five studies. Pooling results showed that lower knee extension at 60^0 was significant between PFPS and healthy controls. <u>Kinematic measures</u> **Patella** Contradictory results were found for patella malalignment **Angles**	**groups that is, athletes and military recruits** in a prospective cohort study design.	There was no evidence about athletic or normal civilians with PFPS or where the studies were conducted (research centers or clinics)

Significant larger angles were found for hip adduction peak hip internal rotation and knee flexion during functional tasks.

Velocity

The joint motions for hip adduction and hip external rotation velocity were significantly lower in PFPS patients in one study.

Excursion

A greater hip internal rotation excursion was found in PFPS patients during one-leg squat.

Peak stance-phase

Peak knee flexion in the stance phase was significantly lower in PFPS patients in two studies.

<u>Muscle function</u>

Flexibility

Four variables were found significant in PFPS compared to healthy controls (Tightness of hamstrings, quadriceps, gastrocnemius and soleus).

Muscle strength

Pooled data showed less hip abductor strength in PFPS patients compared to controls and less hip external rotation strength. Individual studies also showed less quadriceps strength during knee extensions.

Muscle endurance

Less muscle endurance in the PFPS group was found compared to the control group expressed by eight out of ten variables.

Muscle timing

55 studies showed no significant association between different LE muscle timings on several functional tasks. The rest studies (42) studies mostly showed EMG onset timing difference of VMO during different functional tasks.

<u>Other measures</u>

			Joint position sense Errors between demonstrated and performed action was significant greater in PFPS in weight-bearing joint position sense at 60^0 knee flexion **Joint mobility** One study showed that PFPS patients were hypermobile compared to controls **Joint effusion** No difference were found **Psychological factors** Self-perceived health status and increased metal distress was found significant different between PFPS and healthy controls in one study. **Neurological** No difference were found **Extrinsic factors** Mileage accumulating in shoes before discarding, participating in sports before basic military, previous knee injuries, competitive sports was significant lower in PFPS group		
Lankhorst et al., 2012	7	Yes	**Demographics** Pooling was possible for height, weight, body mass index, and age. No difference was found. Only one study reported that women are at higher risk. **Psychological Parameters** A significant value was found for 'looking for social support'. **Physical fitness** Participation in sports less hours per week, ability to perform more push-ups and a lower vertical jump were found as risk factors for PFPS compared to healthy controls. **Joint angles** Pooling was performed for Q-angle and no significant	The results of the study indicate that less knee extension strength is significantly associated with a higher risk for future PFPS. It is noteworthy that most evaluated risk factors in the 7 studies were biomechanical and neuromuscular risk factors and not structural	The reviewers observed that although this systematic review is a high standard because it includes RCTs only, the results are based on less than 10 PFPS

	difference was found. No difference was also found for hip and knee angle variables **Posture** A larger medial tibial intercondylar distance was a significant risk for PFPS in 1 study. Navicular drop was significantly higher in future PFPS patients compared to controls. **Patella** No differences were found in for patella mobility **Vertical ground reaction force** Found lower in the PFPS group in one study **Plantar Pressure** Two out of 37 variables were found significant in one study. A slower maximal velocity of the change in the center of pressure in the lateromedial direction during the forefoot contact and mediolateral component of the center of the pressure was more laterally directed to the heel-metatarsal II axis in future PFPS patients than in controls. **Electromyographic onset timing of VMO and Vastus Lateralis** The onset timing of VMO before VL was significant in 80% of controls whilst this was the case in 42.3% of future PFPS patients **General joint laxity** Thumb-forearm mobility, knee extension and elbow hyper-extension were significant in PFPS compared to healthy controls. **Strength** Hip muscle strength was not associated with future occurrence of PFPS. Strength deficit of knee extension was a risk factor **Joint moments** No differences were presented **Peak torques**	(static) risk factors. Structural abnormalities and lower extremity malalignment are often examined as associative factors for PFPS in case-control studies.	individuals for each variable. Therefore the interpretation of the data should be done with consideration. Unfortunately there are still only a few RCTs and generalization of the evidence is difficult. In addition the authors did not report enough data about the patient characteristic of the RCTs.

	Pooled data for concentric peak torque of the knee flexors and extensors during isokinetic testing relative to body weight measured at 60^0/s and 240^0/s was significantly associated with future PFPS. Lower concentric peak torques for the knee extensors, measured by at 60^0/s and 240^0/s were statistically risk factors for future PFPS. The concentric flexor-extensor peak torque ratios measured at 60°/s and 240°/s were significantly higher in those with future PFPS compared to those in the control group	

Abbreviations: ACL= Anterior cruciate ligament

Appendix Sixteen. Exercise treatment in PFPS.

Review	Number of studies	Meta-analysis	Exercise treatment in PFPS	Authors' summary of findings	Reviewers' comments
Fagan and Delahunt, 2008	11	No	**Efficacy of hip joint musculature strengthening in subjects with PFPS** No evidence to suggest that hip joint strengthening can improve symptoms in subjects with PFPS **Efficacy of physiotherapeutic interventions aimed at addressing quadriceps muscle imbalances in subjects with PFPS** Strong evidence to suggest that physiotherapeutic intervention is efficacious in addressing quadriceps muscle imbalances in subjects with PFPS **Efficacy for open versus closed kinetic chain exercises in subjects with PFPS** Strong evidence to suggest that both open and closed kinetic chain exercises are beneficial in reducing symptoms associated with PFPS	There are currently no RCTs to support the efficacy of hip joint musculature strengthening in subjects with PFPS. However, a number of intervention studies do support its use in clinical practice. Physiotherapy intervention programmes appear to be an efficacious form of intervention for addressing quadriceps muscle imbalances. Both OKC and CKC exercises appear to be appropriate forms of treatment for subjects with PFPS.	The reviewers agree that research should focus on long term-follow-ups. If 91% of respondents continue to have knee pain after they get treated and 1 out of 4 patients continue to have knee pain for the next 20 years, then what is the point of talking about the efficacy of exercise treatment?
Bolgla and Malone, 2005	N/A	No	<u>**Open kinetic exercise (OKC)**</u> **Hip muscle strengthening** Studies relating to the role of the musculature proximal to the knee are limited. There is no specific evidence to support the theory that hip	Although might have a bias toward either OKC or CKC exercise, either type of exercise can benefit PFPS population.	The reviewers took into consideration that the authors included studies with a minimum of 4-

			muscle strengthening could help patients with PFPS **Isometric quadriceps exercise** Patients with PFPS can benefit from isometric quadriceps-strengthening and SLR exercises. Exercises should be performed in a pain free range of motion **Isokinetic exercises** Results have shown that patients with PFPS can benefit from isokinetic exercises **<u>Closed kinetic chain (CKC) exercises</u>** Results from several studies have shown that closed chain exercises are also beneficial. However, all exercises should be performed in a pain- free manner.		week (12 visits according to their report) intervention. They also used this criterion as an evaluation of evidence clearly stating in the review that this method would be better than a meta-analysis. The reviewers consider whether clinicians in national healthcare services see their patients 12 times in 4 weeks.
Selfe, 2004	N/A	No	Initial strengthening should be performed at 40° of knee flexion. **Open kinetic chain exercises** should be avoided in the first 30° of knee joint flexion. **Closed kinetic chain** exercises may be more effective than joint isolation exercise in restoring function in patients with PFPS. **No differences** were found between OKC and CKC exercises. **Function activity** is composed of both OKC and CKC components and each is important in the rehabilitation.	Both **isometric** exercises and **eccentric** exercises improved PFPS patients **significantly**. Both exercises should be performed pain free. Clinicians should consider **less intensity** and **longer time** periods in the management of PFPS. **Home-based exercises** are a cheaper alternative and appear to be slightly more effective than formal physiotherapy and should be tried for six weeks before	There is no much evidence to support the conclusions of this review. Most of the suggestions are based on individual studies

				instituting formal physiotherapy	
Frye et al., 2012	10	No	**Single exercises** had significant improvement in pain and so did exercise prescriptions that included flexibility, strength and muscle balance (quadriceps, adductors and gluteals) Only 1 study showed that **exercise did not improve pain;** however results suggested that adding transverse abdominis, hip abductor and lateral rotator muscles may improve the pain outcomes in PFPS patients Several studies reported that patients with PFPS will benefit from doing **exercise** rather than **nothing** **Patient education-including activity recommendations, sham treatments, low intensity exercises and anti-inflammatory drugs** have a role in improving patient outcomes, however; when the patients are treated with various interventions it is difficult to isolate the source of improving. In patients who had benefited from exercise interventions or home exercise programmes, patient outcomes clearly **diminished once the rigorous guidance stopped.**	Exercise interventions including quadriceps, hip abductor, gluteal muscle strengthening, leg presses, closed chain exercises, lower extremity strengthening and ITB stretching are effective for PFPS patients and can immediately decrease pain and increase function. However, these data suggest that improvements may not be maintained after a short-term follow-up	The reviewers feel that they need to emphasize a little bit more than the authors the fact that half of the studies (4) **did not include control groups.** Therefore, the conclusions should be treated with reservation
Collins et al., 2012	13 studies on exercise, 27 in total	Yes	**Evidence from RCTs supports the use of exercise for AKP.** Three studies showed significant effect favouring exercise over a no-treatment control Both **closed and open kinetic chain** exercises have shown large to very large effects favouring both types of exercise.	Until further high-quality RCTs are conducted addressing issues of sample size, long-term follow up and adherence to the CONSORT statement, sports	Agree

			Leg press with hip abduction showed significant moderate effect over controls. **Contrasting results** were reported in the comparison of short-time **open and closed chain exercises.** One study showed that closed chain exercises had a significant moderate effect over open chain exercises whilst another showed no difference. A 5-year follow-up study showed a significant small effect in favour of open chain exercises. All RCT studies reported that **the addition of hip components**, supervision or other adjunct interventions to quadriceps-based programmes **did not change** AKP outcomes. **No** difference was found between **supervised & unsupervised home** exercises.	medicine practitioners should prescribe local, proximal and distal components of multimodal physiotherapy for appropriate AKP patients	
Bolgla and Boling, 2011	22	No	**Hip strengthening** Hip strengthening exercises can benefit individuals with PFPS. Moderate evidence has supports the use of hip abductor and external rotators strengthening. **Clinicians should consider an exercise dosage focusing on endurance and high repetitions** **Quadriceps strengthening** Clinicians may prefer weight bearing exercises that stimulate functional activities. However, the use of non-weight exercises may be equally beneficial	Quadriceps exercise continues to represent an important treatment strategy. This review also supported the addition hip strengthening exercises. However there is a need to isolate the effect of hip strengthening on PFPS.	Agree
Harvie et al., 2011	10	No	**Type of exercise** Both open and closed chain kinetic exercises are suggested for PFPS	These myriad of exercise options provide clinicians with the flexibility to tailor	Agree

			Program duration An intervention of 6-weeks could be considered for programmes targeting PFPS **Frequency and intensity** The majority of studies prescribed 5 or more days of exercises per week. However it is also supported that frequency of training should be chosen with respect to the type of exercise and perceived goals of training and progression should be considered where strength is a target of intervention. **Strength** The high reporting of exercises that strengthened both hip and knee muscle groups among programmes which demonstrated positive outcomes supports their inclusion in exercise programmes and reflects the hip and knee strength deficits that shown to exist in patients with PFPS **Flexibility** The frequent inclusion of stretching (hamstrings, quadriceps, gastrocnemius, Iliotibial band and anterior hip stretches) in studies reporting positive outcomes support the use of stretching as an inclusion in exercise protocols **Selective muscle/recruitment/muscle timing** The review reports that clinicians should not overly focus on the VL/VMO timing difference **Sets and repetitions** A minimum of 20-40 total repetitions should be considered when prescribed exercises for PFPS	their exercise programmes to suit individual needs. Each programme should be used independently or in combination with other treatments. Compliance with exercise is the main problem and future studies should focus on this component of treatment.
Heintjes et al.,	12	Yes	**Exercise versus no exercise** There is limited evidence to support the	Based on limited evidence for effectiveness, physicians

2009	hypothesis that exercise therapy reduces anterior knee pain in patients with PFPS. There is conflicting evidence that exercise can reduce both pain and function. **Open kinetic chain versus closed kinetic chain** The results of both high and low quality RCTs are consistent for both pain and function. Closed chain exercises provide equal results to open kinetic chain exercises for either pain reduction or function improvement.	may consider exercise therapy for the treatment of PFPS. Future research should focus on a larger number of participants Power calculation are needed before conducting each study

APPENDIX SEVENTEEN. OUTCOME MEASURES IN PFPS.

Review	Number of studies	Meta-analysis	Outcome measures in PFPS	Author's Summary of findings	Reviewers' comments
Selfe, 2004	N/A	No	The **FIQ** was ranked as the easiest questionnaire to complete. The **Flandry** questionnaire was ranked as the best for accurately depicting symptoms but it was also very confusing The **MFIQ** was recommended to be used routinely in the UK with a change in score of 10 point or more probably being clinically significant	No additional summary	The individual primary study from the same author of this review is not enough evidence to propose the MFIQ for clinical use.
Howe et al., 2012	12 on PFPS 47 in total	No	**AKPS** contains most of the functional limitations identified except kneeling. It shows good content validity and is responsive to change. It includes questionnaires not clear to patients (atrophy of thighs) **Goniometer** Parallelogram and universal goniometer	Only the AKPS was developed for PFPS, whilst LEFS was developed for general conditions. Many other tests such as	Agree

			were reported with good intra-tester reliability. A significant difference was found between goniometer and radiographic measures of knee extension in one study. **LEFS** It shows excellent reliability (r=0.94) and is more responsive than AKPS in detecting change in AKP. It is not specific for any condition especially ligamentous lesions.	the PSS, PSFS, VAS, Lysholm, PFPS impairment scale, FIQ and ADLS scale were assessed in PFPS populations but with several results.	
Esculier et al., 2013	24	No	**Validity** **Content validity** Content and face validity for ADLS and Lysholm scale were found to be adequate. Only 4.4% of the AKPS items were left unanswered. Regarding FIQ, 20-30% of the 56 patients marked the questions about walking and running as unknown. However, in another study FIQ was chosen as the easiest questionnaire to complete but the AKPS was better to describe symptoms. **Construct validity** Moderate to high correlations 0.50-0.90 were reported in a number of studies which compared ADLS-Lysholm scale, IKDC-Lysholm scale and AKPS-FIQ. Moderate to strong correlation were also found previous questionnaires and other scales such as the WOMAC, physical component of SF-36 and the VAS.	Among the five commonly used knee-specific scales the use of the ADLS is recommended for individuals with PFPS. The AKPS and IKDC would be appropriate for PFPS but properties still need to be defined in larger samples. The FIQ and Lysholm scale are not recommended for individuals with PFPS.	The reviewers agree with the authors' conclusions; however they think that an important limitation is the criterion of excluding studies with less than five publications on PFPS. Therefore 10 scales including the LEFS and the

Known-group validity
ADLS, AKPS and Lysholm scale were found to be able to differentiate PFPS from other knee conditions. ADLS was found to have the best known-group validity whilst, the FIQ and IKDC have not been evaluated yet.
Factorial validity
Only IKDC and ADLS had this structural aspect of validity investigated in PFPS patients. Two studies found that the IKDC had a single dominant component (symptoms function and sport activity) whilst a third reported two; symptoms and knee articulation and activity limitations. Therefore, all three concluded that the IKDC is a one- or two-dimension scale. These dominant components are The ADLS was found to have two factors; named Symptoms and functional limitations.
Language and cultural adaption
The AKPS, ADLS and IKDC have been translated and culturally adapted in many languages.
Administration burden/time to administer
The time to administer has only been established in the Thai version of the IKDC (less than 10 minutes). All versions of the translated scales were found to have adequate construct validity.

WOMAC, PFPS severity scale were not mentioned in this review. Future research should focus on these scales as well.

<u>Reliability</u>

Test-retest reliability

Except for FIQ all the rest reviewed scales (AKPS, ADLS, IKDC and Lysholm scale) reported excellent test-retest reliability (0.81-0.99).

Absolute reliability

Low for ADLS, IKDC, AKPS and higher for the FIQ and Lysholm scale

Internal consistency

Cronbach α was reported from 0.81 to 0.93 for ADLS, AKPS, FIQ and IKDC. Lower for Lysholm scale (0.66)

<u>Responsiveness</u>

Effect size and standardized response mean

ADLS, AKPS, IKDC and Lysholm scale were highly responsive in patients with PFPS with ES or SRM≥0.90. FIQ had moderate responsiveness ES=0.59. When compared the AKPS was more responsive than the FIQ following conservative treatment and ADLS was more responsive than Lysholm scale following non-operative treatment.

Clinically important difference

Smallest change that represents an important difference for patient (CID) was established for all scales except Lysholm. CID was lower for FIQ that for AKPS in one study (FIQ 6.3%; AKPS 8%in one study and 19 in another). CID of 7% was

found for ADLS and 11.5% for IKDC
Longitudinal validity
Changes in a global rating of change measure correlate moderately to strongly ($r>0.50$) with change in ADLS, moderate with changes ($0.50<r<0.70$) in Lysholm and FIQ, low to moderate ($0.30<r<0.70$) with changes in AKPS

Abbreviations: FIQ= Function index questionnaire, MFIQ= modified function index questionnaire, AKPS= Anterior Knee Pain Scale, WOMAC= Western Ontario and McMaster Universities Arthritis Index, CID= Clinical Importance Different, IKDC= International Knee Documentation Committee, ES= Effect Size; SRM: Standardized Response Mean, ADLS= Activities of Daily Living Scale, LEFS= Lower Extremity Functional Scale, AKP= Anterior Knee Pain, VAS= Visual Analogue Scale, PSFS= Patient Specific Functional Scale, PSS=Patellofemoral Severity Scale

APPENDIX EIGHTEEN. CHARACTERISTICS OF THE PRIMARY STUDIES INCLUDED IN THE SYSTEMATIC REVIEWS

Systematic review	Original paper	Athletes/non-athletes	No of participants	Gender	Country	Setting	Study design	Dynamometers
Nunes et al., 2013	Haim et al., 2006	Military	61 PFPS 25 controls	86 males	Israel	Military base	Controlled clinical trial	No
	Naslund et al., 2006	Unclear	29 PFPS 17 controls	15 women with PFPS 14 men with PFPS 12 female controls 5 male controls	Sweden	University hospital	Controlled clinical trial	No
	Nijs et al., 2006	Outpatients	20 PFPS 19 controls	9 women with PFPS 11 men with PFPS 5 female controls 14 male controls	Belgium	University	Controlled clinical trial	No
	Cook et al.,	Athletic	52 PFPS	17 women	USA	Sports	Prospective,	No

	2010	particip ants	24 controls	with PFPS 25 males with PFPS 8 male controls 13 female controls		medicine practice	consecutive-subjects design	
	Sweitzer et al., 2010	Unclear	59 PFPS 23 controls	Unclear	USA	Orthopaedic Clinic	Inter-rater reliability	No
Cook et al., 2012	Doberstein et al., 2008	Unclear	106 healthy	37 women 69 men	USA	University	Validation study	No
	Elton et al., 1985		20 PFPS	Unclear	USA	University	Pilot study	Cybex isokinetic (non-portable)
	Niskanen et al., 2001	Unclear	85 PFPS	44 females 41 men	Finland	Hospital	Prospective study	No
	Pihlajamak et al., 2010	Military	56 PFPS	56 men	Finland	Hospital	Prospective	No
Duplicates	**Sweitzer et al., 2010** **Cook et al., 2010** **Haim et al., 2006** **Naslund et al., 2006**							

	Nijs et al., 2006							
Waryasz & McDermott, 2008	Witvrouw et al., 2000	Young athletes	282 subjects 24 revealed PFPS after 2 years	Unclear	Belgium	University	Prospective study	Cybex 2 (non-portable)
	Milgrom et al., 1991	Military	390 non-PFPS patients	All men	Israel	Hospital	Prospective cohort	Hand-held dynamometer
	Cowan et al., 2002a	Unclear	37 PFPS 37 controls	23 women with PFPS 14 men with PFPS 23 female controls 14 female controls	Australia	University	Cross-sectional	No
	Cowan et al., 2001	Unclear	33 PFPS 33 Controls	11 men with PFPS 22 women with PFPS 13 male controls 20 female controls	Australia	University	Cross-sectional	No

Crossley et al., 2004	Unclear	48 PFPS 18 controls	31 women with PFPS 17 men with PFPS 9 female controls 9 male controls	Australia	University	Randomised double-blinded placebo-controlled tria	No
Thomee et al., 1996	Unclear	11 PFPS 9 controls	9 women with PFPS 11 unknown	Sweden	University	Case-control study	Kin-com dynamome ter (non-portable)
Thomee et al., 1995a	Athletic	40 PFPS 20 controls	All women	Sweden	University	Case-control study	No
Thomee et al., 1995b	Athletic	40 PFPS 20 controls	All women	Sweden	University	Case-control study	KinCom dynamome ter (non-portable)
Loudon et al., 2002	Unclear	29 PFPS 11 controls	19 women with PFPS 10 men with PFPS Controls unclear	USA	Clinic	Test-retest reliability	No
Piva et al., 2005	Average populati on	30 PFPS 30 controls	17 women with PFPS 13 men with PFPS	USA	University laboratory	Case-control study	Hand-held dynamome ter

			17 female controls 13 male controls				
Fairbank et al., 1984	Outpatients	52 with knee pain 446 adolescents (pupils)	Unclear	UK	Hospital and school	Case-control	No
Cichanowski et al., 2007	Athletic patients	13 PFPS 13 controls	All women	USA	Unclear	Case-control	Hand-held dynamometer
Ireland et al., 2003	Athletic patients	15 PFPS 15 controls	All women	USA	Clinic	Cross-sectional	Hand-held dynamometer
Winslow et al., 1995	Dancers	12 PFPS 12 controls	All women	UK	Unclear	Case-control	No
Caylor et al., 1993	Unclear	50 PFPS 26 controls	32 women with PFPS 18 men with PFPS	USA	University	Reliability study	No
Messier et al., 1991	Runners	16 PFPS 20 control	Unclear	USA	Lab of biomechanics	Case-control	Isokinetic Dynamometer (non-portable)
Callaghan &	Outpatie	57 with	35 women	UK	Hospital	Cross-	Biodex

	Oldham, 2004	nts	PFPS 10 controls	with PFPS 22 men with PFPS 6 female controls 4 male controls			sectional	dynamometer (non-portable)
	Kibler, 1987	Athletes	76 PFPS	Unclear	USA	Unclear	Clinical trial-not controlled	Cybex (non-portable)
	Puniello, 1993	Active patients	17 PFPS	16 women 1 man	USA	Private practice setting	Clinical trial-not controlled	No
	Bennett & Stauber, 1986	Unclear	130 patients with various knee problems	Unclear	USA	University laboratory	Cross-sectional	Kin-com dynamometer (non-portable)
Duplicates	**Smith et al., 1991** **Haim et al., 2006** **Aglietti 1983** **Niskanen et al., 2001**							
Pappas & and Wong	Boling et al., 2009	Naval populations	1597 asymptomatic	632 women 965 males 16 males	USA	Army center for health	Prospective cohort	Hand-held dynamometer

-Tom, 2012		40 had PFPS after 2.5 years	24 women reported PFPS after 2.5 years				
Thijs et al., 2007	Military	84 asymptomatic 36 Reported PFPS after six-weeks training	65 males 19 women 25 males 11 females Reported PFPS after six-weeks training	Belgium	University	Prospective cohort	No
Thijs et al., 2008	Runners	102 asymptomatic 17 reported PFPS after 10 weeks	89 women 13 men 16 females 1 male reported PFPS after 10 weeks	Belgium	University	Prospective cohort	No
Van Tiggelen et al., 2009	Military	79 healthy subjects 25	Unclear	Belgium	Unclear	Prospective cohort	No

			reported PFPS after a six-weeks training					
Duplicates	**Witvrouw et al., 2000** **Milgrom et al., 1991**							
Lankhorst, et al., 2013	Aglietti 1983	Unclear	53 knees with subluxation	Unclear	Italy	Unclear	Case-control	No
	Alberti et al., 2010	Unclear	30 PFPS 44 controls	26 women with PFPS 4 men with PFPS 26 female controls 4 male controls	Brazil	University	Case-control	No
	Al-Rawi 1997	General population	115 PFPS 110 controls	89 women with PFPS 26 men with PFPS 89 female controls 26 male	Iraq	Unclear	Case-control	No

			controls				
Anderson 2003	Athletic	20 PFPS 20 controls	All women	UK	Unclear	Case-control	Cybex dynamometer (non-portable)
Baker et al., 2002	Unclear	20 PFPS 20 controls	15 women with PFPS 5 men with PFPS 15 female controls 5 male controls	Australia	University	Cross-sectional	No
Barton et al., 2010	Unclear	20 PFPS 20 controls	15 women with PFPS 5 men with PFPS 15 female controls 5 male controls	Australia	University	Case-control and reliability study	No
Besier et al., 2008	Unclear	26 PFPS 16 controls	16 women with PFPS 11 men with PFPS 8 female controls 8 male controls	USA	University	Case-control	No

Crossley et al., 2003	Unclear	48 PFPS 18 controls	31 women with PFPS 17 men with PFPS 9 female controls 9 male controls	Australia	University	Cross-sectional	No
Dierks et al., 2008	Runners	20 PFPS 20 controls	15 women with PFPS 5 men with PFPS 15 female controls 5 male controls	USA	University	Cross-sectional	Hand-held dynamometer
Dorotka et al., 2002	Military	133 PFPS 115 controls	All men	Germany	Military center	Case-control	No
Draper 2006	Active patients	34 PFPS 16 controls	22 women with PFPS 12 men with PFPS 8 female controls 8 male controls	USA	University	Case-control	No
Draper 2009	Active	23 PFPS	All women	USA	University	Case-control	No

	patients	13 controls					
Duffey et al., 2000	Runners	99 PFPS 70 controls	31 women with PFPS 68 men with PFPS 17 female controls 53 male controls	USA	University	Case-control	Cybex 2 dynamometer (non-portable)
Eckhoff et al., 1994	Unclear	20 PFPS 10 controls	Unclear	USA	University	Case-control	No
Emami et al., 2007	Outpatients	100 PFPS 100 controls	56 women with PFPS 44men with PFPS 50 female controls 50 male controls	Iran	Hospital	Case –control	No
Jan et al., 2009	Unclear	54 PFPS 54 controls	41 women with PFPS 13 men with PFPS 41 female controls 13 male controls	Taiwan	University	Case-control	No

Jensen et al., 2008	Unclear	91 PFPS 23 controls	Unclear	Norway	University	Case-control	No
Joensen et al., 2001	Athletes	24 PFPS 17 controls	Unclear	Denmark	Unclear	Case-control	No
Keser et al., 2008	Unclear	109 knees with PFPS 74 knees without	Unclear	Turkey	University	Case-control	No
Laprade et al., 2003	Military	33 PFPS 33 controls	Unclear	Canada	University	Case-control	No
Livingston et al., 2003	Mostly athletic	25 PFPS 50 controls	14 women with PFPS 11 men with PFPS 24 female controls 26 male controls	Canada	University	Single-session observational study	No
MacIntyre et al., 2006	Unclear	40 PFPS 20 controls	Unclear	Canada	University	cross-sectiona case-control	No
Magalhaes et al., 2010	Sedentar y	50 PFPS 50 controls	All women	Brazil	Unclear	Case-control	Hand-held dynamom eter

McClinton et al., 2007	Unclear	20 PFPS 20 controls	9 women with PFPS 11 men with PFPS 10 female controls 10 male controls	USA	University	Case-control	No
Morrish 1997	Unclear	49 PFPS 20 controls	Unclear	UK	University	Case-control	No
Muneta et al., 1994	Unclear	60 PFPS 19 controls	All women	Japan	University	Case-control	No
Näslund et al., 2007	Unclear	22PFPS 33 controls	Unclear	Sweden	University	Case-control	No
Ota et al., 2008	Unclear	22PFPS 22 controls	All women	Japan	Unclear	Case-control	Hand-held dynamometer
Owings, 2002	Unclear	20 PFPS 14 controls	12 women with PFPS 8 men with PFPS 4 female controls 10 male controls	USA	University	Controlled laboratory design	Kin-com dynamometer
Patil et al.,	Unclear	20 PFPS	Unclear	UK	Unclear	Case control	No

2011		17 controls					
Patil et al., 2010	Athletic	20 patients 17 controls	12 women with PFPS 8 men with PFPS 10 female controls 7 male controls	UK	Unclear	Case-control	No
Powers et al., 2000	Unclear	23 PFPS 12 controls	All women	USA	University	Case control	Lido dynamom eter (non-portable)
Powers et al., 1996	Unclear	26 PFPS 19 controls	All women	USA	University	Case control	Lido dynamom eter (non-portable)
Salsich et al., 2007	Unclear	21 PFPS 21 controls	16 women with PFPS 5 male with PFPS 14 female controls 7 male controls	USA	unclear	Observational cohort study	No
Souza 2009	Active	21 PFPS 20 controls	All women	USA	University	Controlled laboratory study	Primus dynamom eter (non-

							using a cross-sectional design.	portable)
	Stefanyshyn et al., 2006	Runners	20 PFPS 20 controls	Unclear	Canada	University	Case-control	No
	Tuncyurek et al., 2010	Outpatients	23 PFPS 9 controls	Unclear	Turkey	Hospital	Case-control	No
	Werner et al., 1995	Athletic	27 PFPS 27controls	14 women with PFPS 13 males with PFPS 14 female controls 13 male controls	Sweden	University	Case-control	Kin-com Dynamometer (non-portable)
	Willson et al., 2008	Unclear	20 PFPS 20 Controls	All women	USA	University	Case-control	No
Duplicates	**Boling et al., 2009** **Callaghan and Oldham 2004** **Caylor et al., 1993** **Cowan et al., 2001**							

	Cowan et al., 2002b **Haim 2006** **Piva et al., 2005** **Thomee et al., 1995b**							
Lankhorst et al., 2012	Van Tiggelen et al., 2004	Military	96 without knee pain 31 revealed PFPS after a six week's training. 65 controls	Unclear	Belgium	Unclear	Prospective study	Isokinetic dynamometer (non-portable)
	Duvigneaud et al., 2008	Military	62 without knee pain. 26 revealed PFPS after a six-week's training	All women	Belgium	Unclear	Prospective study	Isokinetic dynamometer (non-portable)

Duplicates	**Milgrom et al., 1991** **Thijs et al., 2007** **Van Tiggelen et al., 2009** **Boling et al., 2009** **Witvrouw et al., 2000**							
Heintjes et al., 2009	Clark et al., 2000	General population	81 PFPS	45 men 36 women	UK	Research center	Randomised controlled tria	Tornvall chair (non-portable)
	Timm et al., 1998	Unclear	100 PFPS	50 men 50 females	USA	Hospital	Randomised controlled tria	No
	McMullen et al., 1990	Unclear	29 PFPS	16 men 13 females	USA	University	Cohort clinica trial	Isokinetic dynamometer
	Wijnen et al., 1996	Unclear	18PFPS	5 men 13 women	Netherlands	Outpatient clinic	Randomised controlled tria	No
	Stiene et al., 1996	Unclear	33 PFPS	13 men 20 women	USA	Sports medicine center	Cohort clinica trial	Isokinetic dynamometer (non-portable)
	Gaffney et al., 1992	Unclear	72 PFPS	47 men 25 women	UK	Unclear	Randomised controlled tria	No
	Colon et al.,1998	Athletes	29 PFPS	19 men 10 women	UK	unclear	Randomised controlled tria	Unclear

	Harrison et al.,1999	Unclear	113 PFPS	Unclear	Canada	University	Randomised controlled tria	No
	Dursun et al., 2001	Unclear	60 PFPS	48 women 12 men	Turkey	University	Randomised controlled tria	No
	Thomee et al., 1997	Athletic patients	40 PFPS	40 women	Sweden	Unclear	Randomised controlled tria	Kin-Com dynamom eter (none-portable)
	Gobelet et al., 2001	Unclear	120 patients with patellar chondro malacia	Unclear	Switzerlan d	Hospital	Randomised controlled tria	Cybex 2 (non-portable)
Dupli cate Collin s et al., 2012	**Witvrouw et al., 2000**							
	Witvrouw et al., 2004	Unclear	60 PFPS	40 females 20 males	Belgium	Hospital	Prospective randomized clinical trial, no control	Cybex isokinetic (non-portable)
	Herrington and AL-Sherhi, 2007	Unclear	45 PFPS	45 males	UK	University	Randomised control trial	Isokinetic dynamom eter
	Nakagawa et al., 2008	Unclear	14PFPS	10 women 4 men	Brazil	Clinical setting with home programme	Randomized control trial	No
	Song et al.,	Unclear	89 PFPS	20 males	Taiwan	Kinesiology	Randomised	no

	2009			69 females		lab	control trial	
	Taylor & Brantingham, 2003							
	Van Linschoten et al., 2009	Unclear	131 PFPS	47men 84 women	Netherlands	Sport physician practice	Open-label randomized control trial	no
	Wiener-Ogilvie and Jones, 2004	Unclear	21 PFPS	unclear	UK	Unclear	Randomized trial	unclear
	Bakhtiary & Fatemi, 2008	Students	32 PFPS	32 women	Iran	University	Quasi-experimental	Isokinetic dynamometer (non-portable)
	Witvrouw et al., 2003	Unclear	60 PFPS	40 females 20 males	Belgium	Hospital	Prospective randomized clinical trial, no control	Cybex isokinetic (non-portable)
Duplicates	**Clark et al., 2000** **Harrison et al., 1999** **Witvrouw et al., 2000**							
Fagan & Delahunt, 2008	Cowan et al., 2006	Athletic participant	10 PFPS 12 controls	Unclear	Australia	University	Randomised controlled tria	No

Keet et al., 2007	Athletic participants	15 PFPS 20 controls	11women with PFPS 4men with PFPS 13 healthy women 7 healthy men	South Africa	Research center	Placebo controlled clinical trial with randomized interventions	Isokinetic dynamometer (non-portable)
Masca, et al., 2003	Civilians	2PFPS	2 women	USA	Clinic	2 case reports	Hand-held dynamometer
Tyler et al., 2006	Athletic participants	35 PFPS	29 women 6 men	USA	Clinic/home	Cohort study	Hand-held dynamometer
Boling et al., 2006	General population	14PFPS 14controls	5 males with PFPS 9 Women with PFPS 5 male controls 9 women controls	USA	Musculoskeletal research lab	Pre/post intervention study	No
Cowan et al., 2002c	Unclear	10 PFPS 12 controls	3 males with PFPS 7 females with PFPS 4 male controls 8 female	Australia	University	Randomised controlled tria	No

				controls				
	Cowan et al., 2002b	Unclear	65 PFPS	42 women 23 males	Australia	Research institute	Randomized controlled tria	no
Dupli cates	**Cowan et al., 2001** **Witvrouw et al., 2000** **Witvrouw et al., 2004** **Herrington and AL-Sherhi, 2007**							
Bolgla and Boling, 2011	Fakuda et al., 2010	Sedentary women	70 PFPS	70 women	Brazil	University settings Exercises were performed at home	Randomised controlled tria	No
	Bily et al., 2008	Unclear	38 PFPS	14 men 24 women	Austria	University	Randomized clinical trial	Chair with full bridge circuit and amplifier
	Hazneci et al., 2005	Military population	24 PFPS 24 Controls	24 male patients 24 male controls	Turkey	Research center	Quasi-experimental	Isokinetic dynamometer (non-portable)
	Syme et al., 2009	NHS patients	69 PFPS	41 women 28 men	UK	NHS Hospital	Randomized control trial	No

	Crossley et al., 2002	Unclear	71 PFPS	46 women 25 men	Australia	Unclear	Randomized control trial	No
	Whittingham et al., 2004	Military populations	30 PFPS	24 men 6 women	UK	Military	Randomized control trial	No
	Lun et al., 2005	Active runners	129 PFPS	57 men 79 women	South Africa	University	Quasi-experimental	No
	Denton et al., 2005	Unclear	34 PFPS	34 women	USA	Sports care and physical therapy clinic	Randomized clinical trial	No
	Collins et al., 2009	Active runners	179 PFPS	100 women 79 men	Australia	University	Randomized control trial	No
	Johnston and Gross, 2004	Unclear	16 PFPS	13women 3 men	USA	University	Observational study	No
Duplicates	**Boling et al., 2006**							
	Clark et al., 2000							
	Witvrouw et al., 2000							
	Witvrouw et al., 2004							
	Dursun et al., 2001							
	Herrington & Al-Sherhi, 2007							

	Song et al., 2009 **Loudon et al., 2004** **Mascal et al., 2003** **Nakagawa et al., 2008** **Bakhtiary & Fatemi, 2008**							
Harvie et al., 2011	Kettunen et al., 2007	No specific characteristics. PFPS patients who visited the Orthopaedic Hospital,	56 patients with PFPS separated in two groups	21 men 36 women	Finland	Hospital settings Exercises were performed at home	Randomized controlled tria	No
Duplicates	**Clark et al., 2000** **Crossley et al., 2002** **Nakagawa et al., 2008** **Bakhtiary**							

	and Fatemi, 2008 Witvrouw et al., 2000 Herrington and Al-Sherhi, 2007 Syme et al., 2009 Van Linschoten et al., 2009 Song et al., 2009							
Frye et al., 2012	Ferber et al., 2011	active recreational athletes running at least 30 minutes per day	15 PFPS 10 controls	PFPS 5 men 10 women Controls 4 men 6 women	Canada	Clinic	Cohort study	Portable, force-dynamometer
	Alaca et al., 2002	Active patients	22 PFPS	Unclear	Turkey	Research center	Prospective cohort study	Isokinetic dynamometer (non-portable)
	Earl et al., 2011	Runners	19 PFPS	19 women	USA	Research center	Case series	Handheld dynamome

								ter
	Sacco et al., 2006	Active patients	11 PFPS	8 men 13 women	Brazil	University hospital	Pre- and posttest intervention cohort study	No
Dupli cates	**Van Linschoten et al. 2009** **Crossley et al., 2002** **Loudon et al., 2004** **Song et al., 2009** **Nakagawa et al., 2008** **Witvrouw et al., 2004**							
Howe et al., 2012	Marx et al., 2003	Athletic populati on	3PFPS 67 other condition s	Unclear	USA	Clinic	Test retest	No
	Watson et al., 2005	unclear	21PFPS 9 other condition s	80% women	USA	Clinic	Intra-subject	No
	Irrgang et al., 2001	Athletic patients	93/533 PFPS	47% women	USA	University	Unclear	No

	Irrgang et al., 2006	Athletic patients	19/207 PFPS	53% women	USA	University	Intra-,inter-subject between groups	No
	Bengtsson et al., 1996	Unclear	9/31 PFPS	Unclear	Sweden	Hospital	Intra-subject	No
	Piva et al., 2006	runners	30 PFPS	17 women 13 men	USA	University	Inter-tester	Hand-held dynamometer
	Laprade & Cullham, 2002	Military	29 PFPS	22 men 7 women	Canada	Force base	Intra-tester	No
	Chesworth et al., 1989	Unclear	18 PFPS	Unclear	Canada	Hospital	unclear	No
	Brosseau et al., 2001	N/A	60 healthy subject	44 women 16 men	Canada	University	Inter-tester	No
Duplicates	**Crossley et al., 2004** **Loudon et al., 2002** **Crossley et al., 2004**							
Esculier 2013	Kujala et al., 1993	Runners	16 PFPS 16 patellar dislocation 19 Patellar	All groups were women	Helsinki	Research institute	Cohort clinical trial	No

		subluxation 17 controls					
Harisson et al., 1995	Unclear	56 PFPS	Unclear	Canada	University	Test-retest	No
MacIntyre et al., 1995	Unclear	10 PFPS	9 women 1 man 90% women	Canada	University medicine center	Unclear	No
Irrgang et al., 1998	Unclear	78/397 PFPS	42% women	USA	University	Test-retest	No
Bennell et al., 2000	Outpatients	50 PFPS	17 men 33 women 66% women	Australia	University	A repeated measures and correlational design	No
Marx et al., 2001	Unclear	21/133 PFPS	48% women	USA	Hospital	Reliability, validity, and responsiveness	No
Bizzini & Gorelick, 2007	Unclear	17/108	47% women	Switzerland	Hospital	Reliability, validity, cross-cultural adaption	No
Higgins et al., 2007	Athletic patients	1517 non specified knee patients	41% women	USA	Sports medicine clinic	Validation study	No
Lertwanich et al., 2008	Athletic patients	6/55 PFPS	2% women	Thailand	Unclear	Test retest study	No

	Heintjes et al., 2008	Unclear	314 non specified knee patients	46% women	Netherlands	Clinic	Prospective cohort	No
	Evcik et al., 2009	Outpatients	37/142 PFPS	86% women	Turkey	University	Adaption and validation study	No
	Piva et al., 2009	Mostly military	60 PFPS	33women 27 men	USA	Air force bases	One group pre-post design	No
	Kuru et al., 2010	Unclear	40 PFPS	32 women 8 men	Turkey	University	Test-retest reliability study	No
	Metsavah, et al., 2010	Unclear	9/117 PFPS	69% women	Brazil	University	Cohort study	No
	Schmitt et al., 2010	Unclear	158/673 PFPS	54% women	USA	Hospital	Cohort study	No
	Cheung et al., 2012	Outpatients	64 PFPS	26 women 38 men	Hong-Kong	University	Translation and validation study	No
	Negahban et al., 2012	Unclear	100 PFPS	71 women 29 men	Iran	Research center	Translation and validation study	No
Duplicates	**Irragang et al., 2001** **Chesworth et al., 1989** **Bengtsson et**							

al., 1996
Marx et al., 2003
Crossley et al., 2003
Watson et al., 2005
Irrgang et al., 2006

APPENDIX NINETEEN: LIST OF PUBLICATIONS AND PRESENTATIONS

PUBLICATIONS RELATED TO THIS PhD THESIS

K.D. Papadopoulos, J. Noyes, M. Barnes, J.G. Jones, J.M. Thom. 'How do physiotherapists assess and treat Patellofemoral Pain Syndrome in North Wales? A mixed method study'. (2012) International Journal of Therapy and Rehabilitation, Vol 19 pp261-272. (Chapter 4) Featured paper of May 2012. Available open access.

K.D. Papadopoulos, J.M. Thom, J Noyes, J.G. Jones, D. Stasinopoulos. 'The Reliability and Meaningfulness of the Anterior Knee Pain and Lower Extremity Functional Scales in Patellofemoral pain Syndrome' (2013) The Open Sports Science Journal, Vol 6 pp26-30 (Chapter 6)

K.D. Papadopoulos, J Noyes, J.G. Jones, J.M. Thom, D. Stasinopoulos. 'Clinical tests for differentiating between patients with patellofemoral pain syndrome and those without' (2014) Hong Kong Physiotherapy Journal, in press, available online 22 January 2014 (Chapter 7)

K.D. Papadopoulos, J.M. Thom, J Noyes, J.G. Jones, D. Stasinopoulos. 'Reproducibility of lower strength tests using a portable dynamometer. Measurement comparisons with a non-portable dynamometer' (2014) Manual Therapy (in preparation) (Appendix 5)

OTHER PFPS PAPER NOT RELATED TO THIS PhD

K.D.Papadopoulos, L. Nardi, M. Antoniadou, D. Stasinopoulos. 'Greek adoption and validation of the Patellofemoral Pain Syndrome Severity Scale' (2013) Hong Kong Physiotherapy Journal, Vol 31 pp95-99.

CONFERENCE PRESENTATIONS

Fourth Pancyprian Physiotherapy Conference. Oral presentation: 'A systematic review of systematic reviews of PFPS risk factors, diagnostic tests, outcome measurements and exercise treatment'. K. Papadopoulos, J. Noyes, M. Barnes, J.G. Jones, J. Thom. To be delivered on 8th March 2014, Nicosia, Cyprus

BASES student conference: Oral presentation: 'A study to differentiate patients with Patellofemoral Pain Syndrome from patients with other conditions of the lower limb'. K. Papadopoulos, J. Noyes, M. Barnes, J.G. Jones, J. Thom, London, April 2012

Rheumatology meeting, Bangor Hospital: Oral presentation 'Patellofemoral Pain Syndrome: Developing an Evidence-Base for Treatment, Assessment and Outcome Measure'. K. Papadopoulos, Bangor, 14th March 2012

International Patellofemoral Research Retreat 'Patients with Patellofemoral Pain Syndrome (PFPS) have weakness of quadriceps and hip external rotators and reduced hamstring and psoas flexibility'. K. Papadopoulos, J. Noyes, M. Barnes, J.G. Jones, J. Thom, Ghent, Belgium 2011

Society of Research in Rehabilitation (winter meeting). Poster entitled: 'A new approach to assessing lower limb muscle strength. Testing reliability and validity of a portable dynamometer and transferring it into the clinic'. K. Papadopoulos, J. Noyes, M. Barnes, J.G. Jones, J. Thom, Keele University, 2011

European College of Sport Science. Poster entitled: 'Patients with Patellofemoral Pain Syndrome (PFPS) have weakness of quadriceps and hip external rotators and reduced hamstring and psoas flexibility'. K. Papadopoulos, J. Noyes, M. Barnes, J.G. Jones, J. Thom, Liverpool, 2011

School of Sport Health and Exercise Sciences. Poster entitled: 'A study to identify the reproducibility of strength tests using a portable dynamometer. Measurement comparisons with Humac Norm©.' K. Papadopoulos, J. Noyes, M. Barnes, J.G. Jones, J. Thom, Bangor, 2011

Society of Research in Rehabilitation. Poster entitled: 'Strength and flexibility differences of PFPS patients and healthy controls'. K. Papadopoulos, J. Noyes, M. Barnes, J.G. Jones, J. Thom, Cardiff, 2010