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Physical function in patients undergoing arthroscopic meniscus surgery of the knee.

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Declaration

I declare that this thesis has not been submitted as an exercise for a degree at this or any other university and it is my own work. Chapter two of this thesis includes published work co-authored with other researchers (Section 2.2-2.7); work carried out is noted specifically at the beginning of the relevant section and the published work is integrated into the thesis. I (Nathan Cardy) completed the data extraction, manuscript review and reformatting of the associated publication.

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Signed: Nathan Cardy **31/05/2019**

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Authors Professional Development

Publications

THORLUND, J. B., ØSTENGAARD, L., **CARDY, N.,** WILSON, F., JØRGENSEN, C. & JUHL, C. B. 2017. Trajectory of self-reported pain and function and knee extensor muscle strength in young patients undergoing arthroscopic surgery for meniscal tears: A systematic review and meta-analysis. *Journal of Science and Medicine in Sport*, 20, 712-717.

Conference Posters

Cardy, N., Thorlund, J.B., Quinlan, J., Hogan, N., Brennan, A., McNulty, K., Wilson, F., (2018). Changes in isokinetic strength and single-leg hop test performance following arthroscopic meniscus surgery: A Cohort Study. *Sports Medicine Congress 2018*. Copenhagen, Denmark, 1-3 February 2018. Scandinavian Sports Medicine Congress.

Cardy, N., Thorlund, J., Wilson, F., (2018). Large Variability in Clinician Expectations of Arthroscopic Partial Meniscectomy; a Study of Physiotherapists and Orthopaedic Surgical Teams. *ISCP Annual Conference*. Radisson Blu Hotel, Sligo, 9 & 10 November 2018: Irish Society of Chartered Physiotherapy.

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Cardy, N., Thorlund, J., Wilson, F., (2018). Surgeons and Patients Report Different Reasons for Surgery; Examination of an Arthroscopic Partial Meniscectomy Cohort. *ISCP Annual Conference*. Radisson Blu Hotel, Sligo, 9 & 10 November 2018: Irish Society of Chartered Physiotherapy.

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Table of Contents

List of Figures

List of Tables

Abbreviations List

6MH: Six Metre Timed Hop

AAOS: American Academy of Orthopaedic Surgeons

ACL: Anterior Cruciate Ligament

ACLR: Anterior Cruciate Ligament Reconstruction

ANOVA: Analysis of Variance

APM: Arthroscopic Partial Meniscectomy

AROM: Active Range of Motion

CBJ: Carsten Bogh Juhl

CI: Confidence Interval

BMI: Body Mass Index

CJ: Claus Jørgensen

ESSKA: European Society for Sports Traumatology, Knee Surgery, Arthroscopy

FW: Fiona Wilson

GLA:D: Good Life with OsteoArthritis in Denmark

HEP: Home Exercise Program

HSS: Hospital for Special Surgery

ICC = Intraclass Correlation Coefficient

ICRS: International Cartilage Repair Society

IKDC: International Knee Documentation Committee subjective knee assessment form

IQR: Interquartile Range

ISAKOS: International Society of Arthroscopy, Knee Surgery and Sports Medicine

JBT: Jonas Bloch Thorlund

KOOS: Knee Injury and Osteoarthritis Outcome Score

LCL: Lateral Collateral Ligament

LØ: Lasse Østengaard

LSI: Leg Symmetry Index

MRI: Magnetic Resonance Imaging

MCL: Medial Collateral Ligament

MDC: Minimal Detectable Change

Nm: Newton Metre

NC: Nathan Cardy

OA: Osteoarthritis

OARSI: Osteoarthritis Research Society International

PAR-Q: Physical Activity Readiness Questionnaire

PCL: Posterior Cruciate Ligament

PRISMA: Preferred Reporting Items for Systematic Reviews and Meta-analyses

PROSPERO: International Prospective Register of Systematic Reviews

PROMS: Patient Reported Outcome Measures

QOL: Quality of Life

REM: Random Effects Model

RevMan: Cochrane Review Manager

RCT: Randomised Controlled Trial

ROM: Range of Motion

RPE: Rate of Perceived Exertion

SD: Standard Deviation

SEM: Standard Error of Measurement

SIGN: Scottish Intercollegiate Guidelines Network

SIPAM: Single Item Physical Activity Measure

SLH: Single Leg Hop

SMD: Standardised Mean Difference

STROBE: Strengthening the Reporting of Observational Studies in Epidemiology

THD: Triple Hop for Distance

TKR: Total Knee Replacement

TRIMS: Trinity Meniscus Study

UK: United Kingdom

USA: United States of America

WHO: World Health Organisation

WOMAC: Western Ontario and McMaster Universities Osteoarthritis Index

WOMET: Western Ontario Meniscal Evaluation Tool

Appendix List

Summary of Thesis

Current evidence does not support the primary use of arthroscopic partial meniscectomy (APM) in the treatment of middle-aged patients with a meniscus tear in a degenerative knee. Findings of these studies are based on Patient Reported Outcome Measures (PROMs). Objective functional performance in patients undergoing APM are poorly reported and research has not been consolidated on this topic. Arthroscopic meniscus surgery continues to be a frequently performed procedure despite recent guidelines; the rationale for surgical treatment in patients with meniscus injuries is not clearly defined.

The aim of this thesis was to investigate expectations, functional performance and activity level in a cross sectional population of patients undergoing arthroscopic meniscus surgery of the knee. Two systematic reviews were undertaken to summarise current research on this topic. The first systematic review examined self-reported function and measures of strength in young patients undergoing APM. The second systematic review and meta-analyses examined measures of objective physical function in patients undergoing arthroscopic meniscus surgery.

A longitudinal cohort study (Trinity Meniscus Study: TRIMS) examined objective and self-reported function in patients undergoing arthroscopic meniscus surgery. Pre-operative baseline assessments were carried out, and patients were followed up for one year post-operatively with PROMs measured at pre-op, three, six and twelve months post-op. Objective measures of physical function were assessed at pre-op baseline and six months post-op follow up. Functional performance was measured using isokinetic strength assessment of the quadriceps and hamstring muscles, as well as a battery of hop tests (Single Leg Hop(SLH), Triple Hop for Distance (THD) and Six-metre Timed Hop(6MH)). Performance was compared to contralateral leg as control and change in physical function over time was reported.

Rationale for arthroscopic meniscus surgery was examined in a study collecting self-reported expectation questionnaires from patients and clinicians. Additional analyses of data from the TRIMS study was also used to compare reasons for surgery from patients' and surgeons' perspectives.

Literature review found that objective measures of functional performance are poorly studied across all age groups undergoing arthroscopic meniscus surgery. Strength

appears to be decreased for up to one year following APM in younger adults, but there is a complete lack of self-reported outcome data in younger populations. Deficits in functional performance are reported both pre and post-operatively in middle aged APM cohorts and RCTs. The TRIMS study found deficits in functional performance compared to contralateral leg, both pre-operatively ($P<.01$ all measures) and post-operatively ($P<.05$ all measures) in middle aged patients undergoing APM. These functional deficits were found to improve bilaterally following surgery but no difference in improvement was found on strength or SLH performance compared to contralateral leg. This indicated that deficits still exist following APM, despite bilateral functional improvements. In contrast to strength and SLH findings, high-level performance assessments (6MH and THD) revealed greater improvements in the APM leg, compared to the contralateral leg over time in the TRIMS study ($P<.05$). Examination of clinician and patient rationale for surgery found that physiotherapists and surgical team members had varied expectations of APM outcome, regardless of clinician discipline. Orthopaedic team members who had a larger yearly caseload of APM patients had a higher expectation of improvement following surgery. Surgeons and patients within the TRIMS cohort reported different perspectives on the reason for surgery, indicating that improvements are need in shared decision making, in order to optimise patient compliance and functional outcome of arthroscopic meniscus surgery.

Improvements in functional performance are important to patients undergoing APM, and objective functional performance is previously underreported. This thesis found that functional performance deficits which exist pre-operatively, are not fully resolved at six months post-operatively. While there is a bilateral improvement in strength and a resolution of self-reported physical activity level; this does not reach a ‘healthy normal’ level and only high performance measures of 6MH and THD were found to improve significantly more than control. Functional performance deficits appear to remain six months following APM.

1 Introduction

The tibial menisci are two wedge shaped discs of fibrocartilage, located between the tibia and femoral condyles within the knee joint. The lateral meniscus is "C" shaped, covering 80% of the lateral compartment while the medial meniscus is more "U" shaped with a larger space between its anterior and posterior horns; covering about 60% of the medial tibial plateau (Kohn and Moreno, 1995). The menisci are rich in water which makes up 65% of their total weight and contributes to the viscoelastic shock absorption capacity of the tissue, meniscal tissue has a dense extracellular matrix which consists mostly of Type 1 Collagen. The unique composition of the menisci allows them to provide increased stability to the tibiofemoral joint, distribute load, absorb shock, and provide lubrication to the knee joint (Fox et al., 2012).

Injury to the meniscus results in self-reported pain, decreased function, and decreased strength, even after surgical intervention (Hall et al., 2015b, Thorlund et al., 2017b). Meniscus injury is associated with long term changes in the knee; 10 – 20 years after diagnosis, 50% of patients have osteoarthritis associated with pain, decreased function and radiographic joint degeneration (Lohmander et al., 2007).

Treatment of meniscus injury with Arthroscopic Partial Meniscectomy (APM) is common for meniscus tears with non-resolving symptoms such as pain or knee locking / giving way. Recent global trends in frequency of surgery show no decrease in the rate of surgery internationally (Kim et al., 2011, Bohensky et al., 2012, Harris et al., 2013, Thorlund et al., 2014), despite recent evidence calling into question the outcome of APM (Katz et al., 2013b, Yim et al., 2013, Sihvonen et al., 2013). This pattern places a large and potentially unnecessary burden on public health resources worldwide. It is estimated that the average cost of APM surgery is 3000 USD (Katz and Losina, 2018), but the cost-benefit of surgery has recently been called into question. Regardless of willingness-to-pay value, APM is not a cost effective alternative to conservative treatment for degenerative meniscus injuries (Marsh et al., 2016). In both Europe and the USA, conservative management for non-obstructive meniscus tears appears to be a cost effective and acceptable alternative to APM (Barnds et al., 2019, van de Graaf et al., 2020). Furthermore, meta-analysis has shown that the risks and potential harms of APM may outweigh the benefits in certain populations (Thorlund et al., 2015)

1.1 Meniscus anatomy and injury

The menisci are commonly injured due to both their anatomical makeup and the frequency of mechanical stresses placed on the knee joint. Both fibrocartilaginous discs are concave superiorly and taper towards the centre, sitting in the medial and lateral tibial fossae inferiorly. Superiorly, the medial and lateral femoral condyles sit in each meniscus which provides stability and ease of movement during knee flexion / extension as well as rotation. A large amount of meniscus stability comes from the strong attachments of each meniscus root to the tibia. A root tear to the meniscus can result in equivalent loss of stability as a partial meniscectomy (Allaire et al., 2008). Meniscal root tears can often go unnoticed, with medial meniscus tears being the most common (Koenig et al., 2009). A loss of meniscus stability results in increased hoop stress - axial forces converting to tensile stresses along the circumference of the meniscus (Johannsen et al., 2012); which in turn leads to a greater concentration of contact pressure on the tibia and femoral condyle in the involved compartment.

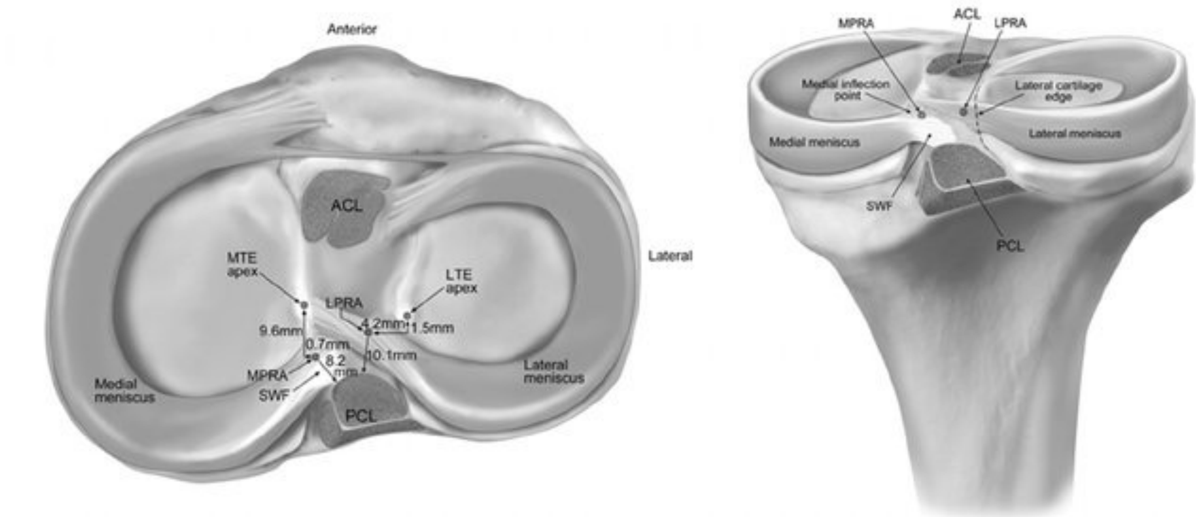


Figure 1.1: Detailed Anatomy of Tibial Meniscus

ACL = anterior cruciate ligament, LPRA = lateral meniscus posterior root attachment, LTE = lateral tibial eminence, MPRA = medial meniscus posterior root attachment, MTE = medial tibial eminence PCL = posterior cruciate ligament, SWF = shiny white fibres. (Adapted from (Pache et al., 2018)).

Special consideration must be given to the attachments of the meniscus when diagnosing and understanding a meniscus injury. The lateral meniscus posterior root attaches just medial to the lateral tibial eminence, while the anterior root attaches just anterolateral to (and largely overlapping with) the distal attachment of the Anterior

Cruciate Ligament (ACL) (LaPrade et al., 2014). The medial meniscus posterior root attaches jut lateral to the medial tibial eminence, and the anterior root of the medial meniscus inserts along the anterior intercondylar crest of the anterior slope of the tibia (Pache et al., 2018). Centrally, the tapered free edge of the meniscus is more frequently injured in torsional injuries, particularly the medial meniscus (commonly alongside ACL injury). The circumference of the medial meniscus is also attached to the (Medial Collateral Ligament) MCL (deep medial collateral ligament) which in turn blends with the synovial and capsular fibres of the knee (Fox et al., 2012), with implication for synovial irritation / synovitis and meniscal damage in MCL injuries. Special surgical consideration must be given to the close proximity of the attachment of the anterior horn of the lateral meniscus, and the ACL footprint when drilling for tunnel placement during ACL reconstruction.

The vascular supply of the meniscus is from the medial, lateral and middle genicular arteries which are branches of the popliteal artery. Capillaries arise from the synovial and capsular tissues; supplying blood to the outer 10-30% of each meniscus (Fox et al., 2012). Blood supply is limited to the inner one-third of the meniscus and meniscus tissue injuries are often classified according to three zones; the vascularised outer one-third is referred to as the red-red zone, the middle third portion as red-white and the inner avascular zone is referred to as the white-white zone. The blood supply to these areas has significant implications for potential healing following a meniscus tear (Danzig L et al., 1983); injury to the inner (avascular) white-white zone is unlikely to heal. Nerve supply to the meniscus is also limited; nerve fibres are supplied by the recurrent peroneal branch of the common peroneal nerve, which passes through the lateral capsule of the knee and travel along with the vascular supply to the periphery and posterior horns of the meniscus, where the greatest concentration of nerve fibres are found (Kennedy Jc et al., 1982).

Meniscus tears are caused by an overload to the meniscus tissue, often as a result of a sudden motion of the knee joint. Meniscus tears can also happen as a result of knee joint degeneration over time and are common in middle aged and elderly patients. Injury to the meniscus is classified based on location, thickness and resulting stability of the meniscus (Greis et al., 2002). According to the depth of the tear, injuries are classified as partial or full thickness tears. A full thickness injury can be further classified as stable or unstable. The International Society of Arthroscopy, Knee Surgery and Sports Medicine (ISAKOS) has developed a surgical classification system for documenting surgical finding of meniscus injuries (Anderson et al., 2011). This classification includes diagrammatic records of meniscus damage based on tear pattern. Figure 1.1 shows the ISAKOS classifications of tear pattern. Categorisations of tears may be very important when it comes to deciding a treatment plan and classifying injury cohorts in meniscus injury research.

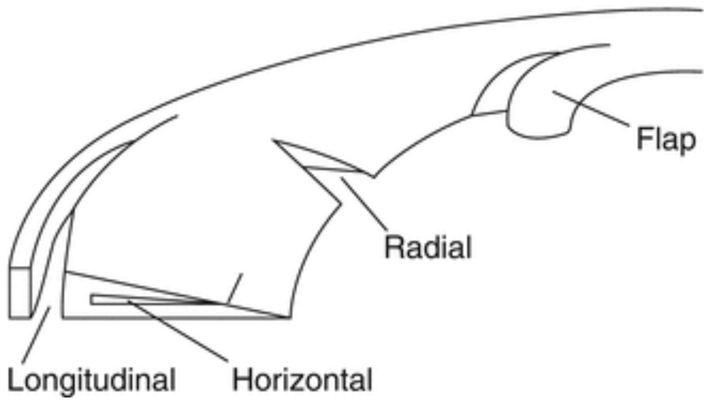


Figure 1.2: ISAKOS Meniscus Tear Patterns
(Adapted from (Anderson et al., 2011).

1.1.1 Consequences of meniscus injury

Damage to meniscus tissue; whether traumatic or degenerative in nature, leads to a change in intraarticular joint anatomy. This has consequences for the load bearing, shock absorption and joint stabilising roles which the meniscus plays in the knee joint (Fox et al., 2012). Meniscus tears are also associated with increased risk of articular joint surface damage (Henry et al., 2012) and while this is not always a causal relationship, meniscus pathology and poor joint health are often related.

Meniscus tears involving >60% of the meniscus width lead to increased contact pressures within the joint (Lau et al., 2018) and there is also an established association between meniscus injury and long term joint degeneration (Lohmander et al., 2007). Increased knee adduction moment, which is a known risk factor for tibiofemoral osteoarthritis, has been repeatedly found in patients with meniscus injury (Lau et al., 2018). There is mounting evidence that a meniscus tear, regardless of management, is the most significant risk factor for developing knee osteoarthritis (Poulsen et al., 2019, Lie et al., 2019)

1.1.2 Effect of meniscus injury on knee function

Changes in joint health can lead to changes in overall quality of life and deficits in both self-reported and objective physical function. This is most frequently researched through self-reported outcome measures of knee function such as the Knee injury and Osteoarthritis Outcome Score (KOOS) and International Knee Documentation Committee (IKDC) subjective knee assessment form.

Following meniscus injury, there is a decrease in self-reported knee function for both younger (Thorlund et al., 2017b) and older (Khan et al., 2014) patients who undergo knee surgery, although very few studies have examined these outcome measures in the pre-operative phase of management.

1.2 Management of meniscus injury

1.2.1 Conservative Management

The first line of treatment following a meniscus injury is normally conservative (non-operative) treatment. This involves symptom management and often exercise therapy. Symptoms are frequently managed using non-steroidal anti-inflammatories and activity modification. If patients fail to respond to conservative management, further evaluation and surgical treatment may be pursued.

The focus of physiotherapy treatment for meniscus tears is to build strength and function through appropriate rehabilitation. Very few studies have been published examining the effectiveness of conservatively managed meniscus injuries, but exercise protocols for physiotherapy management have been researched and published. Good Life with osteoArthritis in Denmark (GLA:D) is an evidence based education and neuromuscular exercise program facilitated by Physiotherapists which has been developed in Denmark and further expanded worldwide. The GLA:D project is a management option for patients with hip and knee osteoarthritis including meniscus pathology, the program consists of regular education and exercise training including balance, strength and light cardiovascular exercise. Participation has been shown to improve patient symptoms and physical function while also reducing the use of painkillers and sick leave (Skou and Roos, 2017).

Although pain management strategies and physiotherapy programs are used to conservatively target symptoms of meniscus injury, the consequences of knee injury are still present and do have long-term consequences for joint health. There is a lack of data on non-surgically managed meniscus tears in the long term and consequence of injury is generally reported in the context of surgical intervention. It is generally accepted that there is up to a 50% increased risk of knee osteoarthritis following meniscus injury (Lohmander et al., 2007) although the effect of surgical intervention on long-term outcome should also be considered as surgery is associated with risks as well as benefits. Meniscectomy has been found to be a consistent risk factor for developing osteoarthritis after ACL surgery (Lie et al., 2019). Randomised controlled trials which compare conservative or sham treatment with surgical treatment in the short or medium term have shown no added benefit of surgical intervention in a degenerative knee (Katz et al., 2013c, Kise et al., 2016a, Sihvonen et al., 2013).

1.2.2 Surgical Management

Patients who do not respond to conservative treatment are often referred to orthopaedic surgeons for further evaluation and management. This routinely includes Magnetic Resonance Imaging (MRI) of the knee and surgical intervention if meniscus pathology is identified.

Traditionally, meniscus surgery has been regarded as a straightforward procedure with few complications. Historically, it was thought that removing damaged meniscus tissue was similar to removing a damaged tooth. This resulted in the removal of most, if not all of the meniscal tissue following injury up until the late 1900s. In 1948, Fairbank described the characteristic degenerative radiographic changes that occur after meniscectomy, he hypothesised that this was caused by increased joint articulation forces and incongruent surfaces (Fairbank, 1948). This study was followed by a decreasing trend in total meniscectomy in order to try and preserve healthy meniscus tissue. Surgeons have increasingly attempted to balance the immediate gratification of potentially relieving pain and mechanical symptoms; with conserving as much native meniscal tissue as possible to prevent future joint degeneration.

Gillquist suggested partial meniscectomy as an alternative to complete meniscectomy in 1982 (Gillquist et al., 1982), and the first account of meniscus transplant was published in 1989 (Milachowski et al., 1989). These studies have led to numerous investigations into different treatment approaches. The largest change in meniscus surgery technique has come with the advancement of arthroscopic surgery and arthroscopic partial meniscectomy is now the most commonly performed meniscus surgery worldwide.

Arthroscopic knee surgery involves the passing of portals into the joint in order to allow visualisation and the use of arthroscope to perform surgery without the need for opening and exposing a joint. Knee arthroscopy is commonly performed using two – three portals (Figure 1.3). Portals are created using a small blade; the first anterolateral portal is typically placed 1 cm above the joint line (Figure 1.3: E) and just next to the patellar tendon in a palpable soft spot, the anteromedial portal is placed 1 cm above the joint line and 1 cm medial to the patellar tendon (Figure 1.3: D), also in a palpable soft spot. A third portal may be created superior and medial to the knee joint line (Figure 1.3: G), allowing fluid to pass out of the knee during surgery (Ward and Lubowitz, 2013). A cannula with a blunt obturator is then used to insert the instruments and camera into the knee join. During APM, light and a camera are passed into the joint through one portal, and tools including a rasping device are passed through the other, these tools are used to clean the edges of torn meniscus and fragments of torn meniscus are removed by grasping and suction through the portals.

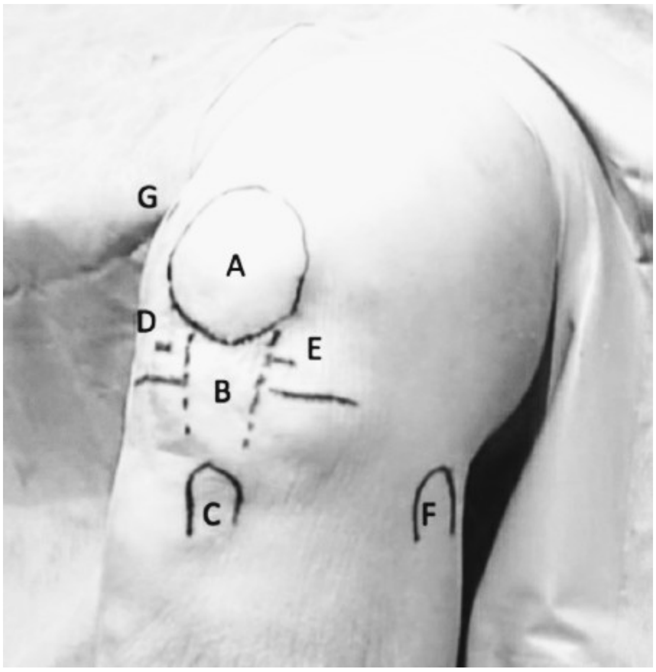


Figure 1.3: Surface Anatomy for knee (left) arthroscopy.

A = patella, B = patellar tendon, C = tibial tubercle, D = anteromedial portal, E = anterolateral portal, F – fibular head, G = optional superior medial portal. (Adapted from (Ward and Lubowitz, 2013)).

In addition to the primary procedure, intraarticular photographs of the meniscus and articular cartilage may be taken prior to and following the procedure for future diagnostic purposes. Local anaesthetic is often used prior to incision and may also be injected into the knee joint following the procedure to provide intra-articular analgesia (Müller-Rath et al., 2010). Peri-operative and post-operate pain killers normally consist of anti-inflammatory medications and opioids (Ekman et al., 2006, Nahravani et al., 2017).

Types of meniscus surgery

While Arthroscopic Partial Meniscectomy (APM) is the most common arthroscopic meniscal procedure, other surgeries include meniscal repair, implantation of a scaffold replacement or meniscus transplantation. Arthroscopic partial meniscectomy is commonly performed in combination with Anterior Cruciate Ligament reconstruction (ACLR) and less commonly with osteochondral surgery to address areas of deficient cartilage on the femur or patella.

Purpose of surgery

The purpose of modern meniscus surgery is to remove obstructive lesions (loose fragments / bucket handle tears) which are resulting in reduced joint movement or mechanical symptoms of the knee such as locking or giving way. Current evidence suggests that priority is given to preserving the non-damaged meniscus tissue and where possible, performing a meniscus repair. However, the majority of modern surgery is still performed as a partial meniscectomy in degenerative knees.

1.2.3 Frequency of Arthroscopic Surgery

Knee arthroscopy is a low risk procedure which can be easily performed in an outpatient or day-admission setting. Frequency of meniscus surgery increased with progressions of arthroscopic techniques and trends have continued to rise over the past few decades.

The past decade has revealed increasing evidence to suggest that degenerative knees do not benefit from surgery. Rates of arthroscopic knee surgery in Sweden and Finland show that this is beginning to affect clinical practice. While the incidence of arthroscopies for degenerative knees declined after 2008 in both Sweden and Finland (Mattila et al., 2016), the rate of surgery was almost double in Finland compared to Sweden. Analysis of public funded knee arthroscopy in the Norwegian national database showed a decrease in arthroscopy for degenerative knees between 2012 and 2016 (Holtedahl et al., 2018).

The number of arthroscopic knee interventions in the UK decreased overall from 2000 to 2012. Arthroscopic irrigation (without debridement) decreased by 80% during this time. Unusually however, the number of arthroscopic meniscal resections performed in people aged over 60, increased by 230% during this time period (Lazic et al., 2014). It is most likely that the majority of these procedures were performed on degenerative knees. The large increase over this period may be due to updating of diagnostic coding to reflect APM rather than debridement.

Irish Rate of Surgery

Data from the Institute of Public Health in Ireland include rates of surgery in Ireland (whole island data including Northern Ireland). Most recent data on the rate of arthroscopic excision of meniscus (between 2005 and 2011) is shown in Figure 1.2 (Ireland, 2016). The overall rate of surgery decreased slightly during this period. Although analysis of this data has not been published; it would appear that there is currently a slight downward trend in the use of arthroscopic meniscus surgery in the Irish public healthcare system.

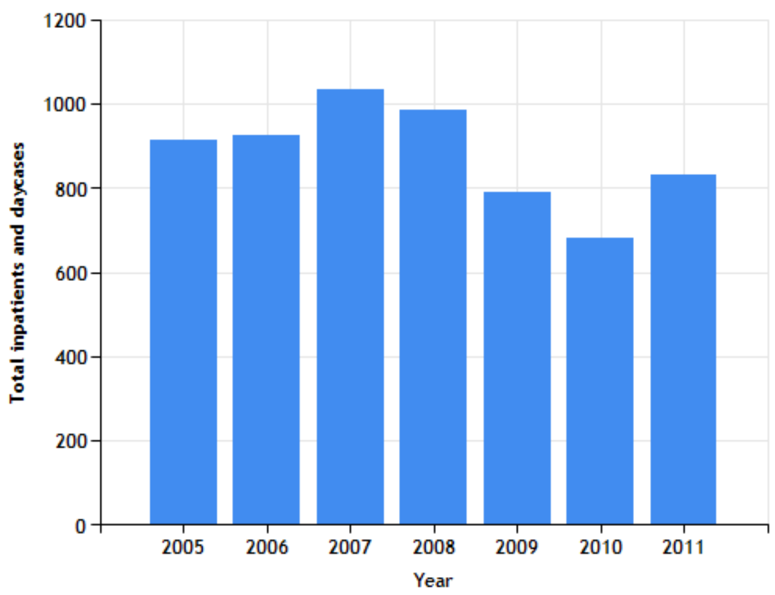


Figure 1.4: Rate of APM in Ireland; 2005 – 2011.

(Adapted from: http://www.publichealthwell.ie/data-visualiser. Reproduced with permission).

Worldwide rate of surgery

Arthroscopic Meniscus Surgery is one of the most common procedures performed by orthopaedic surgeons in the United States (Montgomery et al., 2013). Over half of all outpatient knee arthroscopies performed in the United States between 1996 and 2006 were performed for meniscus tears (Kim et al., 2011), with an increased rate of surgery in middle-aged patients. Analysis of insurance records show that between 2004 and 2009, there was no change in rate of medial or lateral meniscectomy performed. There was a decrease in meniscus repair over this period, and age group analysis showed that repair was more common in younger patients, while meniscectomy was more common in older adults (Montgomery et al., 2013).

While data collection methods are varied and international comparison of trends is difficult, it appears that recent evidence is beginning to affect surgical practice in Europe. The continued high rate of surgery and varied rates of surgery in different regions shows that there is still a lot of variation in clinical practice and vast numbers of arthroscopic meniscal procedures are still being performed on degenerative knees worldwide.

1.3 Outcome of meniscus surgery

Arthroscopic meniscus surgery is still a frequently performed surgery for patients with both degenerative and traumatic meniscus injuries. Currently, debate continues regarding the consequence of meniscus surgery for long-term joint health. Anecdotal reports of athletes returning to high performance activities within days of surgery lends to the ‘bad tooth’ analogy, and many orthopaedic surgeons maintain that patients experience relief from mechanical symptoms. Recent research and guidelines have refuted the benefits of meniscectomy in a degenerative knee (Beaufils et al., 2017a).

Recent guidelines cannot be applied to all patient populations as current research has been performed in mixed populations with diverse injury mechanisms and meniscus tear classifications. It is unclear if certain age groups, genders or populations stratified by sporting / physical activity level may experience long-term benefits from the partial removal / repair of damaged meniscus tissue.

1.3.1 Known outcome of meniscus surgery

Recent research has focussed largely on self-reported outcomes of arthroscopic knee surgery and in particular; the outcome of surgery in the middle-aged and older population. The majority of current evidence applies to degenerative meniscus tears.

The detrimental effects of meniscectomy on joint health have been shown to lead to long-term symptoms and functional deficits. At an average of nineteen years after meniscectomy, patients showed worse self-reported knee function when compared to controls (Roos et al., 2001). In this study, deficits were found in knee-bending and one-leg rising tests, results were confirmed by self-reported function using a knee related questionnaire. Similar deficits were found in quadriceps strength and functional performance 4 years post meniscectomy, in comparison to the non-operated leg of middle aged patients (Ericsson et al., 2006a). Self-reported outcome was measured using the KOOS and objective deficits correlated with worse reported outcome for pain, function and quality of life. Undergoing APM in a degenerative knee is associated with a three-fold increase in the risk of subsequent knee replacement surgery (Rongen et al., 2017).

Self-efficacy of knee function is also reduced following meniscectomy in middle aged patients (Ericsson et al., 2011); this study found that health related quality of life and self-efficacy were both reduced compared to age-matched controls at a mean of three years after meniscectomy.

A systematic review of lower limb strength after meniscectomy shows that middle aged patients undergoing APM have deficits compared to control data, in quadriceps strength both before surgery and up to four years after surgery (Hall et al., 2015b). Research in younger patients undergoing APM have not been consolidated in systematic review, there is a lack of consensus on strength and functional outcomes in this population.

Randomised Controlled Trials

Randomised controlled trials (RCTs) assessing the effectiveness of arthroscopic meniscectomy confirm the findings of earlier research in middle aged patients. A large RCT carried out in North America (Katz et al., 2013c) compared APM to physical therapy in patients who have mild to moderate radiological evidence of osteoarthritis. The primary outcome in this study was a subjective measure (Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)). Findings suggested that surgery was no better than physical therapy outcomes at six and twelve months, although 30% of patients assigned to physical therapy had crossed over to surgery at the six-month time point.

Efficacy of APM for treating degenerative meniscus tears in non-osteoarthritic knees has also been challenged by results of a sham-controlled multi-centre RCT (Sihvonen et al., 2013). This study excluded participants with confirmed osteoarthritis and again used subjective measures of function as the primary outcome (Western Ontario Meniscal Evaluation Tool (WOMET) and Lysholm score). Differences between the APM and sham surgery groups were non-significant at one year post operatively, suggesting that APM does not offer any benefit in this population.

(Kise et al., 2016a) and (Stensrud et al., 2015) report a Norwegian RCT of supervised exercise therapy versus APM. The population of this study had younger mean age than previous populations (49.6 years) and 96% did not have definite radiographic osteoarthritis. Patients were followed up subjectively for two years, with objective strength and performance (single leg hop test, six-metre hop test and 30-second knee bend) assessed at three and twelve months. No clinically significant difference was found between groups in any of the outcome measures, suggesting that exercise interventions are a viable treatment option for degenerative meniscus tears in the absence of radiographic osteoarthritis.

Guidelines

Following the increase in evidence suggesting that APM does not add benefit to patients with a degenerative knee, a number of practice guidelines have been developed to inform and update clinical practice. The British Medical Journal triggered a Rapid Recommendation Cluster of experts following their publication of the 2016 study examining APM versus exercise therapy (Kise et al., 2016a). This process culminated in the publication of a clinical practice guideline for the use of arthroscopy in the management of meniscus tears in a degenerative knee (Siemieniuk et al., 2017). This guideline made a strong recommendation against the use of arthroscopy for nearly all patients with a degenerative knee, regardless of whether osteoarthritis is evident on radiography or not.

The European Society for Sports Traumatology, Knee Surgery, Arthroscopy (ESSKA) carried out the “ESSKA Meniscus Consensus Project” and published their consensus on the management of degenerative meniscus lesions (Beaufils et al., 2017a). The primary suggestion of this consensus was to advise against the use of APM as first line treatment for degenerative meniscus lesions and reserves the use of arthroscopy for patients who have not responded to non-operative management following a thorough work up.

Mounting evidence has confirmed that the use of APM to treat degenerative meniscus lesions is not superior to exercise therapy. Systematic review, meta-analysis and expert consensus guidelines published from 2017 have consolidated this research into Level 1 evidence based guidelines which should guide current practice in Europe, Ireland and Internationally.

1.3.2 Unknown outcome of surgery

Despite the emergence of recent evidence on the management of degenerative knee lesions, there are still questions to be answered on the use of arthroscopy for the management of meniscus lesions in non-degenerative populations. No RCTs have been reported comparing surgery to non-surgical interventions (sham surgery / exercise therapy) in younger populations. The long-term outcome of surgery in more active populations is not known. Objective measures of high performance are also not known in arthroscopic meniscus surgery populations. The effect of physical activity and training on outcome of meniscus injury or meniscus surgery is poorly researched longitudinally. Most exercise interventions are reported as short-term alternatives to surgery, and very few studies looking at change in objective physical performance over time. There is a lack of data reporting change in objective physical performance from before to after surgery.

The effect of meniscus injury on frequency and grading of habitual exercise is also poorly understood. Regular physical activity may reduce the risk of knee osteoarthritis (Rogers et al., 2002) which is a consequence of meniscus injury, and traumatic meniscus injuries often occur due to twisting of the knee during sporting activities (Rath and Richmond, 2000). Exercise is of huge importance to both degenerative and traumatic meniscus injury populations; structured rehabilitation is a frequent component of conservative management and post-operative treatment. Despite the relevance of physical activity, activity levels are poorly reported and classified in APM literature.

1.4 Definition of successful treatment

Implementing recent evidence and guidelines in clinical practice creates a challenge for many clinicians; probable outcome of surgery must not be predicted solely based on research publications. Clinicians who manage patients with meniscus injuries must interpret this evidence critically and decide if arthroscopic surgery is a viable treatment option. In order to improve clinical practice in this area, a definition of success that incorporates both research based guidelines and clinically relevant outcomes is needed. A surgeon or physiotherapist treating patients with knee injuries should make a decision on the likely success or failure of a surgical intervention based on the current evidence and also the individual patient who they are treating. Predictors of outcome following APM are unclear and the expected outcome for individual patients is not always straightforward.

The concept of evidence based medicine informs clinical practice internationally and necessitates ongoing research into the effectiveness of current treatment standards. Evidence based medicine is defined as integrating the best external evidence with individual clinical expertise and patients' choice (Sackett et al., 1996). This model is shown in Figure 1.3 and often underpins the translation of research into clinical practice.

In the context of APM usage in the treatment or meniscus injuries, external evidence (RCTs guidelines etc.) must also be interpreted in the context of both clinical expertise and patient values / expectations. Clinicians must be aware of research guidelines and external evidence but also integrate their own clinical experience and the expectations of their patients in order to plan and implement an evidence based treatment plan. Current evidence does not fully inform the treatment of all patient groups, as outlined in Section 1.3.2.

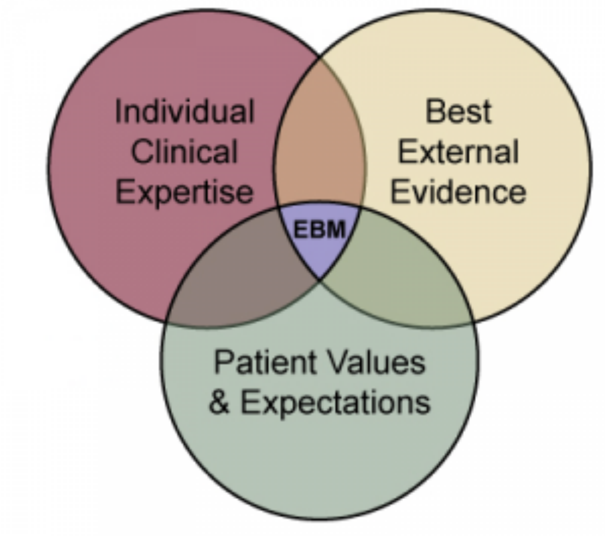


Figure 1.5:Sackett's model of Evidence Based Medicine
(Adapted from (Sackett et al., 1996)).

1.4.1 Significance of objective function

Best external evidence for the treatment of non-degenerative meniscus injuries and the management of patients with high levels of habitual physical activity is currently lacking. Although meniscus injury frequently occurs with ACL injury, there is little evidence of how meniscus injury should be managed in more active populations. Meniscus tears have been found in 73% of acute ACL tears and 85% of chronic ACL tears, with a higher proportion of medial than lateral tears, many of which require partial meniscectomy at the time of ACL repair (Hagino et al., 2015).

The mechanism of non-degenerative meniscus injuries is often a twisting movement of the knee and can occur in young otherwise healthy individuals during both sporting and everyday activities. The relevance of physical performance and habitual physical activity in a more active and often younger, traumatic meniscus injury population is unknown. The significance of physical activity level and pre-injury strength / functional performance is very difficult to establish without very large cross sectional studies of the general population. It is likely that the acute and long-term results of meniscus injury would have an even larger effect on quality of life and self-efficacy in this non-degenerative population. Recent research has not focussed on this population or included measures of higher level physical activity which may be unique to non-degenerative populations.

Relying solely on self-reported measures of outcome is insufficient in highly active populations as these measures cannot detect objective deficits such as strength or compensatory movement patterns, of which respondents may be unaware. In order to investigate any potential association between high level physical performance and results of meniscus injury / surgery, it is necessary to gather data on objective physical performance in populations which include non-degenerative meniscus lesions. High performing individuals with traumatic meniscus tears may be suitable for performance testing similar to that of athletes undergoing ACLR (speed hop tests etc).

1.4.2 Significance of expectations of surgery

Establishing best external evidence for management of meniscus injury has received a lot of research attention in recent years. Less attention is given to establishing the other elements of evidence based medicine; quantifying clinician expertise and patient expectation of meniscus surgery. Clinicians develop expectations of surgery based on training and previous clinical experience. Patient expectation is often independent of evidence but plays a key role in establishing shared decision making.

What is expected of meniscus surgery?

Despite the frequency of arthroscopic meniscus surgery, little is known about the expectations of patients or clinicians managing these patients. Clinicians have varied expectation of recovery time following arthroscopic meniscectomy, with the average expected recovery time reported by surgeons as 5 weeks following isolated meniscus tear (Roos et al., 2000b). This expectation does not match the trajectory of functional performance found in systematic review of younger or older patients undergoing meniscectomy (Hall et al., 2015b, Thorlund et al., 2017b). Systematic review has also shown that patients frequently overestimate the benefits of treatments (Hoffmann and Del Mar, 2015). Patient expectations of demanding physical activities following knee joint surgery are often not met (Nilsdotter et al., 2009) and fulfilment of pre-operative expectations of surgery is one of the main determinants of patient satisfaction (Bourne et al., 2010). Establishing current expectations of both clinicians and patients is necessary in order to improve shared decision making based on accurate external evidence.

Clinician beliefs, rather than clinical expertise, often dictates treatment prescription (Haynes et al., 2002) and this can cause large variability in how similar conditions are managed by multiple clinicians. This may explain the continuing use of APM for patients with degenerative knees, despite recent literature and guidelines. Many surgeons suggest that patients with a traumatic knee injury and particularly mechanical symptoms of the knee causing pain, will benefit from APM regardless of the presence of osteoarthritis. Given the difficulty in manging these symptoms, surgery is often seen as the best option, but whether or not this hypothesis is correct has not been proven. Recent evidence has shown that APM has no added benefit over sham surgery in relieving mechanical symptoms, and that presence of mechanical symptoms pre-operatively does not correlate with presence of meniscus tears or other joint pathologies at arthroscopy (Sihvonen et al., 2016, Thorlund et al., 2019, Pihl et al., 2019).

Over optimistic expectations regarding leisure activities and recovery were found in a recent cohort study of middle aged patients (Pihl et al., 2016b). It is necessary to further establish what patients expect when going for surgery – particularly more active patients who have a traumatic meniscus injury and may experience a large and acute change in physical performance.

Why is expectation important?

Patient values and expectations are a key factor in the Sackett model of evidence based medicine; understanding patient expectations of meniscus surgery is key to ensuring optimal clinical practice. The expectation of young and active individuals who experience an acute change in their physical activity and ability to perform higher functioning physical tasks is especially important. If clinicians believe that these patients will benefit from surgery, it is crucial that this is based on robust clinical evidence and not just biased clinical beliefs. Establishing current expectation of surgery and how this relates to physical activity / sporting performance can better guide the use of meniscus surgery in patients with acute meniscus injury.

1.5 Summary

Arthroscopic Partial Meniscectomy is a simple procedure performed worldwide in the management of patients with symptomatic meniscus tears. Recent evidence suggests that arthroscopy is not a beneficial treatment for patients with a degenerative knee. Evidence for the use of APM in non-degenerative knees is sparse and much of the current data is based on self-reported outcomes rather than objectively measured function following APM. Further research is needed to explore the current rationale for surgical selection and confirm with objective data, the findings of patient reported outcome measures, specifically including patients without concurrent degenerative changes in the knee.

1.6 Aim of thesis

To investigate expectations, functional performance and activity level in a cross sectional population of patients undergoing arthroscopic meniscus surgery of the knee.

1.7 Objectives of thesis

1. Review the evidence examining functional outcomes of arthroscopic meniscus surgery and identify gaps in current knowledge.
2. Investigate functional ability and activity levels in a cross-sectional cohort of patients undergoing arthroscopic meniscus surgery (pre-operatively).
3. Investigate functional ability and activity levels in a cross-sectional cohort of patients who have undergone arthroscopic meniscus surgery (post-operatively).
4. Investigate the relationship between functional status / activity levels, and surgical findings / patient demographics in patients undergoing arthroscopic meniscus surgery.
5. Assess the relationship between measures of post-operative physical function and activity level in this population.
6. Explore the current rationale for APM by comparing both clinician and patient perspectives of arthroscopic meniscus surgery.

1.8 Hypothesis

Due to the explorative nature of this thesis, an overall hypothesis was not determined prior to beginning research. In light of current evidence and a lack of research on longitudinal objective function in this population, a working hypothesis was maintained throughout the project; that objective functional outcome of arthroscopic partial meniscectomy is predicted by pre-operative function and activity level.

2 Literature Review

Although recent guidelines do not recommend meniscectomy for degenerative tears of the meniscus, a large number of arthroscopic meniscectomies continue to be performed. There is a lack of clarity on the effect of physical activity on the outcome of meniscectomy, particularly participation in higher level sporting activities and the outcome of surgery in athletes and highly active individuals. This population often perceive surgery as a quick fix to allow them to return to their activities after a traumatic meniscus tear.

In order to consolidate current evidence in more highly active individuals, review of current literature was carried out. Objective measures of physical performance are essential in these populations as they are often used to guide decisions around return to sports in arthroscopic knee surgery patients. Objectively measured strength is often taken as an indicator of physical function, and functional performance tests are used to determine if there is a residual deficit in performance capacity. Upon initial screening of articles and search of ongoing systematic reviews, an ongoing review at the University of Southern Denmark was identified through the PROSPERO registry of systematic reviews. A research collaboration was established and literature review was focussed on two separate systematic reviews.

The first systematic review followed on from published work which reviewed objective strength in middle aged adults (Hall et al., 2015b). A systematic review and meta-analysis were performed of self-reported function and objectively measured strength in younger adults undergoing arthroscopic meniscus surgery. The second systematic review examined performance tests (objective measures of lower limb capacity) such as hop tests in patients of any age undergoing arthroscopic meniscus surgery. These two reviews together synthesise current knowledge, summarising objective measures of functional performance in patients undergoing arthroscopic meniscus surgery of the knee.

2.1 Systematic Review 1:

Strength trajectory in young patients undergoing arthroscopic meniscus surgery for meniscus tears: A systematic review and meta-analysis.

This section has been published and reformatted as part of the current chapter.
(Jonas Thorlund completed the electronic search and Risk of Bias Assessment, Lasse Østengaard and Claus Jørgensen completed the title and abstract screening, Carsten Juhl assisted with the risk of bias screening, Fiona Wilson assisted with the data extraction; Nathan Cardy completed the data extraction, manuscript review and reformatting.

> Thorlund JB, Østengaard L, **Cardy N**, Wilson F, Jørgensen C, Juhl CB. (2017). Trajectory of self-reported pain and function and knee extensor muscle strength in young patients undergoing arthroscopic surgery for meniscal tears: A systematic review and meta-analysis. *Journal of Science and Medicine in Sport*. 20 (8), 212-217.

2.2 Introduction

Recent systematic reviews and meta-analyses have reported no better effect of arthroscopic partial meniscectomy on patient reported pain and function compared to placebo or in addition to exercise for middle-aged and older individuals with degenerative meniscal tears (Khan et al., 2014, Thorlund et al., 2015). In addition, these patients show impaired knee extensor muscle strength up to 4 years after arthroscopic partial meniscectomy (Hall et al., 2015b).

In contrast to degenerative meniscal tears, traumatic tears typically occur in younger adults as a result of an acute injury (Poehling et al., 1999). However, knowledge about the trajectory of self-reported pain and function in young patients with meniscal tears as well as the recovery of muscle strength after surgery is not well understood. This is largely due to most previous studies including mixed cohorts of young and old patients as well as poor recording of symptom onset. Furthermore, no randomized trials exist that have investigated the effect of surgery in comparison to non-surgical treatment alternatives for young patients with meniscal tears (Thorlund et al., 2015).

Patient-reported outcomes are generally considered most appropriate to assess the patient's perspective of their own health status. However, recovery of muscle strength is also considered to be important for young individuals in order to regain capacity to participate in sports or other activities as both pre- and post-operative knee extensor strength have been reported to predict better functional outcome of knee surgery (Pietrosimone et al., 2016, Eitzen et al., 2009).

Thus, the aim of this study was to conduct a systematic review and meta-analysis to investigate the trajectory of patient reported pain and function and knee extensor muscle strength over time in young individuals undergoing arthroscopic meniscal surgery

2.3 Methods

This systematic review and meta-analysis was performed according to the recommendations in The Cochrane Handbook for Systematic Reviews of Interventions (Higgins and Green, 2011), and the findings were reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guideline (Moher et al., 2009). The study protocol (Appendix 1) was registered in PROSPERO (http://www.crd.york.ac.uk, ID: CRD # 42015019815).

2.3.1 Search Strategy:

Electronic searches were performed in MEDLINE via PubMed, SPORTDiscus via EBSCO, CINAHL via EBSCO, EMBASE via Ovid, Cochrane Central Register of Controlled Trials (CENTRAL) and Web of Science up to November 2nd 2015 and updated on October 13th 2016 by one of the authors (CBJ). A manual search of reference list from relevant articles was also conducted. Key search terms were searched as keywords and text words in title and abstracts to create two separate filters, which were then combined. These filters were:

i) Population: 'meniscus', 'arthroscopic surgery'

ii) Outcome: 'muscle strength', 'function' and 'pain'.

The complete search strategy is presented in Appendix 2. No restriction on language or year of publication was applied.

2.3.2 Eligibility Criteria:

Studies of any design, were included if they met the following criteria:

Population and intervention:

Young adults (in this study defined as a mean age of the included participants between 18 and 30 years) undergoing arthroscopic surgery (i.e. repair or partial resection) for a meniscal tear.

Outcomes

1) Self-reported pain and/or function reported on a separate subscale (i.e. not aggregate score)
2) Muscle strength: isometric or isokinetic knee extensor muscle strength measured in the leg undergoing surgery.

Comparison:

1) Self-reported pain and/or function in a non-operative control group (or healthy controls).
2) Isometric or isokinetic knee extensor muscle strength assessed in either a healthy control group or in the contralateral leg of the meniscal patient.

Only full text studies published as original articles were included.

2.3.3 Selection of studies:

Following omission of duplicates from the initial search, two authors (LØ and CJ) independently screened the articles by title and abstract to exclude irrelevant studies. Full-text of all articles considered relevant by either of the two reviewers, was obtained and screened for eligibility by both reviewers.

2.3.4 Data Extraction

To describe the time course of self-reported pain and function and muscle strength deficits the following seven time points were decided a priori for data extraction:

- Pre-surgery
- 1 week post-surgery
- 3-4 weeks post-surgery
- 12 weeks post-surgery

- 6 months post-surgery
- 24 months post-surgery
- 48 months post-surgery.

Data extraction was performed independently by two authors (NC and FW) on published data only. The following information was extracted: authors; publication year; number of participants in surgery group and control group (if applicable); gender; age; technique used to measure strength; outcome measure used for assessing pain and function, mean and standard deviation of the pain scores, function scores and the assessment of knee extensor muscle strength, and time point for measurement.

Predefined hierarchies were used to extract data from studies that had used more than one approach to assess patient reported outcomes and muscle strength. The hierarchy for selection of pain and function has previously been published (Juhl et al., 2012). The hierarchy for knee extensor muscle strength comparison was:

1) healthy controls
2) contralateral leg

The hierarchy for technique used to assess knee extensor muscle strength was:

1) isometric strength
2) isokinetic strength at 60°/sec
3) isokinetic strength at 30°/sec
4) isokinetic strength at 120°/sec
5) isokinetic strength at 180°/sec
6) isokinetic strength at 240°/sec.

For isokinetic strength, concentric strength scores were extracted in the case where eccentric scores were also available.

2.3.5 Data synthesis

Effects were calculated as the standardized mean difference (SMD) to allow pooling of the various outcomes assessed in individual studies. The SMD was estimated as the difference between the surgical leg and the contra-lateral and/or healthy control leg divided by the pooled standard deviation. Standard deviations were extracted or estimated from standard errors, *P*-value, 95% confidence intervals, or extracted from figures when numbers were not available. In case of lacking or incomplete data, attempts to contact authors were made.

A meta-analysis was applied on the SMD of pain, function and knee extensor muscle strength. Random effect models were used as large heterogeneity was expected due to the different approaches used to compare (i.e. controls or contralateral leg) and assess knee extensor muscle strength (i.e. isometric or isokinetic) as well as different pain and function scores. A standard Q-test was used to test the heterogeneity between studies (Cochran, 1954), and the I^2 statistic measuring the proportion of variance attributable to inconsistency was subsequently calculated (Higgins et al., 2003, Higgins and Thompson, 2002). An I^2 equal to 0% indicate minimal inconsistency and an I^2 equal to 100% indicate maximal inconsistency between individual study results. Furthermore, the Tau^2 value expressing the between study variance was estimated. Covariates are defined as variables able to reduce the Tau-squared value when included in the analysis.

2.3.6 SMD Interpretation

A SMD of 0.2 was considered small, 0.5 moderate and greater than 0.8 was considered large (Cohen, 1988). Although, the SMD permits inclusion of studies using various approaches to assess strength, the SMD is not easily interpreted. Therefore, to improve interpretability and approximate the overall SMD values for knee extensor weakness, an algorithm was applied using previously described methods to convert SMD values to percentage differences (Bliddal and Christensen, 2009). This conversion was based on descriptive knee extensor strength data obtained from 3 studies on a total of 74 young healthy controls (20-30 years of age) (Appendix 3) (Danneskiold-Samsøe et al., 2009, Santos et al., 2010, Bolgla et al., 2015).

2.3.7 Risk of Bias Assessment

Two reviewers (JBT and CBJ) independently assessed study quality with regard to risk of bias based on guidelines from the Scottish Intercollegiate Guidelines Network (SIGN., 2015). Prior to assessing the risk of bias of the studies, two authors (JBT and CBJ) set guidelines for scoring each of the criteria in the checklist as detailed in Appendix 4. Each of the criteria listed in Supplementary Table 2 was scored 'Adequate', 'Unclear' or 'Inadequate'. Disagreement was solved by discussion. As described in SIGN50 (SIGN., 2015), the overall risk of bias was judged as 'low' if the majority of the criteria were appropriately met, moderate if most criteria were met (i.e. some flaws in the study associated with risk of bias), overall risk of bias was judged as high if most criteria were not met or significant flaws relating to key aspects of the study design was not met (i.e.

for this study validity and reliability of outcome assessment and blinding of outcome assessors was considered key aspects).

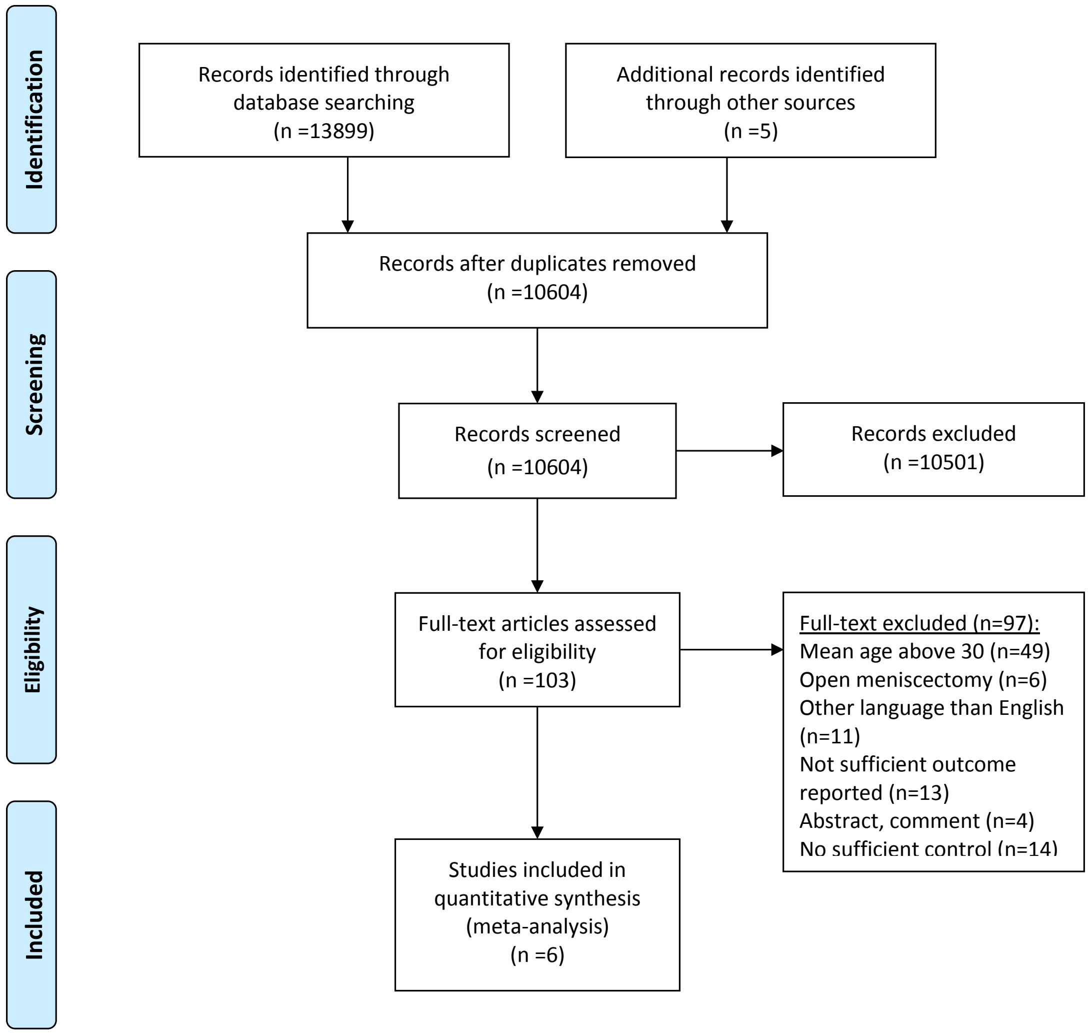


Figure 2.1 Flow Chart of the search and final inclusion of studies

2.4 Results

The search strategy identified 10604 articles after exclusion of duplicate records (Figure 2.1). No studies fulfilled the eligibility criteria on patient reported pain and function. Six studies fulfilled the eligibility criteria for inclusion in the analysis on trajectory of knee extensor muscle strength (deSouza FK, 1992, Eller et al., 1999, Gapeyeva et al., 2000, Gapeyeva et al., 2001, Huber et al., 2013, Ford et al., 2011).

Studies included 137 participants who were predominately male, with the mean age in individual studies ranging from 20 to 29 years (Table 2.1). Only one study included patients that underwent meniscal repair (Huber et al., 2013), the remaining studies included only patients undergoing arthroscopic partial meniscectomy (deSouza FK, 1992, Eller et al., 1999, Gapeyeva et al., 2000, Gapeyeva et al., 2001). Between 35 and 53 patients were assessed

Author and Year	Study-design	Group age at baseline, mean ± SD	Number of participants, n (%, male)	Comparator	Strength assessment	Units	Time points
deSouza et al.1992	Observational	APM 29 yrs	26 (85%)	Contralateral leg	Isometric	Nm	PRE surgery
Eller et al. 1999	Observational	APM 24 yrs	13 (61%)	Contralateral leg	Isometric	N	6 months post-APM
Gapeyeva et al. 2000	Observational	APM 26 ± 9 yrs	21 (100%)	Contralateral leg	Concentric at 60°/sec	Nm	2-4 weeks post-APM 3 months post-APM 6 months post-APM
Gapeyeva et al. 2001	Observational	APM 26 ± 9 yrs	14 (100%)	Contralateral leg	Isometric	N	PRE surgery 2-4 weeks post-APM 3 months post-APM 6 months post-APM
Ford et al. 2011	Observational	APM 20 ± 3 yrs Controls 20 ± 3 yrs	9 (78%) 9 (78%)	Healthy control leg	Concentric at 60°/sec	Nm/kg	3 months post-APM
Huber et al. 2013	Observational	APM 26 ± 5 yrs Repair 23 ± 9 yrs Controls 25 ± 4 yrs	15 (40%) 15 (53%) 15 (Not available)	Healthy control leg	Isometric	Nm	12 months post-APM

APM = arthroscopic partial meniscectomy

Table 2.1: Characteristics of included studies

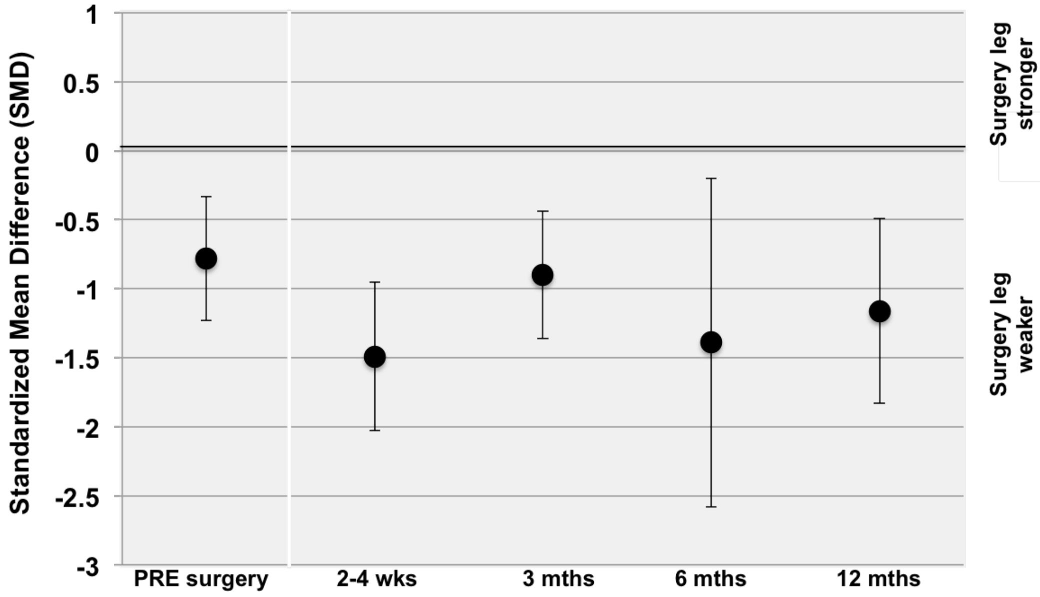
at each time point and no studies assessed knee extensor strength after 12 months. In 4 studies the contra-lateral leg was used as the comparator and in 2 studies healthy controls acted as the comparator group (Table 2.1).

Knee extensor muscle strength seemed to be impaired up to 12 months after meniscal surgery (Figure 2.2 and table 2.2 for specific estimates). At 12 months legs undergoing meniscal surgery were around 25% weaker compared with control legs (SMD: -1.16; 95% CI: -1.83, -0.49 - for conversion of SMD to % see Appendix 3). Sensitivity analyses excluding patients with meniscal repair (n=15) at the 12 months time point demonstrated similar SMD as when these where included in the analysis (SMD: -1.31; 95% CI: -2.10, -0.51).

The overall risk of bias was judged as high across all studies, as several items in the SIGN 50 was not appropriately met (Appendix 4). Especially, none of the included studies reported any effort in blinding the outcome assessors and the validity and reliability of the outcome measurements were not stated. None of the included studies addressed that participants could have had lower muscle strength in the operated leg before surgery. Lastly, the influence of potential confounders was not addressed in any of the included studies.

Time Point	SMD (95% CI)	Study	Surgery leg (Mean ± SD)	Comparator (Mean ± SD)
Pre-surgery	-0.78 (-1.23, -0.32)	deSouza et al. (1992)	146.7 ± 52.9 Nm	191.3 ± 49.1 Nm
		Gapeyeva et al. (2001)	460.6 ± 151.2 N	541.4 ± 90.7 N
Post-surgery				
2-4 weeks	-1.49 (-2.03, -0.95)	Gapeyeva et al. (2000)	163.8 ± 39.9 Nm	229.5 ± 34.8 Nm
		Gapeyeva et al. (2001)	404.0 ± 151.2 N	557.6 ± 90.7 N
3 months	-0.90 (-1.36, -0.44)	Gapeyeva et al. (2000)	190.4 ± 42.2 Nm	237.4 ± 42.2 Nm
		Gapeyeva et al. (2001)	460.6 ± 120.9 N	565.7 ± 60.5 N
		Ford et al. (2011)	2.5 ± 0.7 Nm/kg	2.7 ± 0.6 Nm/kg
6 months	-1.39 (-2.58, -0.21)	Eller et al. (1999)	548.2 ± 54.1 N	705.4 ± 48.2 N
		Gapeyeva et al. (2000)	194.6 ± 46.3 Nm	237.8 ± 42.2 Nm
		Gapeyeva et al. (2001)	517.2 ± 90.7 N	565.7 ± 90.7 N
12 months	-1.16 (-1.83, -0.49)	Huber et al. (2013)	130.2 ± 14.8 Nm	147.6 ± 14.8 Nm

Table 2.2: Overview of included data for meta-analysis at each time point



No. of studies	2	2	3	3	1
Patients (n)	40	35	53	48	45
I^2 (%)	0	0	7	84	-
p-value (I^2)	0.63	0.34	0.34	0.002	-

Figure 2.2: Metaanalysis of strength

Standardized mean difference (SMD) with 95% confidence intervals in knee extensor muscle strength between individuals undergoing meniscal surgery and controls over time. Positive values indicate that the surgery leg is stronger than controls, and negative values indicate that the surgery leg is weaker than controls. Where applicable, each time point represents an individual meta-analysis.

2.5 Discussion

In this systematic review and meta-analysis no randomized trials were found comparing the trajectory of patient reported pain and function for young patients undergoing meniscal surgery compared with non-operative treatment. No studies were found comparing the trajectory of pain and function after surgery to a healthy control group. Six studies were included in the analysis on the trajectory of knee extensor muscle strength over time compared to healthy controls or the contra-lateral leg of the included patients. Impaired muscle strength was observed up to 12 months after meniscal surgery. However, given the risk of bias assessment, the observational nature and the limited amount of patients in the included studies the certainty of estimates should be interpreted with caution.

The present study aimed to include young individuals with traumatic meniscal tears, as most previous systematic reviews have focused on assessing pain, function and knee extensor strength in middle-aged and older patients with degenerative meniscal tears (Khan et al., 2014, Thorlund et al., 2015, Hall et al., 2015b, Swart et al., 2016). As recently reported (Thorlund et al., 2015), no randomized trials comparing arthroscopic surgery to non-operative treatments were found for young adults. Such trials are critically needed to assess the effectiveness of surgery compared with non-operative treatments for young patients with meniscal tears. As lack of randomized trials was anticipated the current study allowed for non-randomized comparative studies including either a non-operative comparative group or a healthy control group to assess the trajectory of patient reported pain and function. However, no such studies were found. Furthermore, most studies that included some form of patient reported outcome used the Lysholm score, but none of the studies included a control group for comparison.

A priori it was decided to include only studies that presented separate patient reported outcomes of pain and function. Several knee scores exist that use composite scores of 'knee function', and arbitrarily aggregate differently weighted items assessing sometimes related, but commonly distinctly different, constructs such as swelling, instability, and ability to walk one block into one overall score. It is generally accepted that distinct outcomes should be reported separately at the different levels according to the World Health Organization (WHO) International Classification of Functioning. According to this classification, pain belongs to the "Body function and structure" and physical function to the "Activity" level (Karsten Dreinhöfer, 2004).

Analyses of strength suggested that reduced knee extensor muscle strength is present in young patients with meniscal tears before surgery and seem to increase within the first 2-4 weeks after surgery. This is likely caused by an inevitable surgery induced trauma. It is unclear why reduced knee extensor strength is present before surgery, and why it persists up to 12 months following surgery. Possible explanations may be reduced physical activity or muscle atrophy and/or arthrogenic muscle inhibition, which have been suggested to be caused by injury and/or surgery and thought to affect knee extensor muscle function for extended periods of time (Rice and McNair, 2010).

Knee extensor muscle strength seemed to be impaired up to 12 months after surgery. Patients in all included studies (deSouza FK, 1992, Eller et al., 1999, Gapeyeva et al., 2000, Gapeyeva et al., 2001, Huber et al., 2013) received some form of post-operative rehabilitation. These rehabilitation protocols may have been of too poor quality (i.e. low intensity and/or frequency, lack of progression, etc.) to elicit improvements in muscle strength. Specifics of rehabilitation protocols were not well described thus no firm conclusions can be drawn on this. Nevertheless, a recent systematic review did not find any difference in effect of rehabilitation after meniscal surgery, regardless of rehabilitation type (though the included patients were somewhat older than in the present study) (Swart et al., 2016).

A recent study on knee extensor strength in middle-aged and older patients with degenerative tears found that knee extensor strength was impaired up to 48 months after arthroscopic partial meniscectomy (Hall et al., 2015b). From the available data it is unknown how the trajectory of knee extensor muscle strength proceeds after 12 months in young patients with meniscal tears. Nevertheless, 25% lower knee extensor strength in the surgery leg 12 months post-surgery is considered clinically relevant as return to sport criteria for patients with knee injuries such as anterior cruciate ligament injury is often considered to be less than 10% strength difference between legs (Grindem et al., 2016).

The 6 studies included in this review were all considered to have a high risk of bias, as none of the studies scored 'adequate' on all applicable criteria. The main methodological considerations that influence the quality of the studies in the current review relate to all studies failing to blind the outcome assessor to which leg had the meniscal tear. Furthermore, no studies addressed the potential influence of any confounders, such as sex in their analysis. Another consideration relates to units of strength, where two studies failed to adequately report strength as Nm. We consider strength as the generation of muscle force in combination with the moment arm of the muscle. As such, strength is optimally reported as the product of the force (N) and the distance (m) from axis of rotation to where the transducer attaches to the limb (Jaric, 2002). Clinicians and researchers should be aware of these methodological considerations when designing future studies and interpreting strength related measures.

Limitations of this study warrant consideration. Firstly, it is important to consider that the described trajectory is a combination of data from individual studies at each time point and do not represent longitudinal data. Secondly, our findings and point estimates should be interpreted with caution due to high risk of bias (i.e. low study quality), the size of the individual studies and the small number of studies available for meta-analysis at each time point. Furthermore, only one study was available at 12 months and the SD had to be estimated for this study as we failed to get additional data from the authors. Thirdly, our aim was to primarily include young patients with traumatic meniscal tears. However, symptom onset was not reported in the included studies, thus some patients may have had non-traumatic injuries. In addition, the results of this study cannot be generalized to middle-aged and older individuals with degenerative meniscal tears. Lastly, we had to deviate from the registered study protocol on 2 accounts. We decided to adjust the age criteria from “more than 80% of study sample are older than 30 years or more than 80% of study sample are younger than 18 years” to “studies with a mean age between 18-30 years” in order to include more studies in the analysis. Thus, some studies include a smaller proportion of patients above 30 years of age. The time point “3-4 weeks” was adjusted to “2-4 weeks” to be able to include 2 studies for analyses at this time point.

2.6 Conclusion

No randomized trials where found comparing the trajectory of patient reported pain and function for young patients undergoing meniscal surgery with non-operative treatments. No studies were identified comparing the trajectory of pain and function to a healthy control group. Knee extensor strength seemed to be impaired up to 12 months after surgery in young patients undergoing surgery for meniscal tears. The results of the present study should be interpreted with caution due to a limited number of available studies with high risk of bias including relatively few patients. This systematic review highlights the need for randomized trials comparing the effectiveness of arthroscopic meniscal surgery for young adults to non-operative treatment as well as longitudinal studies to better appreciate the trajectory of muscle strength recovery over time.

2.7 Practical Implications

Inferences about improvements in pain and function after meniscal surgery in young adults are based on data with no comparison to non-surgical treatments or reference groups as no such studies were identified. Knee extensor strength seems to be impaired in young patients undergoing meniscal surgery up to 1 year after surgery. These results indicate a potential for rehabilitation of muscle strength within the first year after surgery. Results from this study should be interpreted with caution due to a small number of studies including few patients and having a high risk of bias.

2.8 Systematic Review 2:

Systematic Review and meta-analysis of objective functional performance prior to and following arthroscopic meniscus surgery.

2.9 Background

Following arthroscopic partial meniscectomy, rehabilitation programs often target strength; success is often defined as the return of full strength and self-reported function. Strength measurements only assess one construct of overall physical function; objective functional assessment can be used to quantify physical function and establish if any true deficits in physical performance exist following surgery. Many measures of objective function are used in patients undergoing APM and populations at risk of knee osteoarthritis (Kroman et al., 2014), quantifying performance of functional tasks rather than strength alone. This second literature review adds to the summary of current literature already discussed on self-reported and strength measures in this population and aimed to examine measures of knee specific functional performance across any arthroscopic meniscus surgery study population.

2.10 Objectives

This second systematic review was performed to examine objective performance measures in arthroscopic meniscus surgery populations before and after surgery. The protocol for this systematic review has been published on the PROSPERO International retrospective repository of systematic reviews (Appendix 5: PROSPERO registration: Systematic Review 2). https://www.crd.york.ac.uk, ID: CRD # 42017050313.

2.10.1 Review questions

1) Do objective functional performance limitations exist in patients scheduled for arthroscopic meniscus surgery (pre-surgery)?

2) Do objective functional performance limitations exist in patients who have undergone arthroscopic meniscus surgery (post-surgery)?

3) What is the timeline of functional performance changes in patients who have undergone arthroscopic meniscus surgery?

4) Does physical activity level change in patients who undergo arthroscopic meniscus surgery and what is the timeline of changes in activity?

5) Does participation in structured rehabilitation (physiotherapy, group exercise, home exercise programs) influence objective measures of functional performance in patients before or after arthroscopic meniscus surgery?

2.11 Methods

2.11.1 Criteria for considering studies for this review

Studies were restricted to English language publications. No start date restriction was applied, and all articles to date of search were included. Only case reports and commentaries / reviews of other articles were excluded from screening. Publications as conference abstracts were only included if they contained data on an objective performance measure and met all of the inclusion criteria. Conference publications were excluded if they formed part of studies which were also included as journal articles (excluded as duplicates).

2.11.2 Types of participants

Inclusion:

- Studies including patients of any age over 18 years old, undergoing arthroscopic meniscal surgery.
- Studies where the primary or secondary outcome measure was an objective performance test.

Exclusion:

- Studies where the primary surgical procedure was a ligament reconstruction (ACL / PCL) combined with meniscectomy.
- Studies where the surgical procedure was arthroscopy assisted, but not true arthroscopy (eg. Meniscal Allograft Transplantation).

2.11.3 Types of interventions

Objective functional performance measures – objective tests designed to assess functional ability of the knee joint, excluding self-reported measures. These measures included both clinically driven and research-based outcome measures, Studies on functional performance (i.e. Jump tests, running tests, agility tests, etc.) were included, tests of biomechanical kinetics/kinematics or tests of proprioception were not considered as functional performance tests.

Inclusion:

- Validated or clinically relevant objective measures of physical function or performance.

Exclusion:

- Measures of self-reported physical function.
- Measures of knee strength as an indicator of function, rather than an objective measure of function.

2.11.4 Types of outcome measures

In order to capture all published data on objective physical performance measures, the inclusion & exclusion criteria were deliberately broad and inclusive.

Primary outcomes

Due to the heterogeneous nature of functional assessment and the multitude of functional measures in use by clinicians and researchers, a single primary outcome measure was not selected prior to article screening. As previously published reviews of functional measures in young and middle aged people known to be at risk of knee OA (Kroman et al., 2014) indicated that functional hop tests were the most reliable measure of function in a knee injured population, it was hoped that performance in functional hop tests would be available for meta-analysis. A number of hop tests are commonly used in clinical practice and published in the literature for this population, the following (non-exhaustive) hierarchy of hop tests were taken as the primary outcome measure prior to article screening:

1. One legged hop for distance
2. 6m timed hop
3. Crossover hop for distance
4. Triple hop for distance
5. Vertical Jump.

Secondary outcomes

Secondary measures included objective functional knee tests and other physical performance assessments. The following (non-exhaustive) hierarchy of tools was used:

Functional Knee Tests:
1. Single leg bend repetitions in 30 seconds
2. One leg rise
3. Stairs hopple test

Other Physical Performance:
1. 6-minute walk test
2. Timed up and go test
3. Figure of 8
4. Chair stand test
5. Get up and go test
6. Stairs running test
7. Stair-climb test
8. Functional assessment system

2.11.5 Search methods for identification of studies

Electronic searches

Searches were performed in MEDLINE, EMBASE, CINAHL, Cochrane Central Register of Controlled Trials (CENTRAL) and Web of Science. Searches were limited to English language publications. No start date restriction was applied, and all articles to date of search were included. The search strategy (Appendix 6: Search Strategy Systematic Review 2) for this systematic review is available at: https://www.crd.york.ac.uk, ID: CRD # 42017050313.

Searching other resources

A grey literature search was carried out of conference proceedings identified during the electronic search (Osteoarthritis Research Society International: AORSI World Congress and American Academy of Orthopaedic Surgeons: AAOS Annual Meetings). Review of the reference lists of relevant publications were also carried out to search for additional studies.

2.11.6 Data collection and analysis

Selection of studies

Two authors (NC, FW) independently screened title and abstracts, and if a study was considered eligible by at least one of the authors, the full text was screened by both authors. Excluded studies and reasons for exclusion were recorded, and disagreement was resolved through discussion with a third reviewer (JBT).

Data extraction and management

Study particulars, patient characteristics and details on functional performance measures were extracted from the included studies. Data was summarised in order to collate findings, assess patterns in methodology and identify trends in functional performance at different timepoints. Particular attention was given to the variety of outcome measures used, with the hope of pooling frequently reported outcome measures for meta-analysis.

The following data was extracted:
- Study design
- Country of study origin
- No. of participants at each time point assessed
- Study participant characteristics (mean age of participants, percentage of participants who are female, mean BMI of participants, activity level of participants).
- Category of control subjects (healthy controls / contralateral limb / nil)
- Time point of functional performance assessment
- Mean score on objective functional performance assessment at all time points.
- Details of rehabilitation at each time point.

Assessment of risk of bias in included studies

Cohort studies were assessed independently by two reviewers. Randomised Controlled Trials were assessed using the Cochrane Risk of Bias Tool. Observational studies were assessed using the SIGN50 tool for appraisal of methodological quality and risk of bias in Cohort Studies. Study specific criteria for each heading in the SIGN 50 was specified prior to screening (Appendix 7: SIGN 50 Criteria, Systematic Review 2).

Measures of treatment effect

The mean difference with 95% confidence intervals was calculated for continuous data. For continuous data reported on different scales, standardised mean difference was calculated (comparison of multiple outcome measures at specified time-points). Preferentially, continuous data was extracted based on follow-up scores; change from baseline (mean change scores) was used when these were not available.

Dealing with missing data

If full data was not available in published articles, authors were contacted for supplementary data. If this was not available, studies were excluded from corresponding analysis and this is noted in results.

Assessment of heterogeneity

In order to assess for heterogeneity between studies in meta-analysis, the I^2 and Tau^2 statistics were calculated. This was completed using Review Manager (RevMan), Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, (2014). The I^2 statistic describes the percentage of variability in effect estimates that is due to heterogeneity rather than sampling error (chance). A larger I^2 result would indicate that there is large heterogeneity within the included studies and that results of pooling the results should be interpreted with caution. Percentages are interpreted as follows; 0% to 40% might not be important; 30% to 60% may represent moderate heterogeneity; 50% to 90% may represent substantial heterogeneity; 75% to 100% represents considerable heterogeneity (Higgins and Thompson, 2002). The Tau^2 value is an absolute measure of heterogeneity, expressing the between study variance regardless of whether this variance is due to sampling error (change) or true heterogeneity in results.

Data synthesis

A meta-analysis was applied on the SMD of functional performance measures at each time point (difference between surgery leg and control). A random-effects model (REM) was applied as large between study variance was expected.

2.11.7 Subgroup analysis & investigation of heterogeneity

It was initially planned to complete additional analysis on subgroups of participants, as well as subsets of functional performance if sufficient data was available. It was planned to sub-group participants by:

- Age
- Gender
- Classification of meniscus injury as traumatic or degenerative
- Participation in rehabilitation and type of rehabilitation (supervised physio / home exercises / group exercise / not specified).

Due to the heterogeneous age and gender of participants in most studies, sub group analysis was not possible on this basis. The majority of studies which met inclusion criteria included degenerative meniscus tears and no studies reported a purely traumatic tear population. It was planned to analyse functional performance in subsets of:

- Knee specific function
- Overall physical function.

If enough data was available; performance on specific outcome measures, as outlined in the hierarchy of primary and secondary outcome measures, was planned.

2.11.8 Sensitivity analysis

Sensitivity analysis was carried out for studies included in meta-analyses, using Review Manager (RevMan), Version 5.3. Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, (2014). Sensitivity was measured by change in the I^2 statistic after the individual removal of each study and was analysed when a large I^2 value indicated heterogeneity in meta-analysis. Results of sensitivity analysis are discussed for each meta-analysis.

2.12 Results

2.12.1 Results of the search

The search strategy revealed 2776 articles (following removal of duplicates), title and abstract screening removed 2549 articles and 217 full text articles were assessed for eligibility. Thirteen studies reported in seventeen publications, which reported on objective functional performance in an arthroscopic meniscus surgery population were included in the data analysis. Eight Randomised Controlled Trials and one RCT pilot study were included. The remaining six studies were cohort studies, including measures of functional performance following arthroscopic meniscus surgery. Four cohort studies (published in five journal articles) specifically examined functional performance, one study (two publications) reported baseline data in cohorts also reported as an RCT, one other study reported the control group from a previous RCT as an individual cohort.

2.12.2 Description of studies

Seventeen publications reporting on thirteen studies met inclusion criteria after full text screening and were included in final data extraction and meta-analysis. Study populations included a total of 754 participants; mean age 43 years (age reported in all studies), Mean Body Mass Index (BMI) of reported participants was 25.8 $Kg.m^{-2}$ (BMI not reported in three studies). Activity level of participants was only reported in five of thirteen study populations and varied methods of reporting activity level were used in each study. Direct comparison of the physical activity level of participants across studies could not be made.

Classification of meniscus injury was poorly reported across studies. When reported, classification was based on findings at time of arthroscopy in the majority of studies. Studies with pre-operative assessments included participants based on clinical and MRI findings. Classification of meniscus injury was not reported at all in five of thirteen study populations.

Four populations reported degenerative meniscus tears in seven studies (Ericsson et al., 2009a, Ericsson et al., 2006a, Ericsson et al., 2009b, Osteras et al., 2014, Stensrud et al., 2015, Thorlund et al., 2010, Thorlund et al., 2012). One population was a young male population of recreational athletes who were likely to have traumatic tears (Koutras et al., 2012); and classification was unclear in three studies. These three populations were reported as isolated meniscus tears with majority of symptoms being sudden onset, but these study populations were middle-aged with activity level not reported (Hall et al., 2015a, Naimark et al., 2014, Vervest et al., 1999).

Eleven of thirteen studies reported on arthroscopic meniscectomy. One study was a comparative cohort study examining both arthroscopic meniscectomy and meniscus repair (Huber et al., 2013), a second study included debridement of damaged meniscus and ligaments, removal of proliferative synovium and excision of loose articular cartilage fragments (Chang et al., 1993). Characteristics of included studies are summarised in Table 2.3 and Table 2.4. One additional study met inclusion criteria but was poorly reported and data could not be extracted. This study (Westrich et al., 2009) was not included in analysis but is reported narratively.

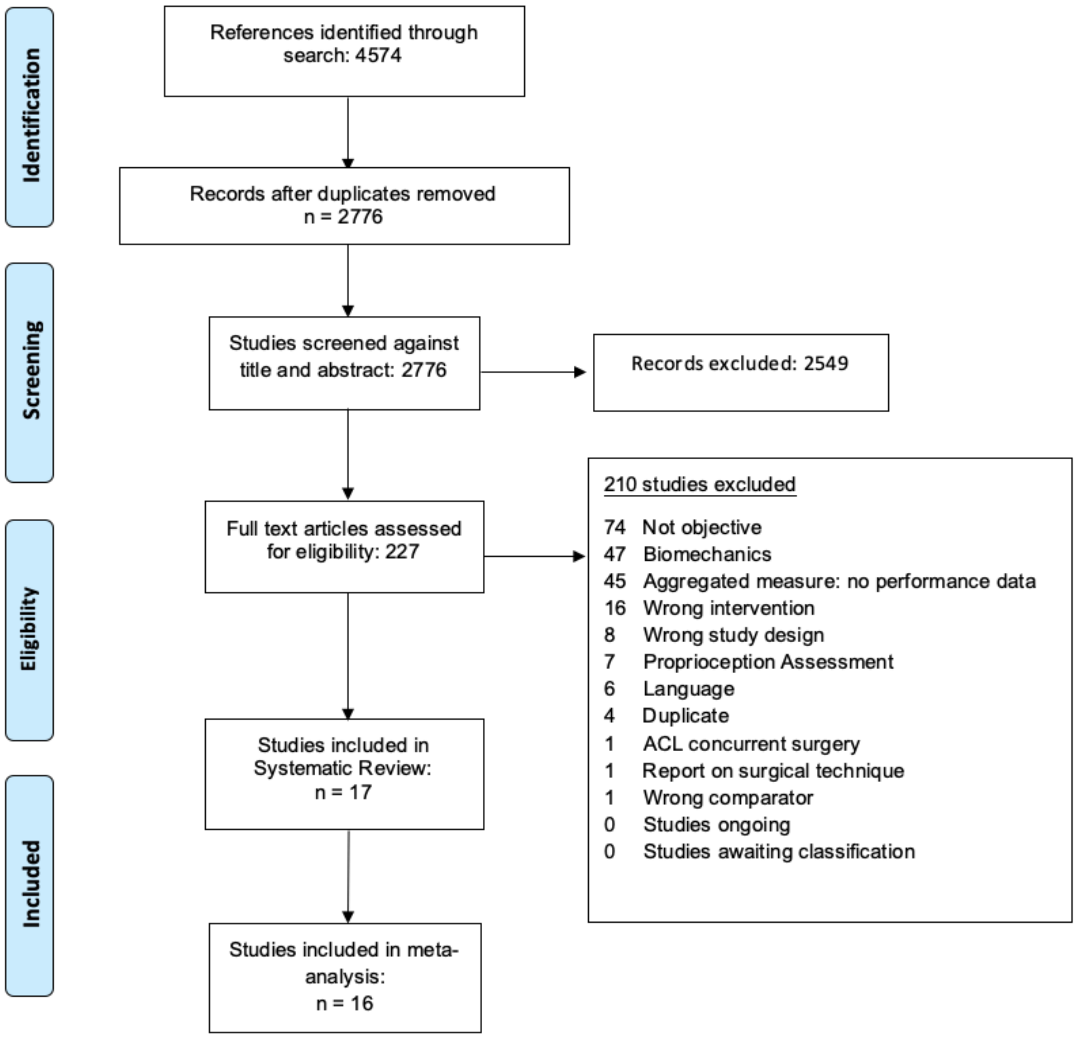


Figure 2.3: PRISMA flow chart of included studies, Systematic Review 2

	Study Design	Baseline no. of participants (% female)	Mean (SD) Age (years)	Surgical Intervention	Category of control	Objective Performance Measure	Time point(s)	Activity Level of Participants	Classification of meniscus injury
Chang et al. (1993)	RCT	18 (72)	61 (11)	Arthroscopic Partial Meniscectomy / Synovectomy / Debridement	Closed Needle Joint Lavage	50-foot timed walk (s)	Pre-operative 3 months post-op 12 months post-op	--	--
Ericsson et al. (2009a)	RCT	22 (36)	45.7 (3)	Arthroscopic Medial Meniscectomy	APM, no additional intervention	One Leg hop (cm) One-Leg rising (n) Square hop (n)	4.4 years post op 4 months later	31 higher activity, 15 lower activity	Degenerative
Goodwin et al. (2003)	RCT	49 (13)	45 (8)	Arthroscopic Partial Meniscectomy	Home Exercise Program only	Horizontal jump (cm)	4 days post op 6 weeks post op	--	--
Hall et al. (2015)	RCT	31 (26)	43	Isolated Medial Arthroscopic Partial Meniscectomy	No exercise group	Max one-leg rises in 30s (n) Max knee bends in 30s (n) One-Leg Hop for distance (cm)	6.4 (2.5) months post-op 13 weeks later	--	Unclear: (Symptom Onset slow : sudden, 11:19)

Table 2.3: continued

	Study Design	Baseline no. of participants (% female)	Mean (SD) Age (years)	Surgical Intervention	Category of control	Objective Performance Measure	Time point(s)	Activity Level of Participants	Classification of meniscus injury
Osteras et al. (2014)	RCT	38 (12)	46.3 (8)	Arthroscopic Partial Meniscectomy	No post-op rehabilitation	One Leg Hop (%)	1 month post-op 4 months post-op 13 months post-op	--	Degenerative
Stensrud et al. (2015)	RCT	42 (38)	48.6 (6)	Arthroscopic Partial Meniscectomy	Exercise Therapy group	Max knee bends in 30s (n) One Leg Hop for distance (cm) 6-metre timed hop (s)	53 days pre-op 107 days post-op	Participation in physical Activities outside of study: 80%	Degenerative Medial Meniscus Tear
Koutras et al. (2012)	Randomised trial	20 (Nil)	28.1 (9)	Arthroscopic Partial Meniscectomy	Contralateral limb	Single Leg Hop (cm) Triple Hop (2legs - 1leg - 2legs) (cm) Vertical Hop (cm)	14 days post-op 33 days post-op	Recreational Athletes	Unclear: ?Traumatic 'Nil other joint pathology'.
Vervest et al. (1999)	RCT Pilot study	10 (20)	35.7 (6)	Arthroscopic Partial Meniscectomy	Physiotherapy group post APM	One Leg jump (height): cm One Leg Hop for distance (cm)	7 days post op 28 days post-op	Unclear: 'Sports Activity n=6'	Unclear: Isolated meniscus Tear

-- = no data presented. RCT = Randomised Control Trial. APM = Arthroscopic Partial Meniscectomy

Table 2.3: Study Characteristics of Included Randomised Studies

	Study Design	Baseline no. of participants (% female)	Mean (SD) Age (years)	Surgical Intervention	Category of control	Objective Performance Measure	Time point(s)	Activity Level of Participants	Classification of meniscus injury
Ericsson et al. (2009b)	Cohort Study (Report on RCT cohort)	45 (36)	46 (3)	Arthroscopic Medial Partial Meniscectomy	Nil	One Leg Hop (cm)	4.4 years post-op	Unclear: '30 Higher Activity, 15 Lower Activity'.	Degenerative
Ericsson et al. (2006)	Cohort Study (Report on RCT Cohort)	45 (36)	46 (3)	Arthroscopic Medial Partial Meniscectomy	Opposite Leg	One Leg Hop (cm) Max One Leg Rising (n) Square Hop (n)	4.4 years post-op	Unclear: '30 Higher Activity, 15 Lower Activity'.	Degenerative
Huber et al. (2013)	Comparative Cohort	15 (60) APM 15 (47) Meniscus Suture	26 (1) 23 (2)	Arthroscopic Partial Meniscectomy Meniscus Suture (Fast-Fix)	Healthy Controls	One Leg Hop (cm) One Leg Rising (n)	12 months post-op	--	--
Malliou et al. (2012)	Observational Cohort	26 (Nil)	34 (6)	Arthroscopic Partial Meniscectomy	Contralateral Limb	Triple Hop (2legs – 1leg – 2legs) (cm)	Between 1-2 years post-op	--	--

Table 2.4: continued

	Study Design	Baseline no. of participants (% female)	Mean (SD) Age (years)	Surgical Intervention	Category of control	Objective Performance Measure	Time point(s)	Activity Level of Participants	Classification of meniscus injury
Morrissey et al. (2006)	Observational Cohort (Establishing HEP benchmarks)	39 (12)	41 (9)	Arthroscopic Partial Meniscectomy	Contralateral Limb	Vertical Hop (ratio) Horizontal Hop (ratio)	50 days post op	--	--
Naimark et al. (2014)	Cohort Study (Validity of a battery of knee tests pre-op and post-op).	50 (27)	44 (13)	Arthroscopic Partial Meniscectomy	Nil	Sit to Stand (reps) Stair Descent (s) Stair Ascent (s) Step Ups (reps) Step Downs (reps) Star Lunges (reps) 6-min treadmill travel (m)	1 week pre-op Day of surgery (pre-op) 6 weeks post-op	--	Isolated Meniscus Injury (88% medial)
Thorlund et al. (2010)	Cohort Study	31 (32)	46 (6)	Arthroscopic Partial Meniscectomy	Healthy Controls	One Leg Hop (cm) Max knee bends in 30s (n)	20.6 months post-op	Unclear: 'Median 3.2 hrs physical activity per week'	Degenerative medial meniscus tear
Thorlund et al. (2012)	Cohort Study	22 (23)	47 (5)	Arthroscopic Partial Meniscectomy	Healthy Controls	One Leg Hop (cm) Max knee bends in 30s (n)	49.6 months post-op	--	Degenerative medial meniscus tear

-- = No data presented. RCT= Randomised Control Trial. APM= Arthroscopic Partial Meniscectomy. HEP= Home Exercise Program. Reps= repetitions. m= Metre

Table 2.4: Study Characteristics of Included Cohort Studies

2.13 Summary of included studies

Included studies are grouped and summarised in the following section, in order to explain findings and trends in functional performance assessment. Due to the large variability in performance measures and study aims (Table 2.3 and Table 2.4), common themes were not consistent; studies are summarised according to study design with groupings of similar studies presented.

Measures of objective functional performance were included in nine randomised trials (eight RCTs and one Pilot RCT). Although an RCT is the preferred research method for evaluating outcome of a specific treatment, a patient reported outcome is often the primary outcome measure in an RCT and studies which include a functional performance measure as the primary outcome are limited. Furthermore, no studies have examined the objective functional outcome of APM versus no treatment. Most RCTs in an APM population report objective functional outcomes as a secondary research question, and the primary aim of these studies was to examine interventions in addition to APM (e.g. exercise, hyaluronic acid injection). Functional performance assessments were performed in these studies and data can be summarised although for the majority of studies, it was not the primary focus.

RCTs examining outcome of Arthroscopic Partial Meniscectomy.

The oldest RCT including a functional performance measure in an APM cohort (Chang et al., 1993) was carried out in the United States of America. This study examined a mostly female (72% female) and older population (mean age: 61 years) undergoing arthroscopic surgery compared to joint lavage (control group) for osteoarthritis of the knee. Arthroscopic surgery included debridement of damaged meniscus and ligaments, removal of proliferative synovium, and excision of loose articular cartilage fragments. A 50m timed walk (seconds) was assessed pre-operatively, and again at three & twelve months post-operatively. This first study examining functional performance in an APM population did not find any statistically significant improvement in function at either three month (Adjusted Mean Difference (95% CI): -0.8, (-2.8, 1.2)) or twelve month assessments (Adjusted Mean Difference (95% CI): -0.2 (-2.8, 2.3)) compared to control. Although this study did not include healthy controls, and the functional assessment used was bipedal (cannot differentiate between injured and non-injured leg) it appears that APM did not result in a functional improvement at three or twelve months.

The effect of exercise therapy compared to APM was examined by a Norwegian RCT (Stensrud et al., 2015) which randomised patients to either an exercise intervention or meniscectomy. The study population had degenerative meniscus tears and were a mean age of 49 years old (38% female). Patients were assessed functionally prior to randomisation, and again at three months after the initiation of the intervention. Performance was assessed using the SLH test (cm), six-metre timed hop (s) and maximum number of knee bends in 30 seconds (n). Change in performance tests from baseline to three months favoured the exercise therapy group although the study was underpowered to detect significant changes in performance outcomes. Performance tests at three months showed a significant improvement in 30 second knee bending in the APM group (Mean Change (95% CI): 8.5 (5.8, 11.2), $P<0.005$)) and improvements in all three performance measures from baseline to follow up ($P<0.005$) in the exercise therapy group. Although the exercise group did not undergo APM, the results of the surgical intervention group showed deficits in performance change when undergoing APM compared to exercise only at three months post-op.

These two trials reported the effect of AMP on functional performance from pre-op to post-op and found that APM did not result in greater improvement than control at either three months or twelve months' post-op, although this was not consistent for all outcome measures at twelve months.

RCTs examining outcome of exercise interventions.

Six studies reported functional performance in trials assessing the effectiveness of exercise interventions in populations of patients who had undergone APM. Five of these studies examined exercise interventions within the first year following APM and one study assessed an exercise intervention in a population who had undergone APM four years previously (Ericsson et al., 2009a).

Functional performance in the early post-operative period was assessed in a Pilot RCT carried out in The Netherlands (Vervest et al., 1999). This small study (Intervention, n = 10, 10 controls) studied the effectiveness of physiotherapy after meniscectomy in a population which was 20% female; mean age 32 years old. Study participants received nine physiotherapy sessions over a three-week period and were compared to standard care of advice and a Home Exercise Program (HEP) only. Functional performance was measured as the SLH and Single Leg Jump (for height) at seven and twenty-eight days post-operatively. Change in performance outcomes (Difference in effect scores between day 28 and day 7 post-op) favoured the physiotherapy group compared to control in both Mean(SD) SLH (57(39) cm compared to 8 (41) cm, *P*=0.02). and Mean(SD) single leg jump height (11(9) cm compared to 2(12) cm, *P*=0.04). Functional improvement with physiotherapy suggests that functional deficits are present and can be addressed in the early post-operative period following APM.

The effect of supervised physical therapy following APM was examined by an RCT completed in the United Kingdom (Goodwin et al., 2003). This study population was younger that the previous American study (mean age 45) and mostly male (13% female). Study participants were evaluated at (mean) four and fifty days after APM. The intervention group in this RCT underwent six weeks of supervised physical therapy and a HEP, the control group received a HEP only. Functional performance was measured with a Single Leg Hop (cm) and Horizontal Jump (cm) at six weeks post operatively; only results of the horizontal jump (ratio) were reported in this analysis. No difference was found between groups (Mean Difference (95% CI): 0.06 (-0.02, 0.14), *P*=0.165), although both the exercise group and HEP group showed a deficit in their injured leg compared to non-injured leg six weeks after APM.

A Norwegian RCT (Osteras et al., 2014) also examined the effect of exercise therapy in the early post-operative period. This experimental population of middle aged (mean age 46), mostly male (12% female) patients whom had undergone APM for a degenerative meniscus tear were examined one month post-operatively and then followed a three-month exercise intervention. Functional assessments were repeated at four months post-op (following intervention) and thirteen months post-operatively. Results were compared to a control group of patients who underwent APM but did not receive a supervised exercise therapy intervention. Functional performance was calculated using the SLH test and reported as percentage symmetry between legs. There was a significant difference in change between the intervention and control group, favouring the exercise intervention at both four months (end of exercise intervention) (Adjusted Mean Difference (95% CI): 6.2% (3.7, 8.7), *P*<0.01) and thirteen months (follow-up) (Adjusted Mean Difference (95% CI): 3.3% (0.6, 6.1), *P*<0.01) post operatively. The SLH was reported in this study as a percentage of the non-injured leg, and showed deficits at all time points in both the exercise and control group following APM, although this deficit reduced to 3% in the experimental group at 13 months, and improved over time in both groups, deficits still existed at 13 months (18% in control group) after APM.

Contrasting with the effectiveness of exercise therapy following APM, an Australian RCT (Hall et al., 2015a) found no difference in improvement on functional performance following neuromuscular exercise (supervised physiotherapy and HEP) in a middle-aged (mean age 43 yrs, 26% female) population who had undergone APM an average of 6.4 months previously. Performance outcomes was evaluated using the SLH, maximum number of controlled one-leg rises in 30seconds, and maximum number of knee bends in 30seconds. Results were reported at thirteen weeks; one week following a twelve-week intervention, and compared to a randomised control group who did not receive the neuromuscular training program. This trial did not find any significant between-group differences in change in functional performance following the intervention (SLH: *P*=0.21, Max one leg rises: *P*=0.23, Max knee bends: *P*=0.40) suggesting that the exercise intervention did not improve function over time. Differences between groups at each time point were not reported, however improvements were noted on all performance measures following the exercise intervention. Results of performance at each time point are included in meta-analysis.

The functional outcome of specific type of rehabilitation were examined in a Greek study (Koutras et al., 2012) which compared isokinetic rehabilitation to isotonic rehabilitation after APM. This male only study (mean age 28) was completed in recreational athletes (n=20) and also examined correlations between deficits in strength and performance measures. Functional performance was assessed using the SLH, triple hop and vertical hop tests on the 14th and 33rd postoperative days. This study was the only randomised trial to use contralateral leg as a control and outcomes were presented as Leg Symmetry Index (LSI). No difference was found between rehabilitation programs (*P*>0.33). The LSI improved over time for all hops, in the combined group of both interventions (SLH: 78% to 92%, Vertical Hop: 74% to 92%, Triple Hop: 88% to 95%, *P*<0.001) suggesting that functional performance improved regardless of rehabilitation type. Only 45% of patients had >90% LSI for all three hop tests at final assessment, indicating that functional deficits may still exist in the surgical leg.

The effect of exercise on functional performance following APM was examined at a later follow up in a Swedish RCT (Ericsson et al., 2009a). This study examined patients who had previously undergone APM (4 years post operatively) and compared effect of functional exercise training on functional performance and thigh muscle strength to a control group of similar APM patients who did not receive exercise training. This cohort had degenerative meniscus tears treated with APM and the mean age was 46, 36% of the cohort were female. Functional performance was assessed as Single Leg Hop (cm), One-Leg rising (n) and Square Hop (n) tests. Strength of the quads and hamstring muscles was also recorded. Baseline assessment was a mean of 4.4years after APM and post-intervention assessment took place four months later. The intervention group in this study had a significant increase in all functional performance measures, over the four-month period (P<0.05). All performance measures remained unchanged in the control group (P<0.1). When compared to the control group not receiving exercise, there was a significant difference in change over time of the SLH performance, favouring exercise (Mean Change (SD): 10(8) cm compared to 2(7) cm, P=0.04). While this study population examined a medium term follow up, it showed that there is potential for functional improvement with appropriate rehabilitation, even after the initial surgical recovery period.

In addition to studies examining the effect of exercise interventions; a study carried out in the USA (Westrich et al., 2009), examined the effect of hyaluronic acid on functional outcome following APM. Patients were randomised to normal post-operative management or a series of three injections during the first 21 days following surgery. Gender was not reported for this study population; mean age was 59 years. Performance outcome was reported using a 50-foot timed walk test. Data for this outcome was not presented, but it was reported that there was no significant difference between groups et either three or six-month follow up. Authors were contacted for further data on this study outcome, but no additional data was provided. Limited conclusions can be drawn from this study, although it does not contradict findings of other studies suggesting that functional performance is impaired following APM. This study was not included in further analysis.

This group of studies reporting on the outcome of exercise interventions in APM populations had conflicting findings in relation to the effectiveness of exercise. For the purpose of this review, functional performance data was examined and findings of all studies suggest that deficits in functional performance exist post-operatively. Four studies reported improvements in functional performance following exercise (Ericsson et al., 2009a, Osteras et al., 2014, Vervest et al., 1999, Koutras et al., 2012). Two studies found no difference between exercise intervention and control; no between-group difference was found following exercise in the first six weeks after APM (Goodwin et al., 2003), however deficits were still reported in the surgery leg compared to non-injured leg. Six months after APM, exercise did not result in a significant change in functional performance (Hall et al., 2015a), although between group differences were not reported and non-significant improvements in function suggest that deficits were present.

Cohort Studies

Four unique cohort study populations were found which reported objective performance measures (across seven publications). In addition to this, baseline and control cohorts of included RCTs were reported and are included in this review as they report additional objective measures / participant numbers to the RCT publications from the same studies.

Functional performance data was reported from the control group of the UK RCT (Goodwin et al., 2003) which examined exercise in the early post-op period. The control data was reported separately as a cohort study (Morrissey et al., 2006) which focused on recovery benchmarks in the group which received a home exercise program. The 39 control participants (Mean Age 41, 13% female) performed the Single Leg Hop (horizontal) and Single Leg Jump (Vertical) 50 days after APM. The uninjured leg was used as a control and performance was reported as a ratio (Injured/Uninjured). Mean (SD) vertical hop ratio was 0.82 (.18), Mean (SD) horizontal hop ratio was 0.90 (.17); deficits were found in both performance assessments at 50 days following APM in this cohort who received a HEP.

Functional performance 4.4 years after APM was reported in two additional cohort publications from a Swedish RCT included in this review (Ericsson et al., 2009a). Both exercise and control groups were combined and reported at baseline as an APM cohort. Three functional performance measures (SLH, One Leg Rising – max reps, Square Hop – max reps) were reported in the first paper (Ericsson et al., 2006b), the second paper (Ericsson et al., 2009b) reported only SLH data without control data and examined correlations between functional performance and cartilage glycosaminoglycan content. Forty-five participants (Mean Age 45.7, 36% female) were assessed and their non-operated leg was used as the control on all performance measures. Differences between the non-operated and operated leg were not found to be significant on the SLH (Mean Difference (SD): 3.6(15.5) cm, P=0.126) or Square Hop tests (Mean Difference (SD): 0.2 (5) reps, P=0.786), the operated leg scored significantly worse on the One-Leg Rising test at 4.4 years after APM (Mean Difference (SD): 3.8(8.5) reps, P=.004). The larger numbers reported in this cohort study confirm the findings of functional deficits on the One-Leg Rising test following APM, which were reported in the RCT, although no deficit was found on SLH or Square Hop tests.

These cohort studies agree with findings of their associated RCTs which found functional deficits in the early post-operative period and longer-term follow up although not all performance measures showed deficits at later timepoints.

Changes in functional performance over time were reported in four additional study cohorts. Performance measures in the early post-operative time period were examined in an American cohort (Naimark et al., 2014). This cohort followed patients who had an isolated meniscus tear from before till after surgery, and assessed the measurement properties of nine objective measures in this population. Two measures (Active Range of Motion, Passive Range of Motion) are not classified as functional performance measures, the remaining six measures assessed functional performance (Sit-to-stand, Stair descent, Stair ascent, Steps-ups, Step-downs, Star lunges, 6-minute timed treadmill). This cohort of 50 patients (Mean age 44, 27% female) were assessed one week before surgery, on the day of surgery (pre-operatively) and 6 weeks post-operatively. No control subjects were assessed in this cohort and many of the performance assessments involved the use of both legs, uninjured leg was not assessed separately. This was the first cohort to examine change in performance measures from before till after surgery, and a significant improvement in performance was found on all performance measures from pre-operatively to post-operatively (P<.01 all measures). Without control data, it cannot be confirmed if deficits which existed pre-operatively had fully resolved in this cohort by the six-week time point.

A Polish study (Huber et al., 2013) included healthy control data in a one-year follow up on a cohort of patients who had undergone either APM (15 patients) or meniscus suture repair (15 patients). This was the only study to report an objective performance measure in a meniscus repair population. Patients in this study were younger than other cohorts (Mean age APM: 25.5. Mean age meniscus suture: 23.1), there was a high proportion of females in this cohort (APM: 60%, Suture: 47%). Patients were assessed at one year following surgery and performed the SLH test and One-leg-rising test. The difference between operated and non-operated legs was compared to the difference between left and right legs in the healthy controls. Significant differences were found between operated and non-operated legs for both surgical techniques, on both the SLH (Mean Difference APM: 11cm, P<0.001, Mean Difference Suture: 5.5cm, P<0.05) and One leg rising test (Mean Difference APM: 6 reps, P<0.001, Mean Difference Suture: 3reps, P<0.05) one year after surgery confirming the presence of functional deficits. The meniscus suture group differed less from healthy controls (P<0.005), suggesting that performance at one year was better following suture than it was after APM.

A male-only cohort was examined between one and two years following APM in a Greek study (Malliou et al., 2012). Twenty-six male participants (mean age 34 years) were identified and recruited through hospital surgical codes. Participants performed the single leg triple jump (measured for distance) on both legs and the healthy leg was used as a control. Participants also completed balance assessments. At a minimum of 12 months after APM, this study found that there was a significant difference in functional performance between the APM and healthy leg, revealing a deficit in the operated limb ($P<0.05$).

Functional performance between two and five years following APM was reported by a Danish cohort in two separate publications. Assessment at 21-months following APM (Thorlund et al., 2010) and 50-months following APM (Thorlund et al., 2012) were carried out and compared to assessments of matched healthy controls. Thirty-one participants were assessed at 21-months (mean age 46 years, 32% female) and twenty-two of these were followed up in the second publication at 50-months (mean age 47 years, 23% female). The study population had a majority of degenerative meniscus tears and performance was measured using both the SLH and maximum number of knee-bends in 30-seconds. Results in this cohort differed from previous studies, and no significant deficits in performance were found. At 21-months after APM, there was no significant difference between performance on the operated leg and either the non-operated leg, or the healthy control group for SLH ($P=0.27$) or maximum number of knee-bends ($P=0.45$). Change over time in the operated leg compared to the non-operated leg and to healthy controls, showed that there was no significant difference in change over time (mean adjusted for baseline) on performance measures between the 21-month and 50-month assessments (SLH: $P=0.25$, maximum number of knee bends: $P=0.22$).

Findings from this group of cohort studies suggest that functional performance deficits improve from pre-op to post-op (Naimark et al., 2014) although this study lacked control data so it is unclear whether these deficits resolved completely or deficits remained following APM. Deficits were still found at one year post-op (Huber et al., 2013) but deficits described at two years post op (Malliou et al., 2012) conflicted with findings at close to two years and five years in the Danish cohort. Functional performance at 21 months (Thorlund et al., 2010) and 50 months (Thorlund et al., 2012) post-op did not appear to show any deficits compared to controls.

Findings of functional performance deficits in cohort studies appear to agree with findings of RCTs, although there is some disagreement between cohort studies at longer term follow up. Despite varied methods of performance assessment in the included studies, trends in functional performance measures assessed in cohort studies showed deficits in function compared to control following APM between one and five years following surgery.

Functional performance assessments in RCTs indicated that APM alone did not result in greater improvement than control at either three months or twelve months post-op; functional performance deficits were present post-operatively in all exercise intervention studies and improved post-operatively in the majority of studies. Cohorts of patients who have undergone APM displayed functional performance deficits in the first year with conflicting findings at later timepoints. These findings are further examined and discussed through meta-analysis in the following sections.

2.13.1 Risk of bias in included RCTs

Allocation (Selection Bias)

Selection bias was common across included studies. Concealment of allocation was not well described in a number of studies and block randomisation based on location or time of recruitment was a common issue.

Blinding (Performance Bias and Detection Bias)

Blinding of participants was not carried out in any studies. This is an understandable weakness in methodology, given that the exposure being examined is surgery and none of the studies meeting criteria included a sham surgery group. This lack of blinding does lead to potential bias in performance of functional assessment if participants believed that the exposure (surgery) should result in a change in physical performance.

A number of studies blinded assessors to the operated leg at time of functional assessment, using a bandage to cover potential operative scars. The majority of studies however, did not attempt to blind assessors or did not describe whether attempts were made at blinding. Some studies included contralateral legs as comparators and many test protocols involve testing the non-involved leg prior to testing the involved leg, this may have made it more difficult to conceal the operated leg from assessors.

Incomplete Outcome Data (Attrition Bias)

Attrition bias was well controlled for most RCTs included, loss to follow up was generally less than 20% and reasons were given in the majority of studies. Due to the use of contralateral leg as a control measure in a number of studies, drop off rates in both intervention and control groups were similar across studies. Intention to Treat Analysis was completed and reported in the majority of studies.

Selective Reporting (Reporting Bias)

The majority of studies reported all outcomes at each time point as described in their methodology. Secondary outcomes were less well reported but overall, studies reported on their intended analysis with reasonable detail. Only one study had a pre-registered trial protocol (Stensrud et al., 2015), one study was retrospectively registered (Goodwin et al., 2003).

Other potential sources of bias

An additional source of bias is the effect of exercise on outcome of meniscus surgery. Activity level was not well reported and exercise beyond the prescribed interventions were not recoded in multiple studies. One study found that 80% of participants were completing other exercise in addition to the intervention (Stensrud et al., 2015). One study reported on the effect of hyaluronic acid injections following APM and it was noted that the injections were sponsored by a pharmaceutical company (Westrich et al., 2009). Funding sources were disclosed clearly in most publications and affiliations / conflict of interest was noted in authors details.

Risk of bias assessment showed that the included studies were generally weaker in methodology with relation to randomisation and blinding (selection and performance / detection bias). Some of this can be attributed to difficulties in recruitment and physical performance assessment. Potential for bias was better managed in reporting and retention of participants. Overall risk of bias is summarised in Figure 2.4. Risk of bias was high or unclear in all studies with regard to blinding of participants and personnel. As only one of the included RCTs were comparing APM with an alternative, most studies looked at randomised interventions in addition to APM, therefore blinding of participants to the intervention (mostly exercise) was difficult.

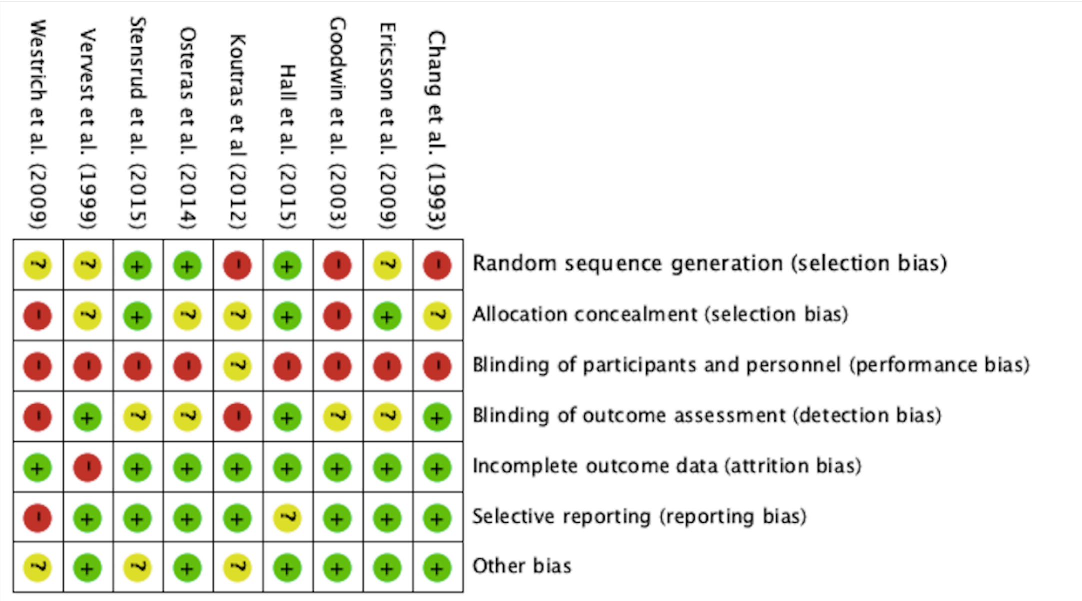


Figure 2.4: Risk of Bias Summary for Included RCTs

2.13.2 Risk of Bias in Included Cohort Studies

Risk of bias in cohort studies was assessed using the SIGN50 criteria (SIGN., 2015) . Specific criteria used to classify methodology as "adequate, unclear, inadequate" for this review was predetermined prior to screening (Appendix 7: SIGN 50 Criteria, Systematic Review 2). Summary of risk of bias in cohort studies is presented in Figure 2.5

Three items were not applicable to the included studies, due to the nature of studies in this review. Participation rates across cohorts (item 1.3 on SIGN50) was not applicable as studies used either contralateral leg, or matched healthy volunteers as a control group. Attempt to counter lack of blinding (item 1.9 on SIGN50) was not applicable as assessor blinding is possible in these cohorts and reported in item 1.8. Repeated assessment of exposure (item 1.12 on SIGN50) was not applicable as the exposure (surgery) could not be repeated.

Selection of subjects

Selection bias was controlled by some methodological considerations across all studies although overall risk of bias in the area was still present. Studies using contralateral leg as comparator were well reported and information on healthy controls showed that demographics were well matched.

Assessment

Information on possible previous injury to comparator leg was not noted in most studies. Due to the high prevalence of degenerative meniscus tears in the study populations, it is likely that many participants had functional deficits in both legs prior to receiving surgery for their index meniscus tear, potentially leading to performance bias.

Dropout rates were well controlled in most included cohort studies, and reasons for loss to follow up were generally well described, controlling for attrition bias. Drop out analysis was not performed in any study to assess for sensitivity or potential bias in outcome reporting.

Blinded assessment was rarely carried out, and poorly reported in included studies. Difficulties in performing functional assessment with blinding were not discussed and it appeared that attempts to control for detection bias in this manner were not included. Most studies used reliable and validated measures of assessment with appropriate referencing to supporting literature. Exposure (arthroscopic meniscus surgery) was consistent across all studies.

Confounding

A minority of studies attempted to account for and discuss confounding variables which may affect outcome (functional performance). In particular, possible injury to contralateral leg (comparator) and attempts to record and examine physical activity level in study populations was poorly conducted.

Statistical Analysis

The majority of included cohort studies reported statistical analysis adequately. Approaches to handling data were explained and plan for statistical analysis was outlined. Results were presented with standard deviations / confidence intervals included in table format for the majority of studies, although pooled results were often presented for secondary outcome measures.

Overall, methodology to mitigate the risk of bias was acceptable in five studies, only two studies were deemed to be of high quality. One study was deemed to be of low quality, the primary purpose of this study was to develop and validate functional performance measures, and methodology was not employed to ensure the appropriate assessment rigour due to the nature of the study.

While risk of bias is consequentially moderate / low due to these adequate methodological strategies, it should be remembered that cohort studies also have inherent risks. Cohort studies can be best used to track variables over time in an exposed population and for the purpose of this review, cohort studies offer equal methodological rigour to RCTs which often include functional performance as a secondary variable at one particular time-point.

SIGN50 criteria:	Ericsson et al. 2006	Ericsson et al. 2008	Huber et al. 2013	Malliou et al. 2012	Morrissey et al. 2006	Naimark et al. 2014	Thorlund et al. 2010	Thorlund et al. 2012
Clearly focused question	A	A	A	I	A	A	A	A
Comparable Source Populations	A	N/A	A	A	A	N/A	A	A
Participation rate across cohorts	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Subjects may have outcome at enrolment	I	I	A	A	I	I	I	I
Percentage drop out	A	A	N/A	A	U	I	A	A
Drop out analysis	I	I	N/A	I	I	U	I	I
Outcomes clearly defined	A	A	A	A	I	A	A	A
Blinded assessment	I	N/A	I	I	U	N/A	I	I
Attempt to counter lack of blinding	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Assessment of exposure is reliable.	A	A	A	A	A	A	A	A
Outcome is valid and reliable	A	A	A	A	I	I	A	A
Exposure is assessed more than once	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Main confounders taken into account	I	I	I	I	A	I	A	A
Confidence intervals provided	A	I	I	A	A	A	A	A
Overall Assessment: Risk of Bias	(+)	(+)	(+)	(+)	(0)	(+)	(++)	(++)

A = adequate. U = unclear. I = inadequate. (N/A=not applicable)

High quality (++): Majority of criteria met. Little or no risk of bias. Results unlikely to be changed by further research.
Acceptable (+): Most criteria met. Some flaws in the study with an associated risk of bias, Conclusions may change in the light of further studies.
Low quality (0): Either most criteria not met, or significant flaws relating to key aspects of study design. Conclusions likely to change in the light of further studies
.

Figure 2.5: Summary of risk of bias for Cohort Studies

2.14 Meta-analysis

Data was pooled for meta-analysis of SLH performance post operatively and for timepoints where more than one study reported any objective performance outcome. Sub-group analysis based on age was not possible due to the largely homogeneous age profile (middle-aged) of included studies. Subgrouping sex could not be performed as data was not presented separately. Analysis of performance based on traumatic versus degenerative tears was not possible due to unclear reporting or no reporting of meniscus injury classification in nine of the thirteen study populations (Table 2.3 and Table 2.4).

Meta-analysis of SLH performance was chosen as it was the most frequently reported outcome measure reported across studies, in keeping with the pre-defined study objectives (Section 2.11.8). Time segments were chosen for meta-analysis of functional performance using the Standardised Mean Difference of any objective performance measure at these time points, in order to examine functional performance over time pre-operatively and post-operative. Performance measures were grouped into pre-operative assessment, three-monthly segments during the first year after surgery, 12+ months and 48+ months post operatively. These time points were selected based on the data points of studies included in the review. If data was collected at more than one time point within pre-set timeframes (eg. six weeks and ten weeks), data was used from the latest time point within that study, or the later study if timepoints were presented for the same population in separate publications. If more than one performance measure was assessed, the highest-ranking measure in the pre-determined hierarchy of outcome measures was chosen as the functional measure at that time point (this was SLH in all cases). If more than one control group was given (data presented on both healthy controls and contralateral leg), preference was given to healthy controls according to the study protocol.

One study was excluded from meta-analysis (Westrich et al., 2009) as previously explained. Data on outcome of meniscus suture was not included as only one study included meniscus suture. If raw data was not presented, attempts to contact authors were made in order to gather additional data. Corresponding authors were contacted with requests for data and follow up emails were sent if no reply was received. Additional data was supplied by only one author. Attempts to calculate Mean and SD from other presented data were carried out using both RevMan software and the additional Cochrane resource (RevMan Calculator, downloadable at:

https://training.cochrane.org/resource/revman-calculator). If Mean and SD of both the APM and control groups could not be calculated from presented data, and authors did not supply additional data, studies could not be included in the analysis.

2.14.1 SLH post-operatively

Eleven studies reported SLH performance with a control group post-operatively at multiple timepoints. Five studies which reported SLH performance could not be included in meta-analysis as full data was not presented; three studies presented performance as a ratio of control leg or leg symmetry index (Koutras et al., 2012, Morrissey et al., 2006, Osteras et al., 2014), one study presented change scores only and raw data was not available (Stensrud et al., 2015), one study did not include standard deviation values and these could not be calculated as presented data was pooled for performance measures (Huber et al., 2013).

Of the remaining six studies, two Swedish studies reported on the same study population (Ericsson et al., 2009a, Ericsson et al., 2006b); data from the RCT study was included in the meta-analysis as this reported healthy control data. More than one timepoint was presented in this RCT, data included in meta-analysis was the latest timepoint (follow up after a sixteen week functional exercise intervention in a population who had undergone APM 4.4 years previously). A Danish cohort was also reported in two studies (Thorlund et al., 2010, Thorlund et al., 2012) using both contralateral leg and healthy control data. Data was included from the study reporting the latest timepoint (mean 50 months post-APM), healthy control data was extracted as comparator.

The Danish and Swedish studies both reported degenerative meniscus populations at 50 and 57 months post-op, respectively; the other two included RCT studies reported on SLH within the first one year following APM with unclear classification of meniscus injury. Outcome at one-month post op (Vervest et al., 1999) and 10 months post-op (Hall et al., 2015a) may represent a different timeframe in the evolution of post-operative functional changes.

Meta-analysis using random effects modelling was performed on data from four studies including 79 participants and 78 controls. A mean difference (95% CI) in SLH performance was found between APM and control post-operatively, favouring the control: 4.20 (2.73, .5.66), $p<.001$. Tau^2 and I^2 statistics were both zero indicating that variability in treatment effect between studies was not important. Figure 2.6 shows a forest plot of included studies.

	Experimental			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Ericsson 2009a	114	30	23	111	37	14	0.4%	3.00 [−19.93, 25.93]
Hall 2015	120	26	31	120	30	29	1.1%	0.00 [−14.25, 14.25]
Thorlund 2012	92.3	2.8	22	88	2.3	25	98.3%	4.30 [2.82, 5.78]
Vervest 1999	94.7	46.66	10	113.8	18.86	10	0.2%	−19.10 [−50.29, 12.09]
Total (95% CI)			**86**			**78**	**100.0%**	**4.20 [2.73, 5.66]**

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 2.51$, df = 3 (P = 0.47); $I^2 = 0\%$
Test for overall effect: Z = 5.62 (P < 0.00001)

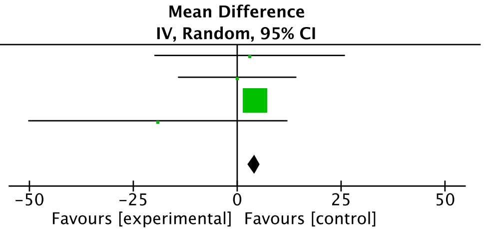


Figure 2.6: Meta-analysis of SLH performance post-operatively

Experimental = APM. Control = APM group, no exercise (Ericsson 2009a); APM group, no exercise (Hall 2015); Healthy Controls (Thorlund 2012); APM group, physiotherapy intervention (Vervest 1999). ■ = Weighted Mean Difference. Error Bars = 95% Confidence Interval. ♦= Pooled Effect Size

2.14.2 Performance at Multiple Time Points

In order to give a perspective on functional performance over time in an APM cohort, meta-analysis was performed using a Random Effects Model on the SMD of multiple functional performance measures, aggregating data at pre-operative and post-operative timepoints. If more than one measure was reported, preference was given according to the hierarchy of performance measures outlined in Section 2.11.5.1. Data from 50-metre timed walk, and SLH was combined pre-operatively. Post-operative analyses included 50-metre timed walk, SLH and triple hop performance data. Post-operative performance was reported at multiple timepoints, determined by the data reported in included studies, timepoints were 0-3 months, 4-6 months, 7-9 months, 10-12 months, 12+ and 48+ months post-op.

Pre-Operative & Early Post-Operative Functional Performance

A number of studies could not be included in this analysis as raw data was not published at all time points. One study reported performance pre-operatively and also 0-3 months post-op but no control data was presented as this study aimed to establish the reproducibility of multiple performance measures (Naimark et al., 2014). Four studies included data at 0-3 months but presented findings as a ratio / percentage of control leg and could not be included in analysis (Goodwin et al., 2003, Koutras et al., 2012, Morrissey et al., 2006, Osteras et al., 2014).

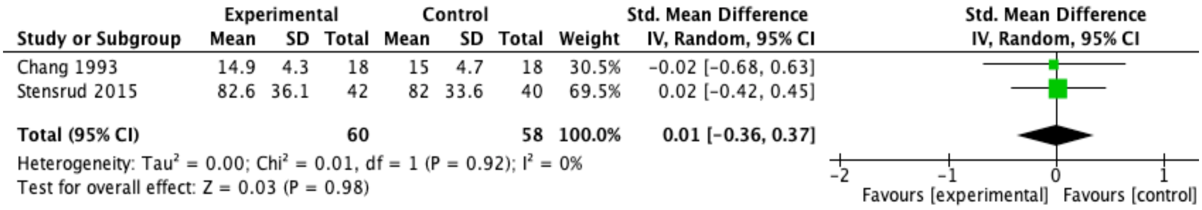


Figure 2.7: Meta-analysis of pre-operative functional performance.

Experimental = APM.
Control = Closed Needle Joint Lavage (Chang 1993); Exercise therapy, no surgery (Stensrud 2015). ■ = Weighted Std. Mean Difference. Error Bars = 95% Confidence Interval. ♦= Pooled Effect Size.

Two studies were analysed at the pre-op time point (Figure 2.7); no significant difference was found between performance in the APM leg and controls; SMD (95% CI): 0.01 (-0.36, 0.36), *P*=0.98. In the early post-op period, two studies showed a trend in favour of APM compared to control (Figure 2.8) but this did not reach the pre-determined level of significance (SMD (95% CI): -0.37 (-0.92, 0.18), *P*=0.19).

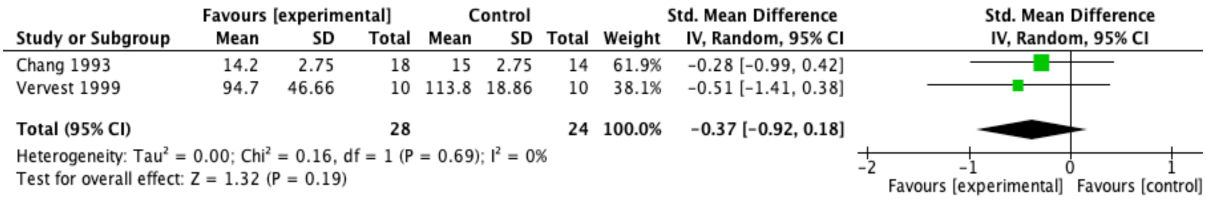


Figure 2.8: Meta-analysis of functional performance 0-3 months post-op.

Experimental = APM.
Control = Closed Needle Joint Lavage (Chang 1993); APM group, physiotherapy intervention (Vervest 1999). ■ = Weighted Std. Mean Difference. Error Bars = 95% Confidence Interval. ♦= Pooled Effect Size.

Performance measured with the 50m timed walk was reported at both of these timepoints in an older population (mean age: 61 years) (Chang et al., 1993). Two other studies reported multiple performance measures but SLH data was extracted from both. All three studies included a randomised control group (described in Table 2.3). A difference in functional performance between APM and control was not detected at these timepoints. Small numbers included in experimental and control groups of these studies along with poor classification of meniscus injury and varying age groups suggests that the findings of pre-op and early post-op meta-analyses should be interpreted with caution.

Functional Performance 4-6, 7-9 and 10-12 months post-op

At 4-6 months, no studies were suitable for meta-analysis as one study reported a ratio (Osteras et al., 2014) and one study reported change values over time (Stensrud et al., 2015). Only one study reported performance between 7 and 9 months post-operatively and is presented in Figure 2.9, no difference was found between control and intervention in this RCT.

Three studies reported functional performance between 10 and 12 months post-op, one of these studies was not included due to lack of Standard Deviation and pooled results (Huber et al., 2013). At close to one year post-op, no difference in functional performance was found between APM legs and control (SMD (95% CI): -0.02 (-0.43, 0.39), *P*=0.93), see figure 2.10.

	Experimental			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Hall 2015	107	31	31	117	28	31	100.0%	-10.00 [-24.70, 4.70]
Total (95% CI)			**31**			**31**	**100.0%**	**-10.00 [-24.70, 4.70]**
Heterogeneity: Not applicable								
Test for overall effect: Z = 1.33 (P = 0.18)								

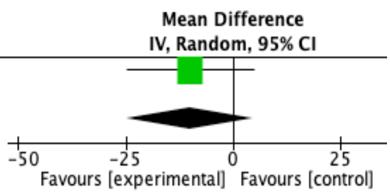


Figure 2.9: Functional performance 7-9 months post-op.
***Note: Mean Difference rather than SMD presented.**

Experimental = APM. Control = APM group, no exercise. ■ = Mean Difference. Error Bars = 95% Confidence Interval. ♦= Pooled Effect Size.

	Experimental			Control				Std. Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Chang 1993	13.9	3.5	18	14.1	3.5	14	34.4%	-0.06 [-0.75, 0.64]
Hall 2015	120	26	31	120	30	29	65.6%	0.00 [-0.51, 0.51]
Total (95% CI)			**49**			**43**	**100.0%**	**-0.02 [-0.43, 0.39]**
Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.02$, df = 1 (P = 0.90); $I^2 = 0\%$								
Test for overall effect: Z = 0.09 (P = 0.93)								

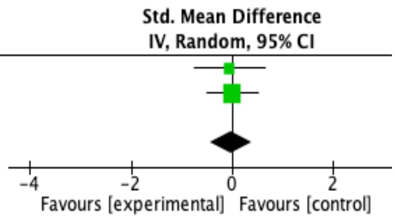


Figure 2.10: Meta-analysis of functional performance 10-12 months post-op.

Experimental = APM.
Control = Closed Needle Joint Lavage (Chang 1993); APM group, no exercise (Hall 2015).
■ = Weighted Std. Mean Difference. Error Bars = 95% Confidence Interval. ♦= Pooled Effect Size.

Between three and twelve months post-op, no significant difference was found between intervention and control. The lack of significant finding may be due to the small number of studies and participants at these timepoints. This was compounded by studies which did not report full data and for which individual group data could not be calculated.

Functional Performance 12+ months post-op

Three studies reported data between one and four years after surgery. One study (Osteras et al., 2014) was not included as performance data was presented as a ratio only. Meta-analysis of two studies found that functional performance was significantly better in the APM group than control (SMD (95% CI): -0.55 (-0.93, -0.18) *P*=0.004).

	Experimental			Control				Std. Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**
Mallilou 2012	481	57	26	525	70	26	44.8%	−0.68 [−1.24, −0.12]
Thorlund 2010	82.4	25.0549	31	91.1	10.022	31	55.2%	−0.45 [−0.95, 0.05]
Total (95% CI)			**57**			**57**	**100.0%**	**−0.55 [−0.93, −0.18]**

Heterogeneity: $Tau^2 = 0.00$; $Chi^2 = 0.35$, df = 1 (P = 0.55); $I^2 = 0\%$
Test for overall effect: Z = 2.89 (P = 0.004)

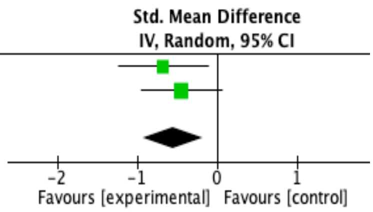


Figure 2.11: Meta-analysis of functional performance 12+ months post-op.

Experimental = APM.

Control = Contralateral Limb (Malliou 2012); Healthy Controls (Thorlund 2010). ■ = Weighted Std. Mean Difference. Error Bars = 95% Confidence Interval. ♦= Pooled Effect Size.

Functional Performance 48+ months post-op

Three studies reported outcome at more than four years after surgery. Two of these studies reported the same population (Ericsson et al., 2009a, Ericsson et al., 2006a), and the study reporting the latest timepoint was included. These two studies reported control group data; a matched healthy control group (Thorlund et al., 2012) and a randomised APM group with no additional intervention (Ericsson et al., 2009a). The medium difference found (SMD (95% CI): 0.88 (-0.66, 2.42)) was not statistically significant (*P* =0.26) and large heterogeneity was found between studies (I^2= 91%). Sensitivity analysis was performed by including data from the additional Swedish study on the same population, and then removing each of the three studies to assess the effect on the I^2 statistic. Heterogeneity in this meta-analysis was highly sensitive to the Danish Cohort (Thorlund et al., 2012). This appeared to be due to the very narrow standard deviation of the mean scores in comparison to other studies, indicating that there was less between participant variability in performance compared to other studies resulting in a more statistically significant finding in this group.

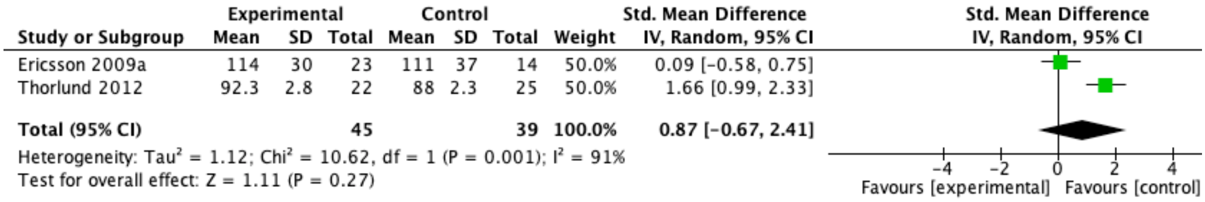


Figure 2.12: Meta-analysis of functional performance 48+ months post-op.

Experimental = APM.

Control = APM group, no exercise (Ericsson 2009a); Healthy Controls (Thorlund 2012). ■ = Weighted Std. Mean Difference. Error Bars = 95% Confidence Interval. ♦= Pooled Effect Size.

2.14.3 Sensitivity analysis

Due to the small number of studies included at each time point, and the low heterogeneity found (I^2= 0% for all analysis up to four years) sensitivity analysis was only performed for the 48+months post-operative analysis (Thorlund et al., 2012). This was performed by sequentially removing studies to examine their effect on meta-analysis as previously discussed.

2.15 Discussion

2.15.1 Summary of main results

This systematic review and meta-analysis included seventeen reports from thirteen studies examining functional performance as a primary or secondary study aim in participants undergoing arthroscopic meniscus surgery. Randomised Control Trials and cohort studies revealed small deficits in multiple functional performance measures post-operatively for APM leg compared to control. Meta-analysis of SLH performance post-operatively found a small difference in SLH favouring control post operatively. Pooled analyses of functional performance on any functional performance measure pre-operatively and post-operatively found no difference in performance pre-op or during the first year post-op. Functional performance between one and two years post-op appeared to be better following APM compared to control, but this finding was not sustained at later timepoints.

Included studies contained a majority population of degenerative meniscus tears and the average participant was middle aged (43 years) and overweight (BMI >25 kg/m^2). No studies were found which examined functional performance in participants who had a verified traumatic meniscus tear in the absence of degenerative knee conditions. Only one study was found which included a measure of objective functional performance in a meniscus repair population, this was a comparative study with APM. Studies reporting functional performance in younger populations were not found; only two studies with a mean age <40 years were included (Huber et al., 2013, Koutras et al., 2012), both with small study populations.

Randomised Controlled Trials found deficits in functional performance following APM but performance assessment was not the primary outcome in the majority of these studies. One RCT examined the effect of exercise compared to APM (Stensrud et al., 2015), one study compared arthroscopy to closed needle joint lavage (Chang et al., 1993), but each of the other eight randomised trials examined the effect of a secondary intervention in a cohort who had undergone APM. Only two RCTs (Chang et al., 1993, Stensrud et al., 2015) included objective performance data at both pre-op and post-op timepoints. Although nine randomised trials met inclusion criteria, RCTs examining the effect of arthroscopic meniscus surgery compared to sham surgery / no intervention and reporting objective functional performance are still lacking.

Results of RCTs which examined structured rehabilitation interventions found that functional performance deficits are present following APM and appear to improve in patients who undergo exercise therapy interventions, although the improvement in APM leg may not be more than control. Exercise in comparison to no exercise (Hall et al., 2015a) in a matched post-op APM cohort 6 months after surgery found that there was also a small (and clinically insignificant) improvement in functional performance in the control group, this meant that there was no significant improvement compared to control although the APM group did also improve significantly during the intervention. The purpose of this review was not to examine the effect of exercise interventions on APM and included studies do not represent all studies on this topic, however the finding of objective improvements in APM populations with functional deficits is important. Previous meta-analysis has also found conflicting results of exercise therapy following APM (Swart et al., 2016) and reported low quality in the majority of included studies.

The majority of cohort studies also found deficits in functional performance post operatively, at different timepoints. Varied controls and populations are reported in cohort studies with only four additional populations (a total of 121 additional APM subjects and 15 meniscal suture subjects) excluding cohorts which were also reported in RCTs. Only one cohort study examined change in functional performance from pre-op to post-op (Naimark et al., 2014) and this study did not include any control data. In contrast to the rest of the included studies, a Danish cohort (Thorlund et al., 2010, Thorlund et al., 2012) did not find any deficits in functional performance at either 21 months or 50 months post-op. This cohort had matched controls in addition to contralateral leg and followed the trajectory of performance over time, contradicting findings in other studies. It appears that deficits in objective performance are not evident at longer follow up although limited studies reported beyond two years. A Swedish cohort study found deficits in the One-Leg Rising test at 4.4 years post-op but deficits were not found on SLH or Square Hop tests. Medium-term and long-term follow-up on APM cohorts with a degenerative meniscus are likely to represent patients with progressive osteoarthritis. Meniscus injury has been shown to be the largest risk factor for developing knee OA (Poulsen et al., 2019) and conflicting findings at these timepoints may represent a change in functional performance due to progression of disease.

Pooling of results and meta-analysis was limited due to high variability in outcome measures reported and populations studied. Lack of published raw data, particularly due to objective measures being a secondary outcome measure in many studies limited the pooling of data. Attempts were made to contact authors and to calculate Mean and SD data from reported analysis, however many functional performance results were pooled and reported as secondary measures, limiting data extraction from a number of studies. It was not possible to perform a meta-analysis on individual performance measures or populations (traumatic v degenerative tears) based on age or activity level.

Meta-analysis of SLH performance following surgery favoured control, the control groups in this analysis varied with two studies reporting APM cohorts which did not undergo a rehabilitation intervention, one study reporting a control group of APM patients undergoing physiotherapy and one study reporting a healthy control group (Figure 2.6). This analysis contained a small number of studies with only 79 APM subjects and represented SLH at a wide range of timepoints (28 days post-op to 57 months post-op). The findings of this analysis were heavily weighted by the findings of the Danish cohort (Thorlund et al., 2012) which reported very small between participant variability at each timepoint in the study. Mean SLH performance was reported with a very narrow standard deviation in comparison to that of other studies and consequentially affected the result of data pooling (Figure 2.6), standardised SLH testing procedure was reported, similar to other studies. The variety of populations and timepoints included in this analysis makes clinical interpretation of this finding difficult. Classification of meniscus injury as degenerative or traumatic was unclear in the two studies looking at SLH in the first 10 months post-op (Hall et al., 2015a, Vervest et al., 1999), these studies may not represent the same clinical cohort as degenerative meniscus tears at 50 and 57 months post-op in the other two studies (Ericsson et al., 2009a, Thorlund et al., 2012). It is important to note that the pooled mean difference of 4.2cm, although statistically significant, is not clinically significant, and represents a change of less than 10% of the mean score on SLH performance for any of the included studies. Future high quality research in clearly defined populations may change the findings of this analysis.

Although there appeared to be deficits in functional performance across the majority of studies, pooling the Standard Mean Difference of performance tests at multiple time segments did not reveal greater functional deficits in participants undergoing APM compared to controls during the first year following surgery. Small numbers of studies and participants limited these analyses; meta-analysis could not be carried out at the 4-6 month time period and only one study reported functional outcome between seven and nine months post-op. The trend in analysis appeared to favour APM over control at 0-3 and 7-9 months, although this overall effect was not significant. One study was included at three timepoints and accounted for 30%-60% of the weighted analyses; this study (Chang et al., 1993) reported the 50-foot timed walk in a small sample (n=18) of older adults (mean age: 61 years) and had high risk of selection bias and reporting bias (Figure 2.4). Poor quality studies with small participant numbers limits the interpretation of performance at each time segment. Post-operatively, findings did not reach statistical significance at timepoints within the first year; all analyses within this period had less than 50 included participants.

A difference between APM and control groups was only found at one time point in meta-analyses of timepoints. Two studies (Malliou et al., 2012, Thorlund et al., 2010) examined functional performance between 1-2 years post op, demonstrating a moderate effect in favour of APM. At 4-5 years post-op, no difference was found between APM and controls. This finding in favour of APM is potentially important, as the justification for APM has been questioned broadly based on the findings of patient reported outcome measures. An improvement in objective functional performance after one year may represent an increase in functional performance capacity which is not captured by subjective outcome measures. Improved functional performance may represent a return to higher functional tasks such as occupational or sporting participation, although this was not reported in the included studies. Despite the statistically significance of this result, participant numbers were still limited (n=57) and performance was measured differently in each study, which limits the clinical application of this finding to specific cohorts. A degenerative meniscus cohort study (Thorlund et al., 2010) assessed SLH in comparison to healthy controls, while a younger (mean age: 34) male only cohort (Malliou et al., 2012) was assessed using a triple hop with the contralateral limb as control. The method of triple-hop assessment in this study involved hopping from 2 legs, onto one leg for two hops, and then landing onto two legs again; the involvement of contralateral leg in both intervention and control assessment weakens the findings of this study and pooling results with an older and degenerative population should be interpreted with caution.

There was no deficit in performance found at pre-operative assessment. Two studies assessed performance in patients with degenerative knees, (Mean Age: 48years and 61years). Function was assessed with 50m timed walk in the older group (Chang et al., 1993), and SLH, 6m timed hop and 30s knee bend tests (Stensrud et al., 2015). No difference in performance was found on any measure or pooled data. The lack of functional deficit prior to surgery seems to suggest that functional performance deficits did not exist. However, these studies included control groups which also had meniscus injury (comparing APM to closed needle joint lavage / exercise intervention). The lack of detected deficit is likely due to a deficit in functional performance observed in both groups.

2.15.2 Limitations

While thirteen study populations were included in the current analysis, findings are only applicable to middle aged patients with a degenerative meniscus tear as there is a lack of data in other patient groups. Habitual physical activity levels were not well reported across studies and the findings of this study may not apply to more active individuals with traumatic meniscus tears. Meniscus injury is strongly associated with progressive knee osteoarthritis and the presence of degenerative changes within the knee may represent a different clinical cohort to healthy individuals with acute changes in knee function.

Despite the variety of study methodologies in included studies, few studies were found which examined change in function over significant amounts of time. A number of RCTs examined performance at more than one time point but only two included pre-operative assessment. Most repeat assessments were just a few weeks apart making comparisons of change between groups difficult. Only one cohort study examined performance changes from pre-op to post-op (this study did not include control data). Meta-analyses of performance data at post-operative timepoints was limited by small numbers and multiple outcome measures. Future studies reporting on change over time with pre-operative and post-operative assessments in longitudinal cohorts would provide data on the trajectory of performance in patients who undergo APM and provide a clearer picture of how APM affects functional performance.

Weaknesses were found in the quality of included studies, particularly in blinding and reporting of physical activity (both recreational or habitual activity and specifics of rehabilitation). Exercise and rehabilitation can affect functional performance in both index and contralateral knees, resulting in changes in outcome of assessment for both APM and control if the contralateral leg is used as a control or outcome is reported as a leg symmetry index.

Six of the included studies examined structured rehabilitation interventions in patients undergoing APM. Control groups in these studies also underwent meniscus surgery but received a different post-operative intervention. Control groups in these studies do not represent non-operative control and the difference between control and intervention in these studies represents the effect of exercise rather than APM. Although raw data was extracted from each study for meta-analyses, the quality of control groups was poor for the purpose of analysing the effect of APM.

Contralateral symptoms were also poorly reported in the included studies, despite the majority of populations being degenerative knees. Bilateral osteoarthritis could influence the outcome of performance assessments using contralateral leg as control. An additional weakness in the quality of included studies is the heterogeneous manner in which functional performance measures were performed and reported. Variety in the use of arms during hop tests, and measuring distance from heel or toe may lead to misinterpretations of individual studies. Reporting outcome as a percentage / ratio rather than Mean and Standard Deviation also limited the inclusion of additional data in meta-analysis.

The inclusion criteria for the current study was deliberately wide in order to capture multiple study designs and outcome measures used to assess objective function. Lack of one specific performance measure at multiple time points and the exclusion of certain studies due to lack of published data may have reduced the ability of meta-analyses to detect effect size based on SMD of limited studies.

2.15.3 Agreements and disagreements with other studies or reviews

Previous studies based on patient reported outcome measures have found that APM is no more effective than control in the management of degenerative knees (Kise et al., 2016b, Thorlund et al., 2015). The current study confirms that finding with objective data, although there does appear to be an improvement in objective functional performance between one and two years post-op.

Recent reviews including the first systematic review in this thesis have also reported on objective measures of strength following surgery (Hall et al., 2015b, Thorlund et al., 2017b) These studies showed that deficits in strength persist after APM in both younger and older patients. It appears that these deficits in strength do not result in functional performance deficits as measured by the studies included in the current review.

2.16 Authors' conclusions

2.16.1 Implications for practice

This review found there to be a lack of high quality studies examining objective functional performance in populations undergoing arthroscopic meniscus surgery. Conclusions cannot be drawn about functional performance following meniscus repair, due to a lack of published studies. Conclusions cannot be drawn about functional performance in younger and more highly active populations, or populations with a normal / healthy BMI. The conclusions of this review apply to degenerative meniscus tears in middle aged populations.

The majority of included RCTs reported on interventions after APM and objective performance measures were not the primary outcome. Deficits in functional performance were found in all RCT populations following APM and these deficits improved following the exercise interventions in most studies. Cohort Studies reported deficits up to 2 years after APM, findings were unclear beyond two years with conflicting results across studies.

Meta-analyses were performed to consolidate reports on SLH post-operatively and examine the trajectory of functional performance over time in patients undergoing arthroscopic partial meniscectomy. Single Leg hop performance favoured control, although this finding was not clinically significant. No difference in function performance was found between surgery and control during the first year post-operatively, or at 4-5 years post-op. Weaknesses due to small numbers of participants and large variations in both study population and performance measures have been discussed. Between 1-2 years after surgery, functional performance appeared to be better in knees which underwent APM compared to controls; meta-analysis at this timepoint contained a small number of participants from two different clinical populations. Further research reporting objective performance over time may confirm or clarify this trajectory of functional performance.

2.16.2 Implications for research

There is a lack of data on functional performance in younger and more active individuals with meniscus injuries, future research on APM should better define and include these populations in order to understand the effect of surgery on performance and self-reported outcomes in these groups. The effect of meniscus repair should also be examined with functional performance measures across all populations, as this is an increasingly popular alternative to meniscectomy. There is a particular lack of RCTs or Cohort Studies (including control data) with a primary aim of reporting the effect of APM on functional performance both pre-operatively and post-operatively while also reporting change over time. Better standardisation of reporting is needed in order to facilitate meta-analysis of functional performance measures. Clearer reporting of data as well as standardisation of outcome measure methodology would strengthen the findings of future analyses. Functional outcome of surgery needs to be defined with both self-reported and objective assessments examining a number of constructs (strength and function).

2.16.3 Differences between protocol and review

Up to date protocols for this systematic review and meta-analysis are published on the PROSPERO repository of systematic review protocols. Prior to final screening and data extraction, an updated protocol was published to better reflect the definition of performance measures in line with the aim of the review, type of study inclusion was updated to exclude case studies and commentaries / reviews of other research.

3 TRIMS: Trinity Meniscus Study.

Elements of this chapter have presented as a conference poster:

> **Cardy, N.,** Thorlund, J.B., Quinlan, J., Hogan, N., Brennan, A., McNulty, K., Wilson, F., (2018). Changes in isokinetic strength and single-leg hop test performance following arthroscopic meniscus surgery: A Cohort Study. *Sports Medicine Congress 2018*. Copenhagen, Denmark, 1-3 February 2018. Scandinavian Sports Medicine Congress:

3.1 Introduction:

Literature review and meta-analysis discussed in Chapter 2 revealed a gap in current knowledge on longitudinal functional performance in patients undergoing arthroscopic meniscus surgery. A prospective cohort study (The Trinity Meniscus Study: TRIMS) was conducted to examine this topic. The primary aim of the TRIMS cohort was to assess functional performance measures pre-op and post-op in an APM cohort. Functional assessment incorporated more challenging functional performance measures which were not previously reported. The secondary aim of this study was to examine changes in physical performance measures (subjective and objective) from before to twelve months after APM surgery. This study also examined whether high level of self-reported physical activity prior to injury, influenced outcome of objective functional performance measures following APM.

Current evidence does not support the primary use of arthroscopic partial meniscectomy (APM) in the treatment of middle-aged patients with a meniscus tear in a degenerative knee (Kise et al., 2016b, Thorlund et al., 2015). Findings of these studies are based on Patient Reported Outcome Measures (PROMs). Recent studies have also reported the effect of APM on objective measures of strength following surgery (Hall et al., 2015b, Thorlund et al., 2017b) showing that deficits in strength persist after APM in both younger and older patients. Functional performance measures are simple clinical measures designed to objectively quantify function; capturing a construct of performance not incorporated in PROMs or strength testing. Deficits in functional performance measures have been found in both RCTs and Cohort studies reporting post-operative function in patients undergoing APM (Chapter 2: Systematic Review 2). Despite mounting consensus against the use of APM in degenerative knees (Siemieniuk et al., 2017), APM is still a frequently performed surgery and the outcome of surgery in non-degenerative populations is less well reported.

Changes in functional performance following APM in more active individuals without knee degeneration is unclear. Physical activity and habitual exercise are poorly reported in studies on APM, and the potential for physical activity levels to influence functional outcome of surgery needs to be established. Certain patient subgroups may benefit from surgical treatment of meniscus tears; changes in high performance functional measures (similar to those used to assess function in ACL cohorts) in APM cohorts have not been reported. Meniscus tears often occur during twisting injuries of the knee, common during sporting activities. Individuals with traumatic meniscus tears and a higher activity level are a poorly studied population. Evidence suggests that a shorter duration of symptoms can predict a better outcome of surgery (Haviv et al., 2017), and that younger and more highly active individuals can return to sports faster following APM (Kim et al., 2013). Participation in higher level physical activity may influence outcome of APM quantified by PROMs, strength tests and functional performance measures. While randomized controlled trials have shown that APM is no better than sham surgery in non-osteoarthritic knees with degenerative meniscus tears (Sihvonen et al., 2013), further research is needed to establish change in objective function as well as subjective and objective activity level. Meniscus Surgery is often seen as a quick fix surgery; 91% of a Danish cohort undergoing APM with degenerative meniscus injuries expected to be fully recovered within three months (Pihl et al., 2016a), 59% of these study participants had unfulfilled expectations post-operatively. Timeframe of recovery in more active individuals and timeframe of return to more challenging physical activities such as occupational labour or sports participation in all populations should be established in order to better understand the effect of APM on physical function.

This study is reported according to the STROBE (Strengthening the Reporting of Observational Studies in Epidemiology) guidelines for reporting observational studies (von Elm et al., 2007).

3.2 Study Design

A prospective cohort study design was used in order to capture longitudinal data on patients undergoing arthroscopic meniscus surgery within the Irish public healthcare system. Patients were recruited to the study prior to surgery and followed up at consecutive time points over one year post-operatively. Baseline testing was performed prior to surgery (1-2 weeks) and patients proceeded for surgery as normal, surgical data was collected by the operating surgical team at time of surgery. Post operatively, patients completed postal questionnaires three months following surgery. At six months after surgery, participants attended for follow up assessments. At one year after surgery, participants again completed postal questionnaires. A summary of the study design is shown in Figure 3.1. Recruitment of participants took place at two university affiliated hospitals in Dublin, Ireland between October 2016 and March 2017. Testing of patients took place in either Tallaght University Hospital, Outpatient Physiotherapy Department, Tallaght, Dublin 24 or the Trinity Centre for Health Sciences at St. James's Hospital, James's St., Dublin 8

Due to the longitudinal nature of this study, and the inclusion of contralateral leg testing (control group), analysis of variance (ANOVA) was used to examine differences over time between the surgical and contralateral leg. The null hypothesis of this study was that there would be no difference in variance between groups (surgical leg & control leg) over time (pre-op and post-op) on any performance measures assessed. A priori, a sample size was not set, as this was the first study to examine change over time longitudinally from pre-op to post op in an APM cohort using this combination of objective outcome measures. A multi-site and multi-surgeon study was established in order to recruit a large sample, representative of the current clinical cohort; and a post-hoc power analysis is reported.

Ethical approval for the study was granted by Tallaght University Hospital / St. James's Hospital Joint Research Ethics Committee (REC Reference: 2016-07 Chairman's Action (12). (Appendix 16: Ethical Approval Letter TRIMS). Participants were first contacted through a gatekeeper and provided a Patient Information Leaflet, allowing them seven days to consider informed consent to participation in the study. All procedures performed were in accordance with the ethical standards of Trinity College Dublin and with the 1964 Helsinki declaration and its later amendments.

3.3 Participants

Patients were recruited prospectively over a six-month period from upcoming surgical lists at both clinical sites. All patients 18 years of age and older, scheduled for arthroscopic meniscus surgery were first contacted by phone and offered an opportunity to take part in the research study. Interested participants were sent follow up information by email including a patient information leaflet (Appendix 8: TRIMS Patient Information Leaflet) and informed consent form (Appendix 9: TRIMS Consent Form). Consenting participants without contraindications to exercise (identified using the Physical Activity Readiness Questionnaire (PAR-Q) were scheduled for a pre-operative baseline assessment in addition to normal care. Patients were excluded only if they had a cognitive impairment that prevented them from giving informed consent, or a recent injury of either leg. Participants were followed up post operatively with postal questionnaires and an assessment appointment six-months after surgery, in addition to usual care.

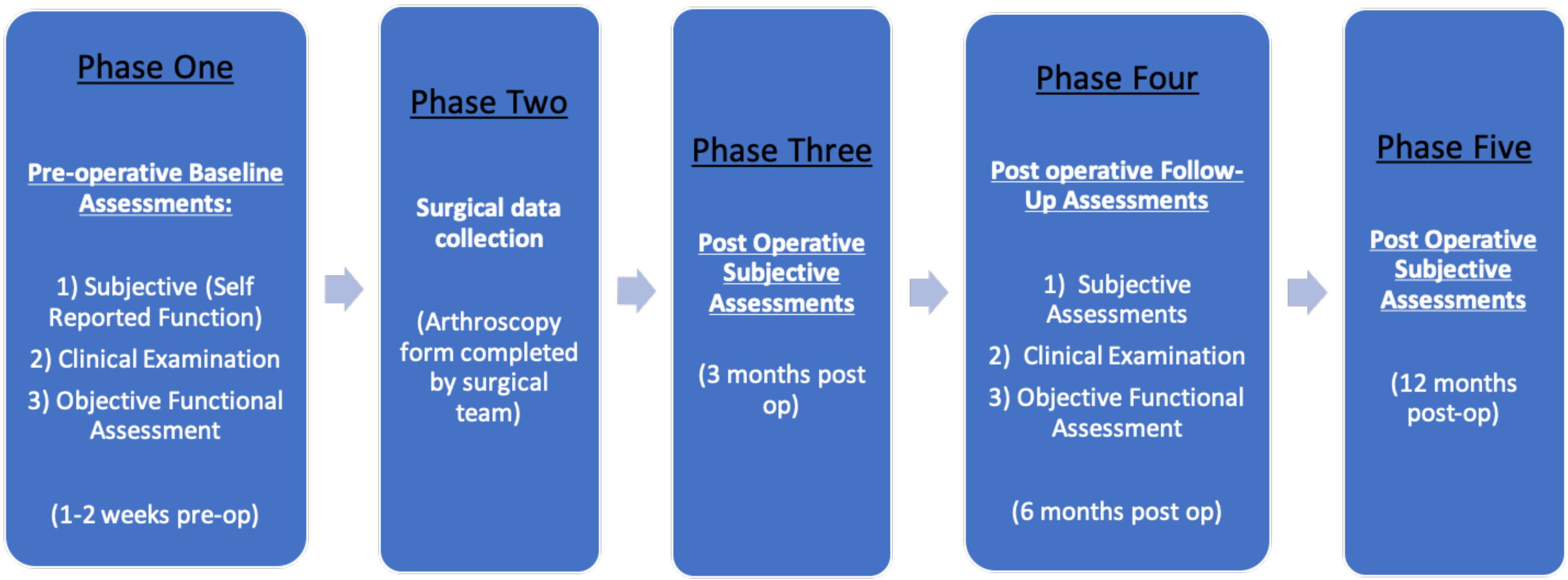


Figure 3.1: Trinity Meniscus Study Overview

3.4 Variables

An overview of study variables is shown in Table 3.1. Details of outcome variables and how they were recorded is described in more detail through the following sub-sections.

Variable	Pre-op	Surgery	12 weeks	24 weeks	52 weeks
Date of Birth	x				
Gender	x				
Height	x			x	
Weight	x			x	
BMI	x			x	
PAR-Q	x			x	
KOOS	x		x	x	x
IKDC Subjective	x		x	x	x
Single Item Physical Activity	x		x	x	x
Tegner Activity Scale	x		x	x	x
AROM	x			x	
Isokinetic 3 speed Strength	x			x	
Hop Tests	x			x	
Joint Line Tenderness	x			x	
Effusion	x			x	
McMurray's	x			x	
ISAKOS Tear Classification		x			
Synovitis info		x			
Reason for Surgery	x	x			
Previous Knee Surgery	x	x			
Contralateral Knee Pain			x		
Mechanism of Injury	x				
Date of Injury	x				
Trauma v Non-Traumatic Tear	x				
Physio Management Details	x			x	
Imaging Details	x				

BMI = Body Mass Index. PAR-Q=Physical Activity Readiness Questionnaire. KOOS=Knee Injury and Osteoarthritis Outcome Scale. IKDC=International Knee Documentation Committee. AROM=Active Range of Motion. ISAKOS=International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine.

Table 3.1: TRIMS Outcome Variables

3.4.1 Subjective Variables & Population Descriptors

Subjective data was collected at each time-point, excluding surgery (Phase Two: Figure 3.1). Both subjective and objective variables were collected at assessment appointments which took place prior to surgery and at six-months post-operatively (Phase Two & Phase Four: Figure 3.1).

Further subjective variables were assessed through postal questionnaires at three and twelve months post-operatively (Phase Three & Phase Five: Figure 3.1). Participants were contacted by phone to confirm current address and questionnaires were sent within one week of the three / twelve-month time-point for each participant. A stamped, self-addressed envelope was included to assist in returning completed questionnaires. If participant responses were not received within two weeks, a further phone call was made to ensure that questionnaires had been received and encourage response.

PAR-Q

The Physical Activities Readiness Questionnaire (Thomas et al., 1992) was used to screen participants for any contraindications to exercise. Patients who were currently taking medication for a heart condition / blood pressure were not excluded if their condition was stable and they had taken their medication as instructed. The PAR-Q was used as a screening tool over the phone when initially contacting participants and was also completed prior to both baseline and six-month objective assessments.

Date of Birth, Date of Injury, Sex

Date of birth was recorded and used to calculate age at time of injury and time of surgery. Participants self-reported their date of injury (month) in order to calculate time between injury and surgery / baseline assessment. Sex was recorded in order to report on study population and facilitate subgroup analysis based on female and male sex.

Previous Knee Injury and Surgery

At baseline, participants self-reported if they had a previous injury to their knee, before the injury for which they were having surgery and also details of any such injuries (Appendix 10: TRIMS Injury Mechanism Assessment Form). Previous surgery was also recorded by surgeons at time of surgery; the arthroscopy data collection form recorded previous repair / resection on medial / lateral meniscus as well as percentage of meniscus previously excised (Appendix 12: TRIMS Arthroscopy Form).

Contralateral Knee Pain & Mechanism of Injury

Participants reported if they had any injury in the opposite knee, and whether they had seen a doctor or had surgery for this injury (Appendix 26: Contralateral and mechanical symptoms). This was recorded for the purpose of study population description. Participants with bilateral knee injuries could be suffering from osteoarthritis and bilateral symptoms could also affect the outcome of performance measures using contralateral leg as control.

Participants self-reported their mechanism of injury (Traumatic v Non-Traumatic Tear) by responding to a standardised question (Appendix 10: Injury Mechanism Assessment Form):
"How did the knee pain/problems for which you are now having surgery develop (choose the answer that best match your situation)?" This method has previously been used to classify meniscus injury as traumatic or non-traumatic (degenerative) in similar cohorts (Thorlund et al., 2013).

No change was made to medication, for patients who were taking analgesia (or other medications) for knee pain or other conditions. Leg dominance was also not recorded or included as an inclusion / exclusion criteria, in order to maintain a cross-sectional sample of patients with unadjusted clinical presentations.

Mechanical symptoms

Self-report of mechanical symptoms of the knee (clicking, locking, giving way) and frequency (Never / Monthly / Weekly / Several Times a Week / Daily) of symptoms were recorded at each subjective time-point (Appendix 26: Contralateral and mechanical symptoms).

Mechanical symptoms are often reported as an indication for meniscus surgery, and this data was collected as a population descriptor. Clicking and locking of the joint are often thought to be due to unstable or flap tears in the meniscus, although this perception has recently been challenged (Pihl et al., 2019, Thorlund et al., 2019). Giving way of the knee is often considered a symptom of anatomical instability. It was hypothesised that subgroups of traumatic or degenerative meniscus tears may report different frequencies of mechanical symptoms throughout timeline of assessment.

Physiotherapy management details

Participants were asked if they had previous physiotherapy treatment for their knee at baseline assessment, and if they had physiotherapy following surgery at the six-month assessment post-operatively. Additional details were also clarified by the assessing clinician; where physio was performed, duration of physio and number of sessions performed, components of physio treatment (Appendix 11: TRIMS Physiotherapy Assessment Form). This data was recorded as a population descriptor and descriptor of subgroups following functional performance analysis.

Reason for surgery

Participants self-reported the reason that they were going for surgery at baseline assessment (Appendix 10: TRIMS Injury Mechanism Assessment form)). This question was an open ended blank question to provide exploratory data on the patient experience and rationale for surgery, establishing patients' understanding of, and reasons for surgery. Surgical teams also reported the reason for meniscus surgery, at the time of surgery in order to facilitate comparison between patients' and surgeons' reported reasons for surgery (Appendix 12: TRIMS Arthroscopy Form).

3.4.2 Functional Outcome Measures (self-reported)

Patient Reported Outcome Measures (PROMs) were completed at baseline and all post-operative assessments. Many patient reported outcome measures have been used to assess function in patients undergoing arthroscopic knee surgery. Key outcome measures were summarised and compared (Table 3.2). It was decided to include the KOOS and IKDC subjective questionnaires for the purposes of recording self-reported function. The Single Item Physical Activity Measure (SIPAM) and Tegner Activity Level Scale were chosen to report on frequency of and grading of habitual physical activity. An outline of PROMs which were considered and further discussion of included measures is presented.

Outcome	Summary	Subscales	Conditions reported	Reliability & Validity	References
Cincinnati Knee Rating System	First published in 1983 to assess outcome in ACL reconstructed knees. Includes objective assessments (radiography, physical examination and functional assessment), patient reported activity and symptoms	Symptom Rating, Patient Perception, Sports Activity, ADL Function, Sports Function, Occupational Rating, Overall Rating	Knee Ligament Injury, meniscal repair and allograft, high tibial osteotomy	High test-retest reliability (All ICCs >.70). Poor construct validity (exhibits floor and ceiling effects). Questionable assessment of content validity (surgeon developed and weighted) hypotheses based testing used to determine accuracy of content	(Agel and LaPrade, 2009))(Barbe r-Westin et al., 1999)
WOMAC	Used for the evaluation of hip and knee osteoarthritis (OA). Also can be calculated from KOOS questionnaire.	Twenty-four items divided into 3 subscales: Pain (5 items), Stiffness (2 items) and physical function (17 items).	Initially used for hip and / or knee OA, now more commonly used in Rheumatoid conditions too	Stiffness subscale: Low test-retest reliability. Physical function subscale limited in detecting change.	(Wolfe and Kong, 1999)
IKDC	Development of the IKDC began in 1987 and has consisted of multiple iterations of the questionnaire which has ultimately lead to the current format seen today (knee specific – not disease specific)	Three categories: symptoms, sports activity and knee function.	ACL, meniscus and articular cartilage injury, patello-femoral pain	Acceptable test-retest reliability. (ICC: 0.95) Acceptable floor and ceiling effects. Responsiveness to Change: Large Effect Size (2.11).	(Crawford et al., 2007)

Table 3.2 cont’d

Outcome	Summary	Subscales	Conditions reported	Reliability & Validity	References
KOOS	Developed in 1998 to distinguish interventions that are effective in treating disorders of the knee. Self-reported	Five subscales: pain, symptoms, activities of daily living, sport and recreation function, and knee-related quality of life (QOL).	Knee OA, meniscus injuries, ACL.	High test-retest reliability in patients with knee injur and OA, ICCs for all subscales range from 0.61-0.95. Subscales more discriminative than WOMAC. Responsive to change following surgery. Minimal Important Change: 8-10.	(van de Graaf et al., 2014)
Lysholm	Originally published in 1982, reviewed in 1985. Designed as a questionnaire to be administered by orthopaedic surgeons to patients undergoing knee ligament stabilisation surgery.	8 item questionnaire, each question scored differently	Ligament injuries of the knee, knee arthroscopy, high tibial osteotomy, patello-femoral knee pain	Content Validity not established, potential for interviewer bias	(Collins et al., 2011)
Oxford Knee Scale	Brief questionnaire for patients undergoing total knee replacement (TKR) reflecting the patient's assessment of their knee-related health status and benefits of treatment	12-item questionnaire	Total Knee Replacement (TKR)	Different scoring methods available, some domains overlap and may mask functional deficiencies	(Collins et al., 2011)

ICC= Intraclass Correlation Coefficient. (Bold indicates PROMS used in TRIMS). **Table 3.2: Outcome Measure Selection**

KOOS

The Knee Injury and Osteoarthritis Outcome Score (KOOS) contains five subscales of self-reported function and has been validated to assess self-reported outcomes in this group of patients (Herrlin et al., 2013, Collins et al., 2016). The KOOS is widely reported in similar cohorts of patients following meniscus surgery and was used as a self-reported measure of functional outcome according to subscale; pain, symptoms, activities of daily living, sports & recreation and quality of life. The KOOS is reported according to these domains, rather than an aggregate score. Each domain is normalised from 0-100 with 100 indicating no symptoms and 0 indicating extreme symptoms.

Reliability of the KOOS has been established in patients with knee injury; Intraclass Correlation Coefficients (ICCs) are high for all subscales; ICC of pain subscale ranges from 0.85-0.93, the Symptoms subscale from 0.83-0.95, the ADL subscale from 0.75-0.91, the Sport/Rec subscale from 0.61-0.89 and the QOL subscale from 0.83-0.95. In patients with knee OA, ICCs for the Pain subscale range from 0.8-0.97, the Symptoms subscale from 0.74-0.94, the ADL subscale from 0.84- 0.94, the Sport/Rec subscale from 0.65-0.92 and the QOL subscale from 0.6-0.91 (Collins et al., 2016); an ICC of >.70 is considered acceptable. The Minimal Detectable Changes in patients with knee injury are 6-6.1 (Pain subscale), 5-8.5 (Symptoms), 7-8 (ADL), 5.8-12 (Sports/Recreation), and 7-7.2 for Quality of Life (Collins et al., 2016). The minimally important change is dependent on patient groups, intervention and time to follow up, but currently suggested to be 8-10 on each scale.

Convergent and divergent validity of the KOOS has been established in multiple studies, including comparison to several instruments such as the SF-36 and Lysholm knee score. The KOOS has been shown to be responsive to change in varied populations including meniscus surgery; following orthopaedic surgery, the Quality of Life subscale is the most responsive to change (Gudbergsen et al., 2011).

The KOOS is patient-administered and user-friendly, it takes about 10 minutes to complete. The KOOS questionnaire is in the public domain and is free of charge. No licensing or permission to use KOOS is required (freely available from: www.koos.nu). The KOOS has previously been reported in APM cohorts and the subscales of self-reported function facilitate the analysis of change over time in each domain.

IKDC

The International Knee Documentation Committee (IKDC) 2000 subjective outcome questionnaire was used as a measure of self-reported function at each time point. The IKDC contains three sub-sections; symptoms, sports activity and knee function. The IKDC has been redeveloped to its current form and has been shown to have good reliability, with acceptable floor and ceiling effects in a population of patients with meniscus injury (Crawford et al., 2007). The ICC for overall IKDC score has been reported at 0.95, importantly, the ICC of specific questions regarding higher functioning tasks has also been found to be high; squat (0.76), run (0.88), jump (0.90), stop (0.91). The IKDC was used in addition to the KOOS, as ceiling effects on the max score for ADL and floor effects of the Sports/Rec subdomain of the KOOS mean that it may be limited in detecting changes in function, in line with TRIMS aims. Acceptable floor and ceiling effects (<30%) are reported for the IKDC, along with criterion validity (significant correlation; $p<.05$ between the IKDC score and the physical component of the SF-12 scale (Crawford et al., 2007).

Physical Activity Scales: Tegner & SIPAM

The effect of APM on physical activity level has not been well reported; in order to assess physical activity in the TRIMS cohort, self-reported activity data was gathered at each timepoint pre-op and post-operatively. Both the Single Item Physical Activity Scale and Tegner Activity Scale were assessed. Both scales were used in order to assess change in either activity frequency, or participation in more challenging occupational and recreational activities such as sports participation.

The Tegner scale describes ten categories of increasingly challenging activities, with participants recording the highest level of activity which they participated in prior to injury and at time of assessment (Appendix 13: Physical Activity Scales). The Tegner scale has been shown to be a reliable and valid activity scale for patients with meniscal injury of the knee; overall ICC for test-retest reliability is 0.82, minimal detectable change for patients with meniscus injuries is one (Scale 0-10). Construct and content validity have been established for the Tegner scale, it is responsive to change with moderate to large effect sizes and floor / ceiling effects are less than six percent (Briggs et al., 2006). Tegner data was collected as a measure of habitual physical activity participation at each time point to examine the intensity of activity that study participants were achieving and assess for changes in occupational or sporting activity over time.

The Single Item Physical Activity Measure (SIPAM) asks on how many days of the preceding week, a participant was completing exercise for 30 minutes or more, which was enough to raise their breathing rate. Inclusion of the SIPAM generated data on whether study participants were reaching physical activity guidelines and whether this changed over time. The SIPAM has been shown to perform similarly to longer physical activity measures (Wanner et al., 2014) and was used to track changes in frequency of participation in physical activity over time.

3.4.3 Objective Variables

Objective physical performance data was gathered from participants at two timepoints. The first assessment (baseline) took place prior to surgery (Phase One: Figure 3.1) and the second assessment took place six months after surgery (Phase Four: Figure 3.1). Orthopaedic surgeons have reported the expected time for recovery following APM to be 5.1 weeks (Roos et al., 2000a), over ninety percent of patients undergoing APM report that they expect to fully recover with three months (Pihl et al., 2016b). A six-month timeframe for post-operative assessment was chosen based on timepoints of strength and functional recovery found in systematic review (Chapter 2). Change in function from pre-op to post-op has not been reported at six months and it was anticipated that recovery of performance on more strenuous activities may not be complete by three months (Stensrud et al., 2015). On both occasions, participants attended a scheduled, study specific 90-minute appointment at one of the clinical sites. All assessments were performed by the same clinician, a senior physiotherapist specialising in Orthopaedics (NC).

On arrival, participants completed a consent form (baseline assessment only) and PAR-Q questionnaire. Subjective outcome measures were then collected in a designated clinic room. A clinical examination of the knee joint was carried out for the purpose of recording clinical cohort descriptors (Range of motion, joint line tenderness to palpation, patello-femoral joint pain on patellar compression and McMurray's test). Following this, participants completed a 10-minute light exertion bicycle warm up (Figure 3.2). Warm up was performed at a Rate of Perceived Exertion (RPE) max of 2-3/10, participants were informed that they should be able to maintain the pace and carry on a conversation with ease of breathing. Resistance was set at 20% on the stationery bike and reduced to 10% if participants felt that their RPE was exceeding 3/10. Following this, height and weight were taken as described in Section 3.7.3.

Figure 3.2: Warm up protocol

Lastly, objective physical performance measures were recorded. Participants completed hop tests first, followed by a 10-minute rest period while the Biodex Isokinetic dynamometer was calibrated. Following isokinetic strength assessment, participants were brought through stretches for hamstring and quadriceps muscle groups. Participants were reminded of the next phase of study participation prior to leaving the appointment.

Effusion, Joint Line tenderness & McMurray's

Suprapatellar effusion was measured using a non-stretching tape measure; Model LCR01, 0-150cm, (HaB International Limited, Warwickshire, United Kingdom). Surgical and non-surgical legs were measured for circumference 1 cm above the patella. Difference between legs was recorded as <1cm / 1-2cm / >2cm difference. Joint effusion was taken as a measure of joint irritation and inflammation in comparison to contralateral leg.

Tenderness on joint line palpation was recorded according to anterior / posterior and also medial or lateral joint line. Palpation procedure was standardised and completed by one researcher (NC) for all assessments. With the participant in crook lying (knee flexed to 60 degrees), the proximal tibia was cupped in both hands and joint lines were palpated to moderate pressure using both thumbs. Following thorough palpation of the joint line and femoral condyles, posterior joint line was palpated using index fingers. Tenderness was documented in the standardised assessment form (Appendix 11: TRIMS Physiotherapy Assessment Form).

Physical assessment of the knee was concluded with the Mc Murray's test which is a special test used to assess for meniscus tears. To perform this test, the examiner brings the leg from a position of acute flexion to a right angle, whilst the foot is retained first in full internal, and then in full external rotation (McMurray, 1942). Clinical assessment was performed based on current clinical practice in the management of meniscus injuries (Doral et al., 2018), the purpose of this assessment was to collect study population descriptors.

AROM

Active Range of Motion (AROM) was measured using a Baseline® hand-held long-arm plastic goniometer, model 12-1001 (Fabrication Enterprises Inc, New York, USA) with the participant lying in supine on an examination plinth. Participants wore shorts and were asked to bend their knee, moving their heel as close as possible to their buttocks without using their hands to help. With the foot placed flat on the plinth, the angle of knee flexion was measured with the goniometer fulcrum placed at the lateral knee joint line over the femoral condyle. The proximal goniometer arm was aligned with the greater trochanter of the hip and the distal goniometry arm aligned with the lateral malleolus of the fibula. Extension AROM was recorded using the same landmarks and asking the patient to flatten their knee into the plinth without the use of their hands. Hyperextension was noted and recorded if present. The measure was repeated three times on each leg and the average recorded as AROM.

Height, Weight & BMI

Barefoot standing height was measured using a Leicester portable height measure (Invincta Plastics Ltd, Leicester, United Kingdom). Participants were asked to stand on the measure footplate, face forward with their back against the stadiometer, legs together, with arms by their sides. Participants were asked to take a deep breath and the headboard was lowered until it touched the crown of the head, compressing the hair. Measurements were taken, from a single trial, to the nearest 0.1 cm. Body mass was measured to the nearest 0.1 kg, using a SECA 875 Class (III) Digital Floor Scales (SECA gmbh & co. kg, Hamburg, Germany). Scales were calibrated annually as part of laboratory servicing. Participants were weighed with one layer of light clothing. BMI ($Kg.m^{-2}$) was calculated according to the formula: mass (kg) divided by height squared (m^2).

3.4.4 Hop Tests

Three hop tests were then performed; Single Leg Hop for Distance (SLH), 6 Metre Timed Hop (6MH) and Triple Hop for Distance (THD). These tests were selected as they assess performance at a high level which is currently underreported in a meniscus surgery population. The 6MH and THD are commonly reported in ACL reconstruction cohorts, as measures of functional capacity necessary for return to sports (Grindem et al., 2016, Kyritsis et al., 2016). The SLH and 6MH are ranked as the best measures of physical function for a knee injured population (Kroman et al., 2014); this comprehensive systematic review established measurement properties of performance based outcome measures providing suggestions for future research. Strong quality evidence was found for the reliability of the SLH in this population (reliability testing; intra-rater reliability ICC >.70, validity established by positive correlation with extensor peak torque; r=0.62), moderate quality evidence was found for the 6MH (intra-rater reliability; ICCs from 0.82 to 0.97, validity established by positive correlation with extensor peak torque; r=.60) and THD (intra-rater reliability; ICC 0.88, validity established by positive correlation with quadriceps performance; r=0.51-0.63).

Measurement variability when completing hop tests is improved by following a specific protocol, completed by an experienced clinician; however a combination of hop tests is recommended to confirm deficits and increase the reliability of results (Noyes et al., 1991). Measurement error for individual hop tests has been reported to be low, with Standard Error of Measurement (SEM) for SLH reported in healthy individuals as <7cm (test-retest) and 1.7cm (inter-rater) (Haitz et al., 2014). Other Athletic populations have also reported low SEM with 4.6cm (Ross et al., 2002), and <8%(normalised to leg length) (Munro and Herrington, 2011). Similar low values for SEM of THD are reported as 11.17cm (Ross et al., 2002), and 17% (male) / 23% (female) – normalised to leg length (Munro and Herrington, 2011). The 6MH has also been examined for reliability, mostly in athletes / military personnel. The SEM for 6MH is reported as .048 sec (male) and .076 sec (female) (Munro and Herrington, 2011), and .06 sec for a combined cohort of athletes (Ross et al., 2002).

Symmetry scores / Leg Symmetry Index (LSI); score on injured / operated leg as a proportion of control leg, are often used to report hop tests with a symmetry of <85% (Grindem et al., 2011) considered to represent abnormality. Variation in reports of normal symmetry, particularly following surgery are reported with >89% on SLH / 95% on THD and 88% on 6MH suggested as optimal following ACL reconstruction (Logerstedt et al., 2012). Recent reports suggest that different populations may have varied leg symmetries (particularly if one or both knees are affected by arthritis) and LSI alone is not an indicator or normal function (Gokeler et al., 2017) . In order to minimise variability / error in data collection, all measures were recorded by one experienced physiotherapist, following a standardised and rehearsed protocol which was demonstrated to participants prior to assessment. Absolute values (cm / sec) were recorded and used for all data analyses.

All hop tests were started with the participant wearing shoes and standing on one leg with the toe of the tested leg touching a perpendicular straight line. Each hop test was then demonstrated by the examiner (NC) prior to assessment and one practice hop was offered to ensure correct technique by the participant. Hop Tests were performed three times on each leg, using the non-surgical leg as a comparator and the furthest / fastest result of each leg was recorded as the best performance for each test.

Figure 3.3: Hop Tests Track

A 6m track was laid at both testing sites on hard flooring using electrical tape as markers (Figure 3.3). A starting point (40cm tape) was placed perpendicular to the placement of the first toe as starting position for all tests. At 50cm intervals, a 15cm strip of electrical tap was laid parallel to the starting marker, over a span of twelve meters. Accuracy of the 50cm intervals was checked by using a tape measure at two points (either end of the 15cm marker) between each segment and marking the ground with a felt tip pen prior to laying the marker. Distance was calculated as the distance from the first line (tip of the first toe) to the heel of the foot at furthest landing; measurements were taken from the closest 50cm marker to heel of the foot using a non-stretching tape measure, Model LCR01, 0-150cm (HaB International Limited, Warwickshire, United Kingdom). Timing for the 6m hop was taken from the word ‘go’ on instructions “ready, steady, go” to when the participant passed the 6m mark (last 50cm segment). The examiner stood by the 6m mark for all timed trials and stood close to the landing point of the practice hop for all distance hops.

Single Leg Hop

Participants started with arms by their side and hopped as far as possible, landing on the same leg. Distance was measured in centimetre (cm) from the starting line to heel of the foot in landing position (Tegner et al., 1986).

Triple Hop

Triple Hop for Distance (THD) was measured in the same manner (cm). Participants were advised to start with arms by their side and hop continuously on one leg as far as possible, without pausing on each hop. To maintain plyometric hop assessment, restriction was not placed on the use of arms (Reid et al., 2007). Distance was measured to the heel of the foot in landing position on third hop forward.

Six metre Hop

Six-metre timed hop (6MH) was performed starting perpendicular to a line with arms by the side. Participants were advised to hop as quickly as possible on one leg, along an indicated six-metre line (Bolgla and Keskula, 1997). Time taken (centisecond) to pass the six-metre straight distance was recorded using a digital stopwatch (Casio F91W-1, Casio Computer CO., LTD, Tokyo, Japan).

Testing order on hop tests was rotated every fifteen participants, with the first 15 participants first completing SLH – THD – 6MH, second next fifteen participants completing THD - 6MH - SLH etc. Testing procedure is summarised in Figure 3.4.

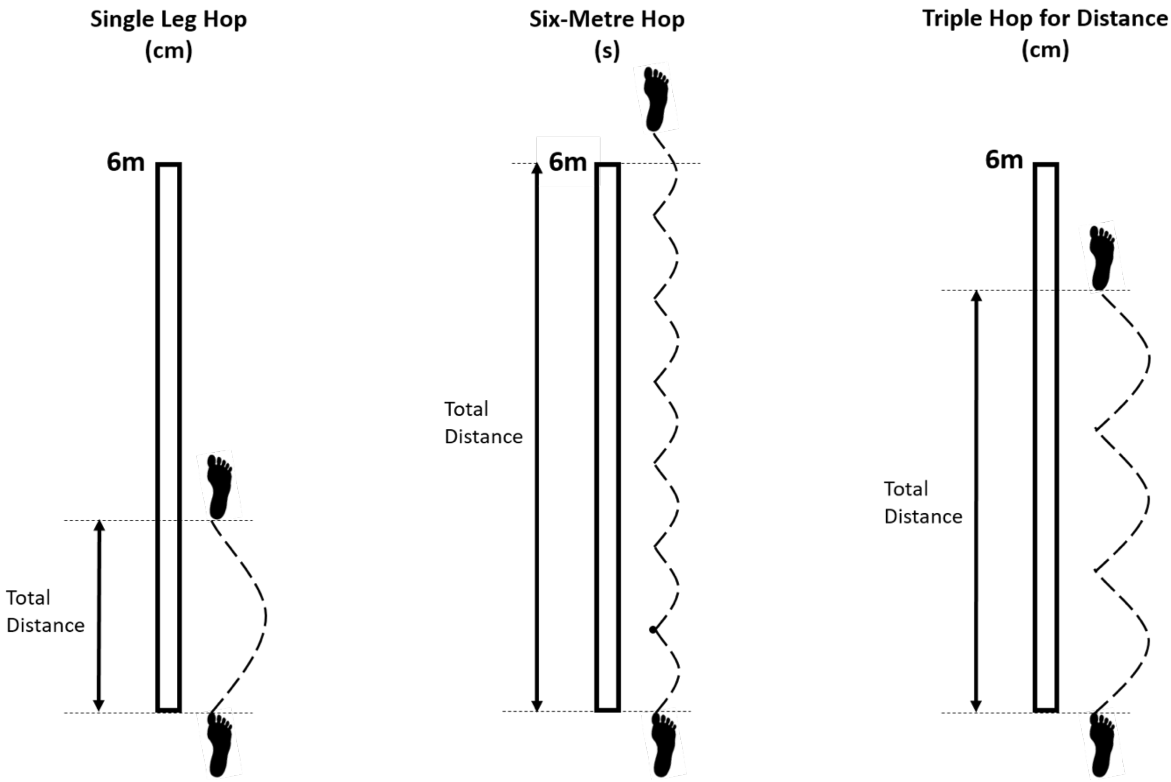


Figure 3.4 Hop Tests Protocol

3.4.5 Isokinetic Three Speed Assessment

Following a ten-minute rest period, participants completed a strength assessment of the quadriceps and hamstrings muscles using a Biodex System 3 isokinetic dynamometer (Biodex Medical Systems, Shirley, New York, USA); see Figure 3.5. Isokinetic dynamometry is considered the gold standard for measurement of muscular strength and endurance. Isokinetic dynamometry is used extensively to measure muscle performance in arthroscopic knee surgery research. The mechanical validity and reliability of measurements of angular position, velocity and isometric torque are deemed to be acceptable for both clinical and research purposes (Drouin et al., 2004). Hardware and software recordings of torque, which was the variable recorded for strength analysis (peak torque) has been shown to be valid within 1% (Coefficient of Variation of method error) (Drouin et al., 2004). Normative values for isokinetic strength have also been reported in healthy individuals (Harbo et al., 2012), and knee extensor peak torque at $60°.s^{-1}$ and $180°.s^{-1}$ has been shown to have a moderate correlation with self-reported knee pain and function (WOMAC score) in knee injured adults (*P*<.001) (Kim et al., 2020).

Prior to testing, the Biodex System 3 was calibrated according to manufacturer's instructions. The test procedure (with emphasis on the maximal nature of the assessment) was explained to the participants. Participants were seated in the test chair with hips flexed to 90˚ and their back supported. The dynamometer axis of rotation was aligned with the external femoral condyle of the knee. The test leg was strapped distally to the dynamometer arm 2 – 3 cm above the lateral malleolus. Additional straps were secured at the thigh, pelvis and trunk to minimise extraneous movement. Range of motion for knee flexion/extension was set to 90˚ (from 0˚ to 90˚ flexion) and gravity correction was obtained by weighing the limb in a relaxed state at 20˚ flexion. Standardised visual and verbal cues were given during the test phase, with one minute rest between sets

Strength was tested concentrically at $60°.s^{-1}$ for five repetitions, $180°.s^{-1}$ for ten repetitions and $300°.s^{-1}$ for 15 repetitions following a standard protocol (Drouin et al., 2004). Three speeds of assessment were included in order to gather a battery of performance data similar to that used for clinical decision making on return to full function after ACL surgery (Grindem et al., 2016, Kyritsis et al., 2016). Protocols similar to ACL testing were used in order to capture a battery of assessments which provide a more robust measure of physical function and remove possible ceiling effects of lower intensity strength / performance measures. Combined strength and hop tests are frequently used to monitor functional recovery and determine progression or readiness for return to sporting participation (Paterno et al., 2018, Kyritsis et al., 2016), successfully reducing the risk of re-injury rate after ACL surgery (Grindem et al., 2016). A collection of performance tests were used in the TRIMS study in order to provide a robust picture of changes in physical performance and capture previously under-reported data relevant to wider clinical populations, as identified through systematic review. Strength is reported as peak torque in Newton metres (Nm). Identical assessments were performed at six-months following surgery.

Figure 3.5: Biodex System 3 Isokinetic Dynamometer

3.4.6 Arthroscopic Findings

Meniscal tears were classified at surgery using a modified version of the International Society of Arthroscopy, Knee Surgery and Orthopaedic Sports Medicine (ISAKOS) classification of meniscal tears (Anderson et al., 2011) and cartilage lesions were classified using the International Cartilage Repair Society (ICRS) grading system (Mats and Winalski, 2003). Both measures were incorporated into a standardised data collection form (Appendix: 12: TRIMS Arthroscopy Form). This form includes information on the location, depth and length of meniscus tears, in addition to classification of osteoarthritis in each compartment of the knee. A similar form had previously been used for data collection in a longitudinal Danish APM cohort (Thorlund et al., 2013), feedback was sought from authors on success and revision of the form in order to optimise data collection.

Surgeons involved in the TRIMS study and their surgical team members were trained in the correct completion of the arthroscopy data collection form through presentations at both clinical sites. The study lead investigator (NC) attended orthopaedic team meetings at both sites and distributed an arthroscopy form and arthroscopy form instructions (Appendix 27: TRIMS Arthroscopy Form Instructions) to entire teams. A brief presentation was given outlining how to complete the form and all questions were answered. A clearly marked folder was prepared for data collection forms, which contained blank forms, a laminated copy of the arthroscopy form instructions and a weekly list of recruited patients. This folder was stored at a secure location in the Orthopaedic department close to the operating theatre for ease of reference.

Additional surgical data

Additional data was collected at time of surgery to confirm injury classification and describe joint health on arthroscopic assessment. Surgeons also reported the reason for surgery in order to facilitate comparison with patient reported reasons and examine the current rationale for surgical selection (further discussion in Chapter 4). All additional data was recorded in the standardised TRIMS arthroscopy form.

Inflammation of the synovial membrane of the knee (synovitis) is related to pain and poor function, synovitis is a potential driver of knee OA onset and progression (Mathiessen and Conaghan, 2017). Degree of synovitis (mild / moderate / severe) was recorded in the surgical data form reported by surgeons to facilitate potential classifications of inflammation and osteoarthritis phenotype at time of surgery.

Previous meniscus surgery, if carried out, was noted and documented at time of surgery by location and percentage of meniscus resected (0-20%. 21-50%, >50%) or repaired. This data was used in cohort descriptive summary as confirmation of previous surgery.

At time of surgery, surgeons reported their reason for surgery under a number of classifications, including an open form reply. Surgeon's responded to tick box options; 'Persisting Pain, Mechanical Symptoms, Failed Conservative Treatment, Other (Please Specify)'. This data was gathered in order to examine the reported reasons for surgery from both a surgeon's and patients' perspective (Further discussion in Chapter 5).

3.5 Summary of data collection Forms:

Specific data collection forms are attached as Appendices (Appendix 10 – Appendix 15). All data was collected and entered by hand to these standardised forms, data was then transferred to Microsoft Excel Version 15.32 (2017) and anonymised to study ID number, an identifier key was only accessible to the lead investigator. Four forms were used to collect the data outlined in this chapter. The injury mechanism assessment form (Appendix 10: TRIMS Injury Mechanism Assessment Form) was used to gather subjective data in addition to the PROMs, the physiotherapy assessment form (Appendix 11: TRIMS Physiotherapy Assessment Form) was used to collect objective data and the arthroscopy form (Appendix 12: TRIMS Arthroscopy Form) was used to collect surgical data. Biodex strength test reports were printed directly from Biodex software, and the Physical Activity Scales (Tegner & SIPAM) were combined in one page (Appendix 13:

TRIMS Physical Activity Form). All other data collection forms were standardised outcome measures as discussed above. (Appendix 14: KOSS (Knee Injury and Osteoarthritis Outcome Score), Appendix 15: IKDC Subjective Form).

3.6 Statistical Methods

Data was assessed for normality using the Shapiro-Wilk and Shapiro-Francia tests, and by examining histograms, QQ plots and analysis plotting residuals to assess for signs of skewness and kurtosis. Descriptive statistics are given as means and standard deviation (SD), medians with interquartile range (IQR), or numbers with percentages as appropriate. Baseline assessments were analysed using un-paired t-tests to assess for between leg difference in the pre-operative cohort. For participants with confirmed meniscus tears at time of surgery, differences between groups (pre-op / post-op between leg differences and within leg changes over time) were assessed by performing a repeat measures ANOVA and assessing for global effects of two factors (treatment and time). If global effects were found, post-hoc corrected *P*-values were calculated for between group analyses using Bonferroni tests. Effect size (Cohen's-*d*) was calculated for statistically significant results, in order to infer clinical significance. Un-paired t-tests were used to analyse between leg difference at last follow up. Relationship between pre-operative physical activity level, and post-operative improvement in performance outcomes were examined with Spearman's rank correlation. Results are reported as means with 95% confidence intervals (CI) unless otherwise stated. Box and whisker plots are presented as min to max values, unless otherwise stated, with line at median and a point indication of mean. A sensitivity analysis was performed to investigate differences in primary outcomes when excluding participants with incomplete assessment data. Stata 15.1 (StataCorp LLC, Texas, USA), PRISM 8.4 (GraphPad Software LLC, California, USA) and G*Power 3.1 (Heinrich Heine University, Düsseldorf, Germany) were used for all statistical and graphical analyses. Level of significance was pre-defined as $P<0.05$.

3.7 Participants:

Fifty-four participants consented to participation in the study and were assessed at pre-operative baseline. Following data analysis, nine participants were removed from longitudinal cohort analysis as they did not have a meniscus tear at arthroscopy. Once enrolled, all participants were followed up for the duration of the study. Forty participants returned subjective PROM questionnaires at three months and forty-four participants attended the six-month post-operative follow up assessment. One participant could not attend the six-month appointment and sent PROMs by post. At the six-month time-point; two participants had not proceeded for surgery, one had developed post-operative complications (infections requiring multiple surgeries), one participant had progressed to a Total Knee Replacement (TKR) and five participants did not respond to follow up. Thirty-seven participants responded to questionnaires at twelve months post-op. At one year follow up, a total of five participants had progressed to TKR and nine participants did not respond to follow up.

Baseline analysis was performed on all participants who attended pre-operative assessment (n=54). Further analysis was only performed on participants who had a confirmed meniscus tear at time of arthroscopy (n=43). A flow chart of participants included in longitudinal analysis is shown in Figure 3.6.

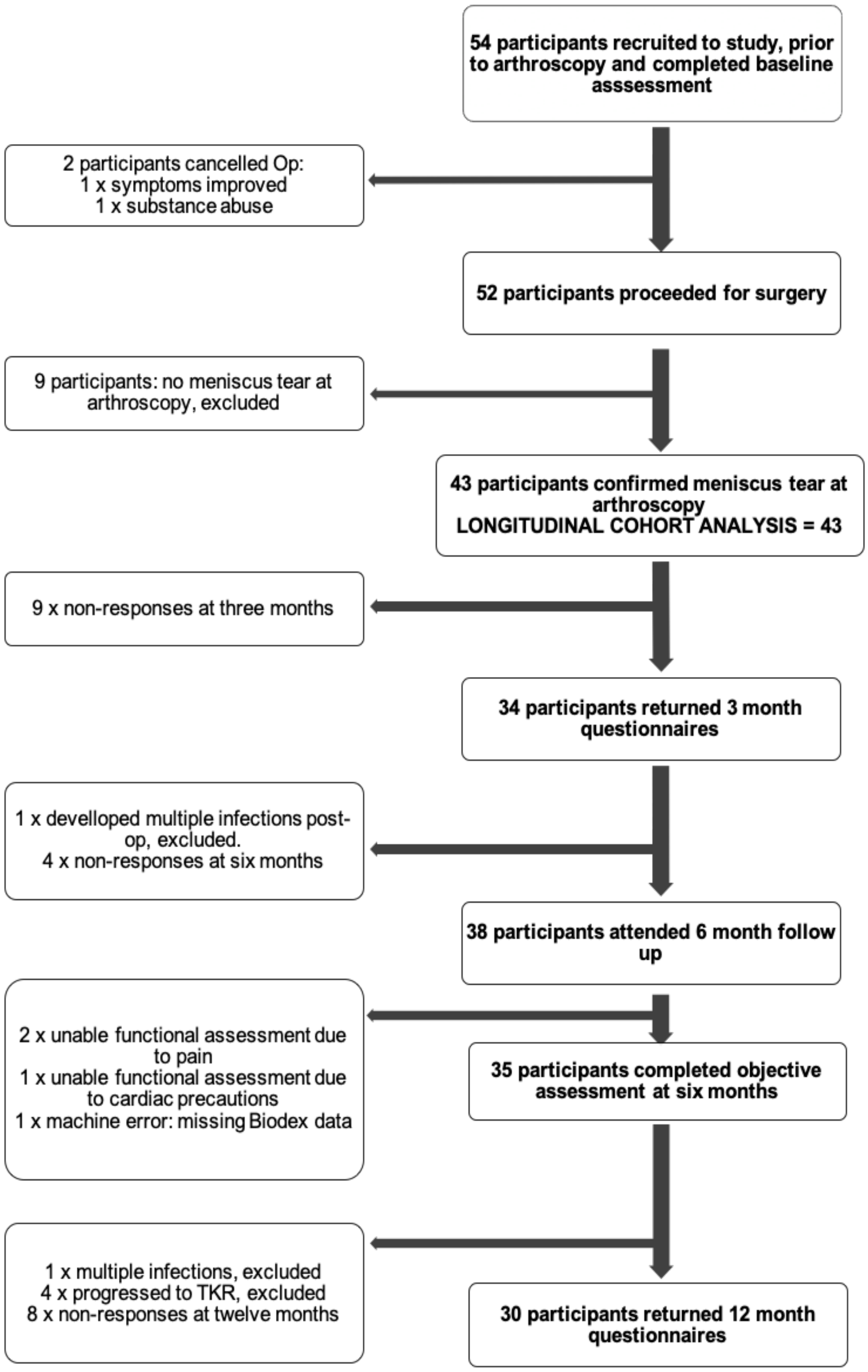


Figure 3.6: Flow chart of TRIMS recruitment and data analysis.

3.8 Descriptive Data:

Participant characteristics and descriptive variables are included in Table 3.3 / Table 3.4 for patients include in pre-operative analysis and longitudinal cohort analysis. Pre-operative statistics were calculated for both cohorts; Table 3.3 outlines the participants included in the pre-operative functional performance assessment as it was deemed that this represents a valid clinical cohort. Table 3.4 describes the participants with confirmed meniscus tears who were included in the longitudinal analysis; all change scores over time were calculated using only the baseline scores of the cohort who had an arthroscopically confirmed meniscus tear.

	Full Cohort: n=54
Age: years, mean (SD)	48 (16)
Female, n (%)	19 (35)
BMI: kg/m^2, mean (SD)	27.7 (4.9)
Contralateral knee symptoms[a], n (%)	
Injury (yes)	17 (35)
Treated by doctor (yes)	19 (39)
Surgery (yes)	9 (18)
Mechanical symptoms, n (%)	
Catching	40 (75)
Locking	25 (46)
Giving Way	40 (75)

[a]Four missing data points.
BMI: Body Mass Index.

Table 3.3: Baseline participant characteristics (Full Cohort)

Participants included in the twelve-month cohort analysis represent a middle aged and overweight cohort (Mean age 52 years, Mean BMI 28.3 kg.m^{-2}). Two-thirds of participants had a medial meniscus tear and 67% had at least one compartment of the knee with a grading >2 on the ICRS grading scale, indicating abnormal cartilage lesions to less than 50% depth. Eighteen percent of participants had previous contralateral knee surgery and >70% of participants reported at least one mechanical symptom.

	Final Cohort: n=43
Age: years, mean (SD)	52 (14)
Female, n (%)	17 (40)
BMI: kg/m^2, mean (SD)	28.3 (4.8)
Meniscus Tear compartment, n (%)	
Medial	28 (65)
Lateral	8 (19)
Both	7 (17)
ICRS Medial score >2, n (%)	29 (67)
ICRS Lateral score >2[a], n (%)	15 (36)
ICRS Patellofemoral score >2[a], n (%)	20 (48)
Contralateral knee symptoms[b], n (%)	
Injury (yes)	15 (38)
Treated by doctor (yes)	17 (43)
Surgery (yes)	7 (18)
Mechanical symptoms, n (%)	
Catching	31 (72)
Locking	21 (49)
Giving Way	30 (70)

BMI: Body Mass Index. ICRS: International Cartilage Repair Society articular cartilage grading scale. SIPAM: Single Item Physical Activity Measure.

[a]One missing data point, [b]Three missing data points

Table 3.4: Baseline participant characteristics for participants with an arthroscopically confirmed meniscus tear.

3.9 Outcome Data:

Results from the TRIMS cohort were analysed under three themes, in keeping with the study aims and objectives:

1. Pre-operative functional performance in an APM cohort:
   Analysis of PROMs and objective functional performance in patients awaiting APM (<2 weeks pre-operatively).
2. Self-reported function following APM:
   Analysis of PROMS at three, six and twelve months post-operatively, including change from baseline.
3. Change in objective functional performance over time following APM.

- Change in objective functional performance from pre-operative to post-operative: two-factor repeat measures analysis of variance with post-hoc analysis of between group differences.
- Correlation analysis: correlation between activity level and change in objective functional performance measures.

3.10 Main Results:

Summary statistics and graphs of outcome trajectory are presented according to each theme of analysis below.

3.10.1 Pre-Operative Functional Performance in an APM Cohort

Pre-operative outcome measures are summarised in Table 4.3 (subjective: PROMs) and 4.4 (objective measures: performance assessment).

	Baseline (n=54)
Median SIPAM (IQR)	2 (1-4)
Median Tegner Score (IQR) [a]	3 (2-5)
Median Tegner Score Pre-Injury (IQR) [a]	5 (4-7)
Mean KOOS Pain (SD)	55 (21)
Mean KOOS Symptoms (SD)	53 (19)
Mean KOOS ADL (SD)	61 (21)
Mean KOOS Sports & Rec (SD)	35 (24)
Mean KOOS QOL (SD)	32 (23)
Mean IKDC (SD)	51 (11)

[a]One missing data point.

Table 3.5: Subjective measures of performance pre-operatively.

The Single Item Physical Activity Measure showed that study subjects were only participating in habitual moderate physical activity for a total of 30 minutes or more on two days per week. The SIPAM was reported as a median (interquartile range) as the data was skewed. A score of three on the Tegner Scale is described as ‘Work - light labour (nursing etc.)’. The median pre-injury Tegner Score was reported as five, which is described as ‘Work - Heavy Labour (construction etc.), Competitive Sports - Cycling, Cross-Country Skiing, Recreational Sports - Jogging on uneven ground, at least twice weekly’ (Appendix 13: TRIMS Physical Activity Scales). One subject did not report their Tegner score at baseline.

Subscales of the KOOS, and the IKDC subjective form are scored from 0 – 100 with higher scores indicating better self-reported function. Control data was not gathered for PROMs, however scores showed deficits in self-reported function prior to surgery, when compared to population based age-matched scores (Paradowski et al., 2006).

Objective functional performance was compared to the contralateral leg using unpaired t-tests and revealed deficits in strength and hop performance on all performance measures (*P*<.006 all measures; Table 3.6). Fifty-three participants completed Biodex strength assessments. Ten participants were unable to complete SLH at baseline, 15 participants were unable to complete the 6MH and thirteen were unable to complete THD. The majority of participants reported pain as their reason for being unable to complete hops, a small number of participants reported decreased confidence and one participant was unable to hop due to a muscle cramp.

Pre-operative Assessment. Cohort: n=54

	Surgery Leg Mean (SD)	**Contralateral Leg Mean (SD)**	**Mean Difference (SD), (95% CI) p-value**
Strength Quads 60°/sec (Nm)	108 (63)	132 (64)	-24 (30) (-33, -16) **p<0.001**
Strength Quads 180°/sec (Nm)	81 (44)	96 (45)	-15 (17) (-20, -10) **p<0.001**
Strength Quads 300°/sec (Nm)	65 (30)	77 (37)	-11 (19) (-17, -7) **p<0.001**
Strength Hamstrings 60°/sec (Nm)	62 (33)	69 (33)	-7 (16) (-12, -3) **p=0.002**
Strength Hamstrings 180°/sec (Nm)	48 (27)	54 (25)	-6 (12) (-9, -3) **p<0.001**
Strength Hamstrings 300°/sec (Nm)	48 (24)	53 (22)	-5 (13) (-9, -2) **p=0.006**
Single Leg Hop (cm) n=44	93 (46)	110 (46)	-17 (27) (-26, -9) **p<0.001**
6 Metre Hop (s) n=39	4.2 (2.3)	3.4 (1.5)	.77 (1.3) (.33, 1.2) **p=0.001**
Triple Hop (cm) n=41	341 (136)	390 (137)	-49 (74) (-73, -26) **p<0.001**

Max n=53 for all pre-op strength and functional assessments: One participant was unable to complete functional assessment at baseline due to excessive knee pain and swelling – subsequent dropout due to multiple infections and surgeries post-operatively. Nm=Newton metre

Table 3.6: Objective Measures of performance at baseline (pre-operatively).

3.10.2 Self-reported function following APM

Subjective outcomes were assessed pre-operatively and at three post-operative timepoints. For the purpose of this analysis, only participants with an arthroscopically confirmed meniscus tear were included (n=43). Tegner score was reported as Median as it is a ranked scale (ordinal data) and SIPAM was reported using median as the data was skewed (not normally distributed). Baseline scores on self-reported measures are presented for participants with a confirmed meniscus tear in Table 3.7

	Baseline (n=43)
Median SIPAM (IQR)	3 (0-4)
Median Tegner Score (IQR)	3 (2-5)
Median Tegner Score Pre-Injury (IQR)	5 (4-7)
Mean KOOS Pain (SD)	57 (18)
Mean KOOS Symptoms (SD)	53 (17)
Mean KOOS ADL (SD)	62 (19)
Mean KOOS Sports & Rec (SD)	35 (23)
Mean KOOS QOL (SD)	30 (21)
Mean IKDC (SD)	50 (11)

Table 3.7: PROMs at baseline (pre-op) for follow up cohort.

No change in days of moderate physical activity per week (SIPAM) was found between baseline and each timepoint, although there was a median change of two points on Tegner Scale at all follow up points showing that participants were participating in activities which are ranked as more challenging to the knee (P <0.05 at each follow up). All subscales of the KOOS and IKDC self-reported function were improved from baseline to each time point (P<0.01 for all KOOS subscales and timepoints, P <0.05 for all IKDC timepoints). Figure 3.9 shows the trajectory of overall improvement in KOOS subscales over time and Figure 3.10 demonstrates the similar trajectory with an initial improvement from baseline to three months in the IKDC scale. Results of all t-tests are reported in Tables 3.8, 3.9, 3.10.

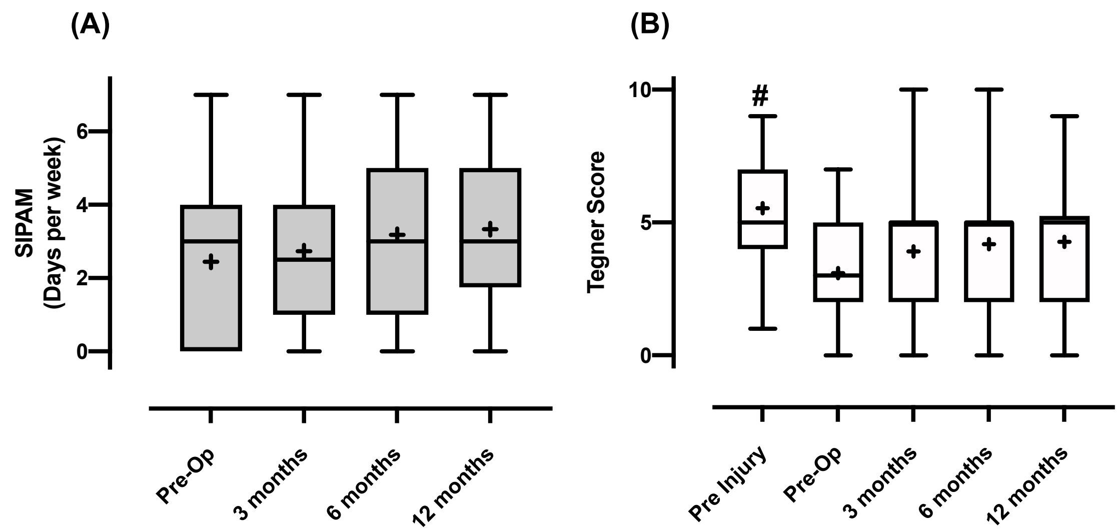


Figure 3.7: Change in Physical Activity Measures

(A) Change in SIPAM from pre-op to 12 months post-op; and (B), Change in Tegner Score from pre-injury (retrospectively reported at baseline assessment) to 12 months. # denotes significant difference in Tegner score at baseline to all timepoints (*P*<0.05) [Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = Range]

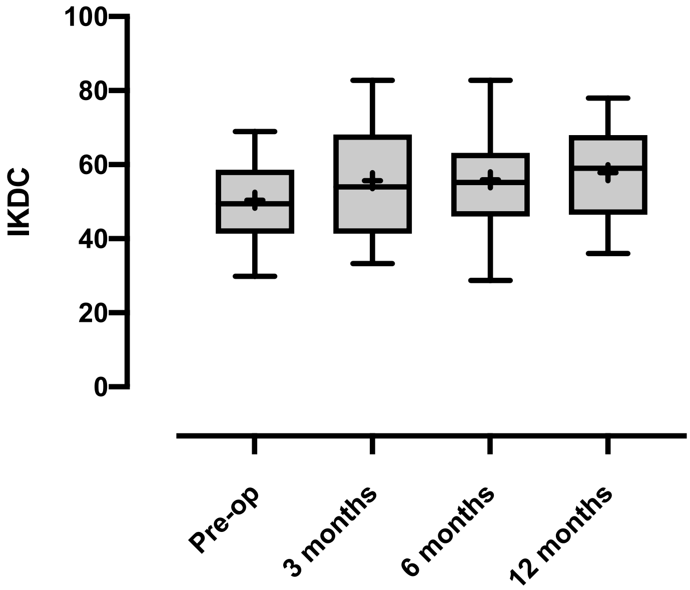


Figure 3.8: Trajectory of IKDC score from baseline to twelve months

[Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = Range]

Trajectory of IKDC score of time was analysed with one-way ANOVA and showed a significant difference in IKDC over time (F (3, 142) = 6.132, P<.001). Analysis of change from baseline is reported in Tables 3-8 – 3.10. Due to the five subscales of the KOOS, graphing of multiple measures over time is most easily represented using KOOS profiles, The KOOS is not designed to be reported as an aggregated scale. KOOS profiles are represented in Figure 3.9, and all between group t-tests are reported (Tables 3.8-3.10). Paired t-tests were used to assess change between timepoints in order to reports the change individually at each timepoint and establish generalisability of the reported function in the TRIMS cohort, with previous APM cohorts. The importance of reporting full performance data on performance measures was highlighted in Chapter 2. Trajectories of function in the TRIMS cohort was found to be similar to that of previous longitudinal studies in middle aged populations with knee injuries (Thorlund et al., 2017a).

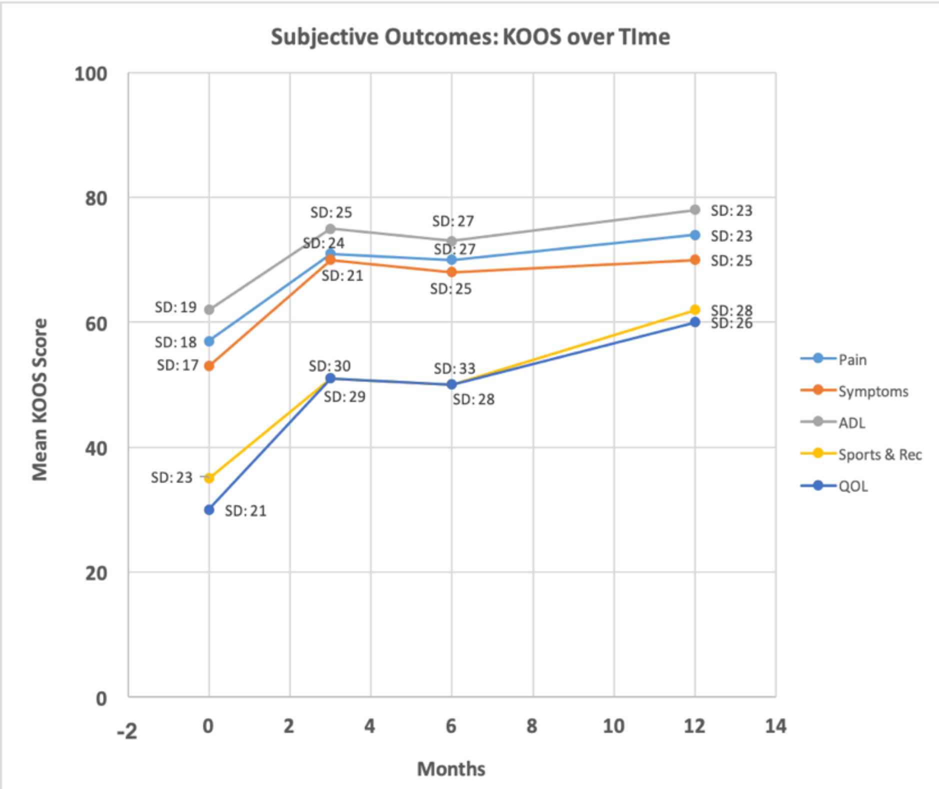


Figure 3.9: Trajectory of KOOS subscales from baseline to twelve months.
Points represent mean score on each subscale, SD = Standard Deviation.

In order to further examine change in self-reported higher level function over time, a one-way ANOVA was conducted on the Sports and Recreation subscale of the KOOS,. Significant differences were found between group means ($F(3,142) = 6.13$, $P<.001$) over time. Corrected bonferroni multiple comparisons revealed a significant difference between baseline and both three & twelve months post-op, at six-months the difference did not reach the predefined significance level (0 – 6 months: P =.08), nor was there any significant difference between scores at three / six months and twelve months. This is presented graphically in Figure 3.10.

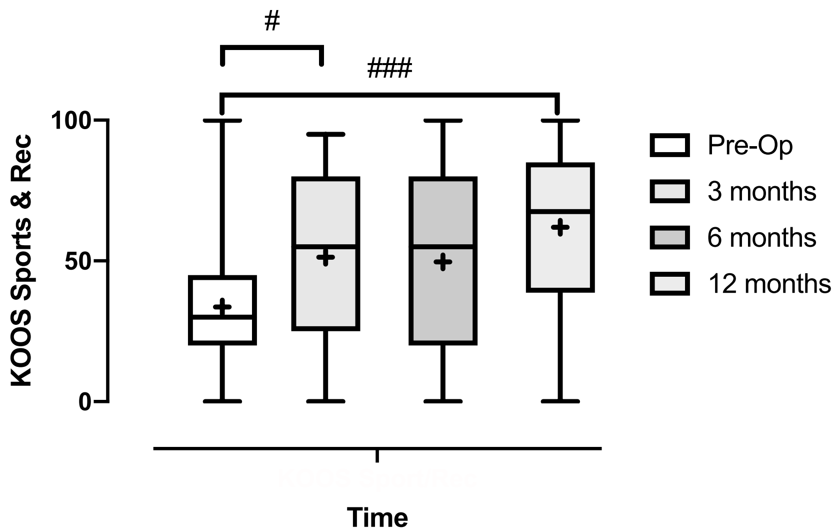


Figure 3.10: KOOS - Sports & Rec Subscale score at pre-op and three, six and 12 months post-op.

# denotes *P*<0.05, ### denotes *P*<0.001 (Bonferroni corrected post-hoc test). [Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = Range]

Differences from baseline to three, six and twelve months post-operatively are presented in Table 3.8, 3.9 and 3.10 respectively; showing significant improvements in all measures excluding the Single Item Physical Activity Measure (SIPAM).

(n = 34)	Baseline	3 months Ax	Mean Difference (SD), (95% CI), p-value
Mean KOOS Pain (SD)	57 (19)	71 (24)	15 (18) (8, 21), **p<.001***
Mean KOOS Symptoms (SD)	52 (16)	70 (21)	18 (15) (13, 23), **p<.001***
Mean KOOS ADL (SD)	61 (20)	75 (25)	13 (17) (7, 19), **p<.001***
Mean KOOS Sports & Rec (SD)	36 (24)	51 (30)	16 (31) (4, 26), **p=.006***
Mean KOOS QOL (SD)	30 (20)	51 (29)	20 (21) (12, 27), **p<.001***
Mean IKDC (SD)	51 (11)	56 (14)	4 (10) (1, 7), **p=.022***
Median SIPAM (IQR)	3 (0-4)	2.5 (1-4)	p=0.727⊥
Median Tegner Score (IQR)	3 (2-5)	5 (2-5)	**p=.021⊥**

*Paired t-test, ⊥Wilcoxon signed-rank

Table 3.8: Patient Reported Outcome Measures at three months post-op.

(n = 39)	Baseline	6 months Ax	Mean Difference (SD), (95% CI), p-value
Mean KOOS Pain (SD)	57 (18)	70 (27)	13 (19) (7, 19), **p<.001**[*]
Mean KOOS Symptoms (SD)	53 (17)	68 (25)	15 (18) (9, 21) **p<.001**[*]
Mean KOOS ADL (SD)	62 (19)	73 (27)	12 (19) (5, 18), **p<.001**[*]
Mean KOOS Sports & Rec (SD)	35 (23)	50 (33)	14 (27) (6, 23) **p=.002**[*]
Mean KOOS QOL (SD)	30 (21)	50 (28)	20 (23) (12, 27) **p<.001**[*]
Mean IKDC (SD)	51 (10)	56 (13)	5 (10) (2, 8) **p=.004***
Median SIPAM (IQR)	3 (0-4)	3 (1-5)	p=0.184[⊥]
Median Tegner Score (IQR)	3 (2-5)	5 (2-5)	**p=.009**[⊥]

[*]Paired t-test, [⊥]Wilcoxon signed-rank (n=39: 38 participants attended follow up, one participant returned subjective outcomes by post.)

Table 3.9: Patient Reported Outcome Measures at six months post-op.

(n = 30)	Baseline	12 months Ax	Mean Difference (SD), (95% CI), p-value
Mean KOOS Pain (SD)	59 (19)	74 (23)	16 (16) (9, 22), **p<.001**[*]
Mean KOOS Symptoms (SD)	53 (15)	70 (25)	17 (18) (10, 23), **p<.001**[*]
Mean KOOS ADL (SD)	64 (18)	78 (23)	14 (15) (8, 19), **p<.001**[*]
Mean KOOS Sports & Rec (SD)	38 (25)	62 (28)	25 (29) (14, 35), **p<.001**[*]
Mean KOOS QOL (SD)	32 (19)	60 (26)	28 (22) (20, 36), **p<.001**[*]
Mean IKDC (SD)	53 (10)	58 (13)	5 (10) (1, 9), **p=.015**[*]
Median SIPAM (IQR)	3 (0-4)	3 (2-5)	p=0.191[⊥]
Median Tegner Score (IQR)	3 (2-5)	5 (2-5)	**p=.027**[⊥]

[*]Paired t-test, [⊥]Wilcoxon signed-rank

Table 3.10: Patient Reported Outcome Measures at twelve months post-op.

3.10.3 Change in objective functional performance over time.

Change in objective functional performance measures were analysed from pre-op to post-op using repeat measures ANOVA for subjects who had a confirmed meniscus tear at arthroscopy and attended the six month follow up appointment. At six months, 34 subjects completed functional assessments. A number of participants were again unable to complete hop tests at the six-month assessment; the majority of subjects who could not complete hop tests at six months reported that this was due to lack of confidence in the knee, compared to pain which was the most frequent reason for not completing hop tests at baseline. Twenty-six participants completed the SLH at both baseline and follow up, 24 participants completed the 6MH and THD at both time points.

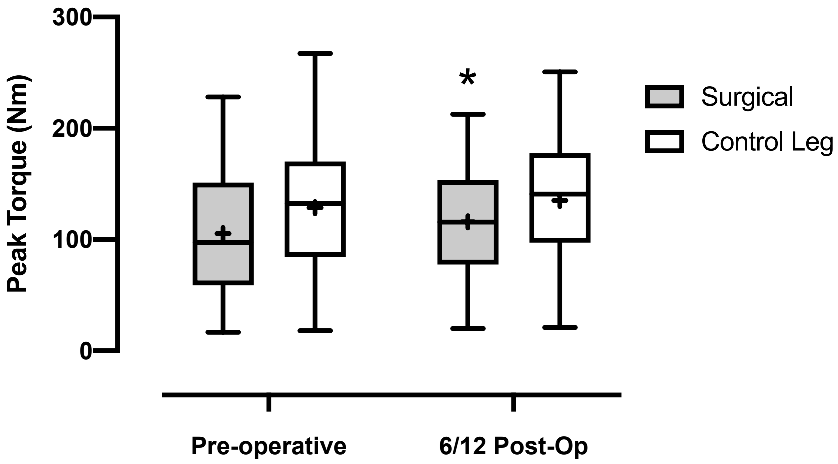


Figure 3.11: Difference in Quad Strength (Peak Torque at 60°.s^{-1}) in APM (Surgical) and Non-Operated (Control) leg at baseline and six-months.

∗ denotes significant difference from pre-op in surgical leg only (corrected *P*-value <0.05). [Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = Range].

Analysis of 60°.s^{-1} quad strength did not reveal a global interaction effect or effect of treatment, a significant global effect of time was found ($F(1,66) = 12.52$, $P<0.001$), indicating that strength changed following surgery. Post-hoc multiple comparison analysis revealed a significant change in the surgical leg over time ($P<0.01$) but not the control leg ($P=0.12$). There was no adjusted significant difference between legs. A small effect size was found for strength change in the surgical leg over time, which was not clinically significant ($d = 0.19$).

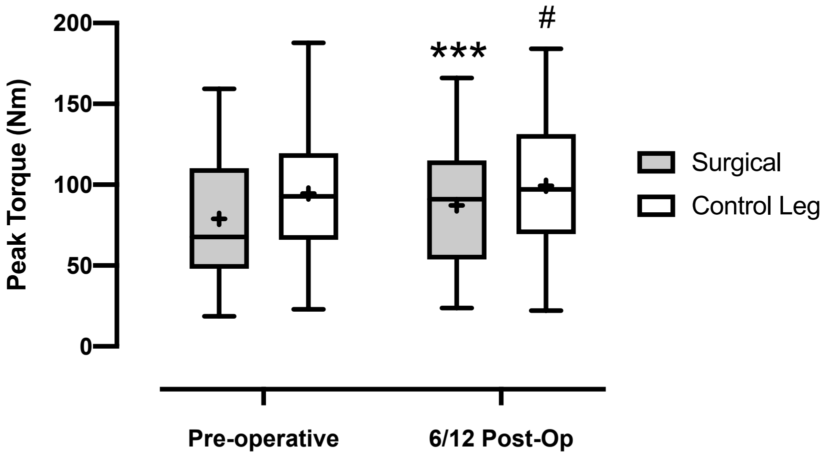


Figure 3.12: Difference in Quad Strength (Peak Torque at 180°.s^{-1}) in APM (Surgical) and Non-Operated (Control) leg at baseline and six-months.

*** denotes highly significant difference from pre-op in surgical leg (corrected *P*-value <0.001), # denotes significant difference from pre-op in control leg (corrected *P*-value <0.05). [Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = Range].

Analysis of 180°.s^{-1} quad strength did not reveal a global interaction effect or effect of treatment, a significant global effect of time was found ($F(1,66) = 20.23$, $P<.001$), indicating that 180°.s^{-1} quad strength also changed following surgery. Post-hoc multiple comparison analysis revealed a significant change in both the surgical leg over time ($P<0.001$) and the control leg ($P<0.05$). There was no adjusted significant difference between legs. A small and statistically insignificant effect size was found for strength change over time, in both surgical leg (d = 0.21 and control leg (d = 0.11).

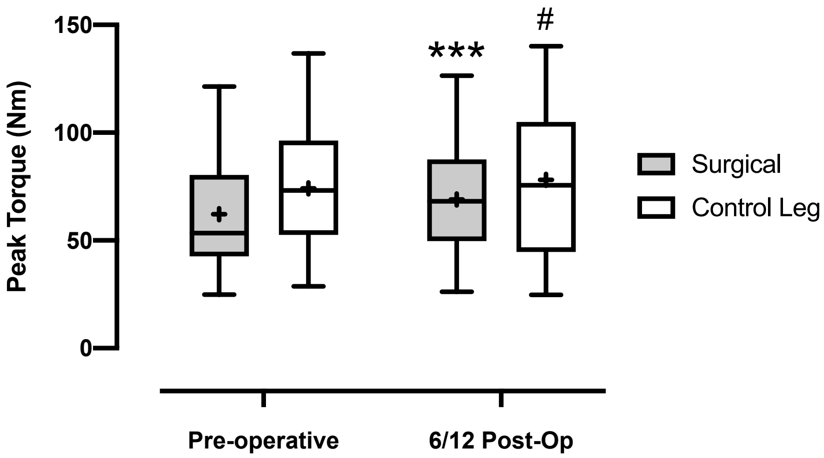


Figure 3.13: Difference in Quad Strength (Peak Torque at 300°.s^{-1}) in APM (Surgical) and Non-Operated (Control) leg at baseline and six-months.

*** denotes highly significant difference from pre-op in surgical leg (corrected *P*-value <0.001), # denotes significant difference from pre-op in control leg (corrected *P*-value <0.05). [Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = Range].

Analysis of 300°.s^{-1} quad strength did not reveal a global interaction effect or effect of treatment, a significant global effect of time was found ($F(1,66) = 20.55$, $P<0.001$), indicating that 300°.s^{-1} quad strength changed following surgery, in keeping with previous speed of assessment. Post-hoc multiple comparison analysis revealed a significant change in both the surgical leg over time ($P<0.001$) and the control leg ($P<0.05$). There was no adjusted significant difference between legs. A small and clinically insignificant effect size was found for strength change over time, in both surgical leg (d = 0.26) and control leg (d = 0.13).

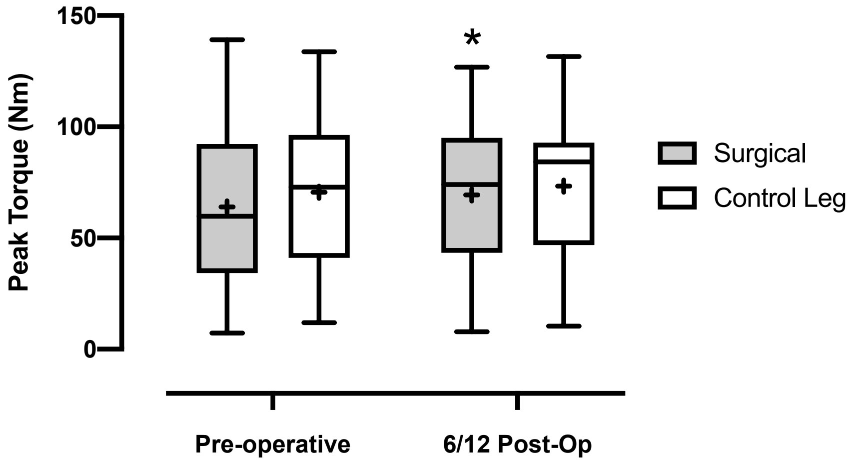


Figure 3.14: Difference in Hamstring Strength (Peak Torque at 60°.s^{-1}) in APM (Surgical) and Non-Operated (Control) leg at baseline and six-months.

∗ denotes significant difference from pre-op in surgical leg only (corrected *P*-value <0.05). [Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = Range].

Analysis of 60°.s^{-1} hamstring strength did not reveal a global interaction effect or effect of treatment leg, a significant global effect of time was found ($F(1,66) = 7.83$, $P<0.01$), indicating that hamstring strength also changed following surgery. Post-hoc multiple comparison analysis revealed a significant change in the surgical leg over time ($P<0.05$) but not the control leg ($P=0.36$). There was no adjusted significant difference between legs. A small effect size was found for strength change in the surgical leg over time, which was not clinically significant (d = 0.16).

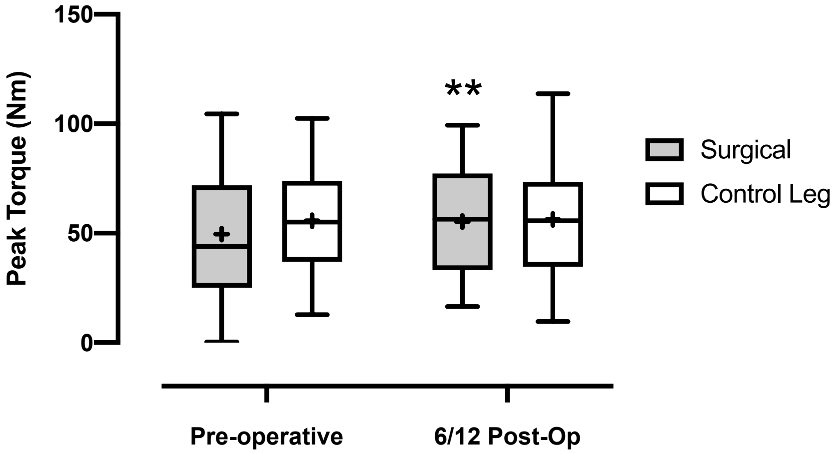


Figure 3.15: Difference in Hamstring Strength (Peak Torque at 180°.s^{-1}) in APM (Surgical) and Non-Operated (Control) leg at baseline and six-months.

** denotes significant difference from pre-op in surgical leg only (corrected *P*-value <0.01). [Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = Range].

Analysis of 180°.s^{-1} hamstring strength did not reveal a global interaction effect or effect of treatment leg, a significant global effect of time was found ($F(1,66) = 5.25$, $P<0.05$), in keeping with previous analysis. Post-hoc multiple comparison analysis revealed a significant change in the surgical leg only, over time ($P<0.01$). There was no adjusted significant difference between legs. A small effect size was found for strength change in the surgical leg over time, which was not clinically significant ($d = 0.22$).

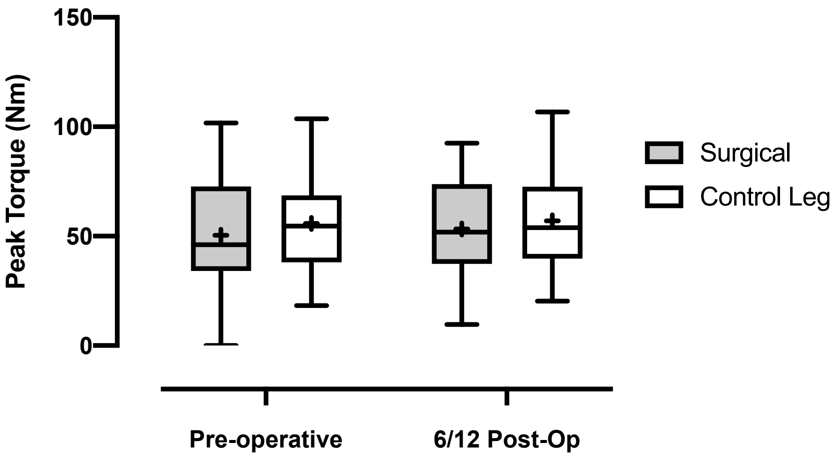


Figure 3.16: Difference in Hamstring Strength (Peak Torque at 300°.s^{-1}) in APM (Surgical) and Non-Operated (Control) leg at baseline and six-months.

[Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = Range]

Analysis of 300°.s^{-1} hamstring strength did not reveal a global interaction effect nor effect of treatment leg, or time. No significant post-hoc multiple comparison were found between legs or within legs over time.

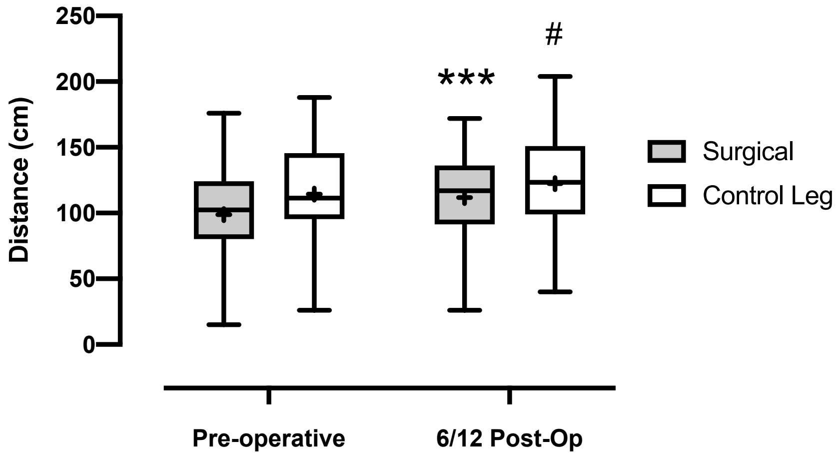


Figure 3.17: Difference in Single Leg Hop scores in APM (Surgical) and Non-Operated (Control) leg at baseline and six-months (n=26).

∗∗∗ denotes highly significant difference from pre-op in surgical leg (corrected *P*-value <0.001), # denotes significant difference from pre-op in control leg (corrected *P*-value <0.05). [Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = Range].

Analysis of SLH performance did not reveal a global interaction effect or effect of treatment leg, a significant global effect of time was found ($F(1,50) = 27.09$, $P<0.001$). Post-hoc multiple comparison analysis revealed a significant change in both the surgical leg ($P<0.001$) and the control leg ($P<0.05$) over time. There was no adjusted significant difference between legs. A small effect size was found for change in hop performance which was not clinically significant in either the surgery leg ($d = 0.33$) nor the control leg ($d = 0.19$).

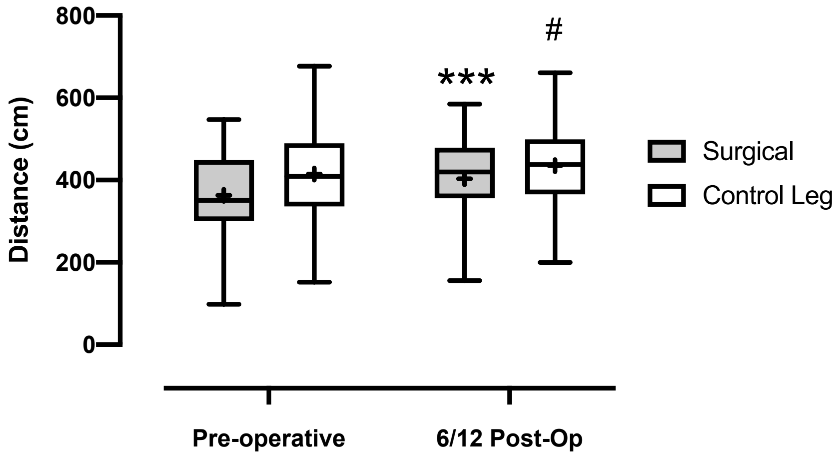


Figure 3.18: Difference in Triple Hop for Distance scores in APM (Surgical) and Non-Operated (Control) leg at baseline and six-months (n=24).

∗∗∗ denotes highly significant difference from pre-op in surgical leg (corrected *P*-value <0.001), # denotes significant difference from pre-op in control leg (corrected *P*-value <0.05). [Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = Range].

Analysis of THD performance did not reveal a global interaction effect or effect of treatment leg, a significant global effect of time was found ($F(1,46) = 29.04$, $P<0.001$). Post-hoc multiple comparison analysis revealed a significant change in both the surgical leg ($P<0.001$) and the control leg ($P<0.05$) over time. There was no adjusted significant difference between legs. A small effect size was found for change in hop performance which was not clinically significant in either the surgery leg ($d = 0.38$) nor the control leg ($d = 0.18$).

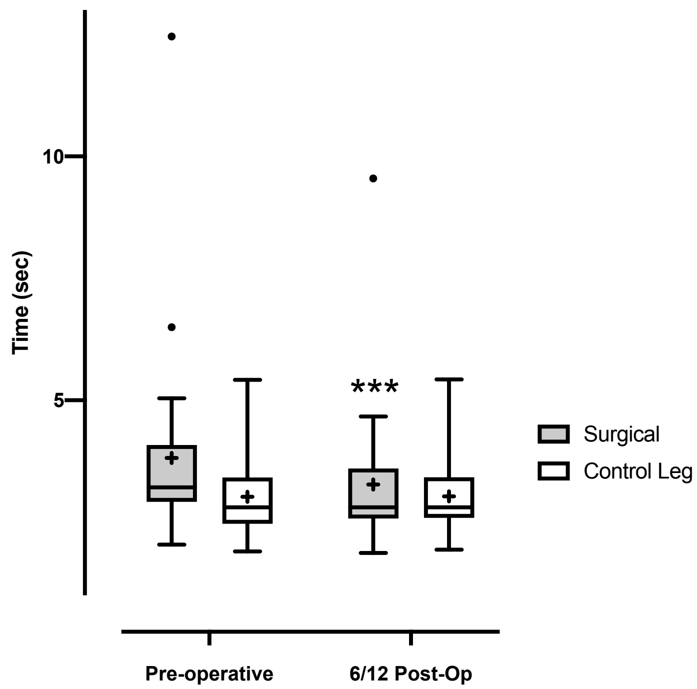


Figure 3.19: Difference in Six-Metre Hop (Timed) scores in APM (Surgical) and Non-Operated (Control) leg at baseline and six-months (n=24).

*** denotes highly significant difference from pre-op in surgical leg (corrected *P*-value <0.001). [Box = Interquartile Range; Bar = Median; + = Mean; Whiskers = 1st to 99th percentile].

Analysis of 6MH performance revealed a significant global interaction effect between treatment leg and time ($F(1,46) = 9.8$, $P<0.001$). No global effect of treatment leg was found, while a significant global effect of time was found ($F(1,50) = 27.09$, $P<0.001$). Figure 4.12 shows outliers within the sample population and is graphed as 1-99th percentile in order to demonstrate the possible influence of two outliers on the overall analysis. The two outlying data points on pre-operative surgical leg represent two study participants who took a disproportionately long time to complete the 6MH; this may have led to the interaction effect between time and treatment. Both of these participants recorded an improved, but also outlying score on 6MH at follow up (the second participant had a repeat assessment score which fell just within the 99th percentile).

Although significant, the interaction effect of this analysis was small (accounting for 0.97% of total variation, treatment effect accounted for 3.37%, time accounted for 0.90% while the majority (>90%) of variation was between subjects). Post-hoc multiple comparison analysis revealed a significant change in the surgical leg ($P<0.001$), over time. There was no adjusted significant difference in control leg over time or between legs at either timepoint. A small effect size was found for change in hop performance in the surgery leg ($d = 0.3$), which was not clinically significant. It is possible that treatment leg and improvement over time are related – suggesting that having surgery could lead to a larger improvement over time in functional performance on the 6MH, than control. This was confirmed by the significant improvement in the surgery leg, while the control leg did not change over time. The apparent improvement (decreased time) in 6MH may not represent true improvement in all populations, as the corrected post-hoc analysis revealed a small effect size and the interaction effect found on this analysis may be influenced by outliers in the sample population.

An additional between-leg analysis of functional performance measures was carried out to detect any residual deficits at six months using unpaired t-tests. This analysis found small but statistically significant deficits between surgical and control legs for objective measures (excluding $180°.s^{-1}$ hamstrings and 6MH) at six-months, suggesting that improvements in performance did not represent a complete resolution of function. Between leg analysis and raw data for post-op function are presented in Appendix 29.

3.10.4 Correlation between activity level and change in function.

It was hypothesised that more highly ranked physical activity levels (Tegner score) prior to injury, or higher levels of habitual exercise (SIPAM) prior to surgery may correlate with change in performance measures over time. An improvement of two on the Tegner scale was found at three months following surgery, and sustained at both six and twelve months post-op (Figure 3.7). However change in performance over time was not significantly correlated with pre-injury activity level for any level of preoperative self-reported activity on the Tegner Scale. Similarly, no correlation was found between pre-operative habitual exercise (SIPAM) and change in performance on any of the objective measures gathered. Correlation coefficients for all performance measures were less than 0.25, Spearman's Correlation coefficients were performed as the Tegner Scale is a ranked scale (ordinal data) and SIPAM scores were not normally distributed. Results of analysis are presented in Table 3.11.

	Spearman's Correlation Coefficient (95% Confidence Interval).	
	Pre-Injury Tegner Score	Pre-Injury SIPAM
Change in Strength Assessment: n=34		
Quadriceps 60°/sec (Nm).	0.03 (-0.3, 0.4)	-0.11 (-0.4, 0.2)
Quadriceps 180°/sec (Nm).	0.09 (-0.3, 0.4)	0.09 (-0.3, 0.4)
Quadriceps 300°/sec (Nm).	0.08 (-0.3, 0.4)	-0.07 (-0.3, 0.4)
Hamstrings 60°/sec (Nm).	0.05 (-0.3, 0.4)	0.10 (-0.2, 0.5)
Hamstrings 180°/sec (Nm).	-0.02 (-0.4, 0.3)	0.08 (-0.3, 0.4)
Hamstrings 300°/sec (Nm).	0.11 (-0.3, 0.4)	-0.01 (-0.3, 0.3)
Change in Hop Tests		
Single Leg Hop (cm) n=26	0.15 (-0.2, 0.5)	-0.24 (-0.6, 0.2)
6 Metre Hop (sec) n=24	0.16 (-0.3, 0.5)	0.21 (-0.2, 0.6)
Triple Hop for Distance (cm) n=24	-0.06 (-0.5, 0.3)	-0.06 (-0.5, 0.4)

Table 3.11: Correlation between change in objective performance and pre-injury activity level (Tegner Scale & Single Item Physical Activity Measure).

Patients who are more highly active prior to surgery are not well reported in APM literature; the effect of meniscus injury on physical function in this population is not well known. While TRIMS participants had an initial drop in the frequency of physical activity (SIPAM: Figure 3.7), this returned to the pre-operative level at six and twelve months. The Tegner score which ranks more challenging occupational and recreational activities such as sports participation, improved from a rank of two at pre-op to five post-operatively. At baseline, participants also reported their pre-injury Tegner activity level as Median 5 (IQR: 4-7) (Table 3.7). This was the only PROM which collected data on pre-injury function, as all other measures are designed to collect data on symptoms / function at time of testing. The minimal detectable change for the Tegner Scale, in patients with a meniscus tear is one (Briggs et al., 2006), verifying that changes in the recreational and sports activity occurred after injury and resolved after APM. This pre-injury Tegner Score did not, however correlate with change in any objective performance measure (Table 3.11), neither was there any correlation between pre-operative SIPAM and performance measure changes. While it is important to determine the effect of APM on physical function in more active cohorts, these results indicate that higher or lower activity level prior to injury is not associated with a change in functional performance over time

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Sensitivity Analysis

Sensitivity analysis was performed in order to assess whether participants who were unable to perform functional assessments at all time points, differed from patients who were unable to complete hop tests at either time point (pre-operatively or post-operatively).

Sensitivity analysis with small sample sizes has limited statistical rigour. However; despite the small sample size, sensitivity to participants with missing performance data appeared to be low. Change in functional performance analyses were run for each performance measure (strength and hop tests) with both entire cohort data sets and the data sets of only participants who completed full functional assessments at both time points. Analysis suggested that trends in performance change would not differ, if only participants with full datasets on all performance assessments were included.

Power Analysis

A post-hoc power analysis was performed to confirm the strength of the ANOVA analysis. Power was calculated using G*Power 3.1 and reported for the global effect of time on each individual performance test; parameters were decided as $\alpha = 0.05$, for a 2-group 2-measurement analysis with a repeat measure, within factor power calculation. Effect size (*F*-Value) and sample size for each measure are reported in table 3.12 with corresponding power. Results demonstrate that the study was highly powered to detect a significant difference in the effect of time, eliminating the risk of type II error.

	ANOVA F-Value (Factor = Time)	**Sample Size**	**Power**
Quadriceps Strength			
60°/sec	12.52	34	1.0
180°/sec	20.23	34	1.0
300°/sec	20.55	34	1.0
Hamstring Strength			
60°/sec	7.83	34	1.0
180°/sec	5.25	34	1.0
300°/sec	2.92	34	1.0
Hop Tests			
Single Leg Hop	27.09	26	1.0
Triple Hop for Distance	29.04	24	1.0
Six Metre Timed Hop	9.025	24	1.0

Table 3.12: Post-hoc power analysis for repeat measures ANOVA.

The TRIMS study assessed self-reported and objective functional performance both pre-operatively and post-operatively. Analysis of change in functional performance found significant improvements in both the surgical leg and the control leg over time for the majority of performance measures. It appeared that there were larger although clinically insignificant improvements (effect size) in the surgical leg compared to control. Objective assessment at six-months post-op revealed significant residual deficits in quadriceps strength, hamstring strength (excluding $180°.s^{-1}$), SLH and 6MH. It appears that while function improves following APM, deficits in performance still exist at six months. Results of the TRIMS study and implications of these findings are further discussed in Chapter 5: Discussion.

4 Rationale for APM: Clinician and Patient Perspectives

Elements of this chapter have been presented as a conference poster and conference oral presentation:

Poster Presentation:

Cardy, N., Thorlund, J., Wilson, F., (2018). Large Variability in Clinician Expectations of Arthroscopic Partial Meniscectomy; a Study of Physiotherapists and Orthopaedic Surgical Teams. *ISCP Annual Conference*. Radisson Blu Hotel, Sligo, 9 & 10 November 2018: Irish Society of Chartered Physiotherapy.

Oral Presentation:

Cardy, N., Thorlund, J., Wilson, F., (2018). Surgeons and Patients Report Different Reasons for Surgery; Examination of an Arthroscopic Partial Meniscectomy Cohort. *ISCP Annual Conference*. Radisson Blu Hotel, Sligo, 9 & 10 November 2018: Irish Society of Chartered Physiotherapy.

4.1 Introduction

Functional outcome of APM has been described in Chapters 1 - 4 through summary of current literature and reporting of the TRIMS cohort. Despite the current trend of evidence suggesting that APM is not beneficial for degenerative knees, it continues to be a frequently selected treatment option. In addition to quantitative data which forms external evidence on the outcome of APM, evidence based practice also necessitates the inclusion of clinical expertise and patient expectations / beliefs in the decision making process (Sackett et al., 1996). In clinical practice, patients are increasingly involved in clinical decision making, despite a lack of understanding on how best to optimise shared-decision making with orthopaedic clinicians (Slover et al., 2012). There is considerable evidence that patients want to be consulted about the impacts of treatments (Frosch and Kaplan, 1999). Benefits to patient outcome have been shown with shared decision making; healthcare decisions which reflect patients' goals promote greater patient satisfaction and compliance (Kaplan et al., 1996). Patients who are presented with best evidence on their condition and treatment are more likely to participate in their care (Epstein et al., 2004) and improved patient participation in care is essential in achieving post-operative functional improvements following APM.

Evolving evidence on the outcome of meniscectomy, and challenges to the use of arthroscopy for degenerative knees do not align with the continued clinical use of APM. This chapter examines the rationale for APM treatment selection by reporting both the reasons given for surgery from the patient and clinician perspective, and also clinicians expectations of surgical outcome. These two aspect of rationale for APM are explored independently using data from the TRIMS cohort, and additional survey data gathered from clinicians (members of surgical and physiotherapy teams).

- Expectation of Surgery was examined using standardised outcome measures: (Hospital for Special Surgery (HSS) Knee Surgery Expectations Surveys).

- Reasons for surgery (both patient's and surgeons perspectives) were extracted from data forms used in the TRIMS study.

4.1.1 Clinicians' expectations of APM

Clinicians have varied expectation of recovery time following arthroscopic meniscectomy. A survey of Swedish orthopaedic surgeons found that the mean expected time for recovery following APM of an isolated meniscus tear was 5.1 weeks (Roos et al., 2000a). This expectation does not match the trajectory of functional performance found in systematic review of younger or older patients undergoing meniscectomy (Hall et al., 2015b, Thorlund et al., 2017b), which showed that strength deficits persist for up to four years after APM. Physiotherapists' expectation of APM has not been reported to date. It is important that clinicians involved in the care of patients undergoing APM are clear on the expected outcome of surgery and that members of the clinical team are in agreement when explaining these expectations to patients.

4.1.2 Patients' expectations of APM

Fulfilment of pre-operative expectations of surgery is one of the main determinants of patient satisfaction following knee surgery (Bourne et al., 2010). It is important that patient's expectations of surgery are aligned with established outcomes, although systematic review shows that patients frequently overestimate the benefits of treatments (Hoffmann and Del Mar, 2015). Patient expectations of demanding physical activities following knee joint surgery are often not met (Nilsdotter et al., 2009) which is particularly important for patients who undergo surgery in the hope of achieving functional improvement. Patients undergoing APM were over optimistic about recovery time and return to leisure activities in a Danish cohort similar to the TRIMS cohort (Pihl et al., 2016b). This study also found that patient satisfaction with knee function was associated with the fulfillment of leisure activity expectations.

4.1.3 Reasons for and Indications for surgery

Increases in recent publications reporting the outcome of APM have resulted in multiple guidelines recommending against the use of APM in degenerative knees. (Thorlund et al., 2018, Siemieniuk et al., 2017, Beaufils et al., 2017b). Meniscus injury, regardless of surgical intervention is a risk factor for knee osteoarthritis and is an issue of public health concern (Englund, 2008). As discussed in Chapter 1, frequency of APM remains high, in degenerative as well as traumatic populations. Highly active individuals and athletes present an additional cohort of patients with injuries who are not well reported in current literature. Whether specific indications for surgery may result in different functional outcome following APM remains unclear.

Conflicting reports on the predictors of clinical outcome following APM make it difficult for clinicians to appropriately select patients who may benefit from surgery. A higher BMI and degenerative changes in the knee joint were found to predict worse outcome in older patients with an acute, trauma-related medial meniscus injury (Sofu et al., 2016). However, a systematic review of predictors of clinical outcome following APM reported conflicting evidence on the effect of BMI and found moderate evidence that pre-operative sporting level, or onset of symptoms (acute v chronic) are not predictors of outcome (Eijgenraam et al., 2017). This study suggested that radiological OA, longer duration of symptoms and resection of >50% of the meniscus may predict worse clinical outcome. Clinicians managing patients who have knee pain and decreased physical function with a meniscus tear may struggle to decide if surgical intervention is indicated, particularly if conservative management is not resulting in reduced pain or improved function.

In addition to explaining perspectives on APM, there are issues of informed consent surrounding appropriate patient education prior to surgery. A review of the benefits and harms of arthroscopic surgery for degenerative knees showed that benefits were limited in time and surgery was associated with harms (Thorlund et al., 2015). Patients under review with orthopaedic surgeons have been shown to overestimate their perception of involvement in decision making (Mertz et al., 2018). In order to assess whether patients are correctly informed of relevant information prior to surgery, rationale for APM and reasons for surgery from clinicians' and patients' perspectives need to be established.

4.1.4 Study aim and objectives

The aim of this study was to explore current expectations of APM and reasons for selecting APM as a treatment option among clinicians and patients in the TRIMS cohort.

Objectives were:

- To establish clinicians' mean expectation of change following APM, and whether clinical experience was associated with a different expectation of APM.

- To establish patients' mean expectation of change following APM, and whether activity level prior to surgery was associated with a different expectation of APM.

- To compare reasons for APM from both patients' and surgeons' perspectives.
    - Establish frequent reasons for surgery from both perspectives
    - Assess if reasons reported for surgery are similar in both groups.

4.1.5 Ethics

Ethical approval for this study was granted by an amendment to the original SJH/AMNCH Research Ethics committee approval of the Trinity Meniscus Study. REC Reference: 2016/09/04 2017-02 List 5 (18). (Appendix 17: Amendment to ethical approval: TRIMS).

4.2 Methods

Additional data for the purpose of this study was collected in addition to data from the TRIMS cohort. Participants recruited in the last month of the study period completed an additional expectation questionnaire. Clinicians at both recruitment sites for the TRIMS cohort (Tallaght University Hospital and St. James's Hospital, Dublin) were surveyed to establish their expectation of surgery outcome for an average APM patient. Both patients' and clinicians' reasons for surgery were collected as part of the original TRIMS data collection forms.

4.2.1 Expectation of surgery

The Hospital for Special Surgery (HSS) Knee Surgery Expectations Survey is a questionnaire designed to grade a patients' expectation of how they will improve following arthroscopic knee surgery (Mancuso et al., 2001) (Appendix 18: HSS Knee Surgery Expectation Survey). The clinician version of the questionnaire is designed to grade a clinicians' expectation of how a patient will improve following arthroscopy (Appendix 19: HSS Knee Surgery Expectation Survey: Clinician Version). Respondents grade 23 items from one to five based on how much relief or improvement they expect to have / expect a patient will have in each area as a result of knee surgery. Scores are transformed to a 0-100% Scale, with higher scores indicating that patients / clinicians expect more improvement. The HSS Knee Expectation Survey is one of only seven validated and reliable evaluation methods for expectation of patients undergoing orthopaedic surgery, and the only specific measure designed for non-arthroplasty knee surgery (Zywiel et al., 2013).

Participants: Expectation of Surgery

Clinician expectation questionnaires were distributed and collected on one occasion at department meetings in both the Orthopaedic and Physiotherapy departments of the two TRIMS clinical sites. A Researcher (NC) attended meetings and outlined the aim of the study, instructions on questionnaire completion were distributed to all staff members present. Meetings included the full departments at both sites and all doctors / physiotherapists were invited to participate.

Participants in the TRIMS cohort completed patient expectation questionnaires as part of their baseline assessment, a detailed description of TRIMS recruitment is given in Chapter 3. All patients scheduled for surgery at two teaching hospitals were invited to the study and consenting patients were followed for one year. This specific study aim was an addition to the original TRIMS study and only participants who were enrolled during the last 6 weeks of the recruitment phase were included.

Variables: Expectation of Surgery

The Hospital for Special Surgery Knee Surgery Expectations Survey (and corresponding clinician version) is a patient derived outcome measure; developed through the use of patient interviews and expert review. The HSS was developed to assess expectation of change following knee surgery. Separate versions have been developed for knee replacement surgery and knee arthroscopy. Test-retest reliability was assessed during tool development, and found to have good reliability (Cohen's Kappa ≥ 0.40 for all items), construct validity was established by comparison with age, sex, education level and functional status, criterion validity was assessed by comparison with SF-36 (Mancuso et al., 2001) A systematic review of tools assessing patient expectations of Orthopaedic Surgery, found only two measures (HSS Survey and Sunnybrook Surgery Expectations Score) suitable for patients undergoing arthroscopic knee surgery (Zywiel et al., 2013). The HSS survey was chosen for this study as it has a corresponding clinician questionnaire and superior reliability to the Sunnybrook questionnaire.

Participants completed the 23 categories on the HSS questionnaire which asks the question "How much relief or improvement do you expect in your knee as a result of your knee surgery?" Clinicians completed the clinician version of the HSS questionnaire which asks the question "How much relief or improvement do you expect your patient will have in each of these areas as a result of this knee surgery?" Although questions in the HSS questionnaire are grouped under different headings; symptom-related, functional and psycho-social, no sub-group analysis of the HSS has been tested or reported previously. Scores were added and transformed as total percentages of improvement, according to scoring instructions supplied by the tool developer.

As a wide variety of clinical presentations are possible for patients undergoing APM, specific instructions were clarified with the authors who developed the tool (Mancuso et al., 2001). Sample patient information was not supplied alongside the survey; clinicians were advised to respond while considering the average patient undergoing arthroscopic meniscus surgery.

Clinicians also reported their job grade; number of years' experience, current specialty and average number of arthroscopic meniscus surgery patients treated in a year. These variables were collected in order to look at correlations between clinical experience and expectation of surgery.

As this study was the first to report on expectation of surgery from multiple stakeholders (surgeons, physiotherapists and patients) a specific sample size was not predetermined. The patient sample population was limited to patients who were recruited to the TRIMS cohort. The clinician sample population was limited to clinicians who were part of the surgical or physiotherapy teams at the two clinical sites. Participation in the study by clinicians was encouraged by outlining the aims of the study and benefits to future practice, targeting as large a sample as possible within these departments.

Statistical analysis: Expectation of Surgery

Transformed scores for the HSS Knee Surgery Expectation Survey were calculated according to scoring instructions supplied by The Hospital for Special Surgery (Appendix 20: HSS Knee Surgery Expectation Survey: Scoring Instructions) and reported for different clinical groups as Mean (SD) transformed score for expectation of change. The transformed score equates to a 0 – 100 scale of how much improvement (or percentage improvement) is expected following surgery, with zero indicating no change and 100 indicating complete improvement or back to normal.

If more than one item was missing from a questionnaire, that questionnaire was removed from analysis. If only one item was missing, it was given the median score (2) in order to calculate the total and transformed score for that questionnaire. This approach was used in order to maximise responses while reducing the effect of an imputed response on the overall transformed score.

Data was assessed for normality using the Shapiro-Wilk test and examining histograms, QQ plots and analysis of skewness and kurtosis . Correlations between the expectation (transformed score for HSS survey) and clinical experience (years' experience / number of patients seen per year) were also assessed. Correlations are reported using Pearson's correlation coefficients and the correlation of determination (r^2). Differences between mean score for different clinician groups was assessed by running a one-way ANOVA to test for global effect and post-hoc bonferroni multiple comparison tests between groups.

Data was collected in paper form and entered into Microsoft Excel Version 15.32 (2017). G*Power 3.1 (Heinrich Heine University, Düsseldorf, Germany) was used for statistical analyses. Level of significance was pre-defined as $p<0.05$.

4.2.2 Methods: Reasons for surgery

Reasons for surgery were recoded from both clinician and patients' perspective as part of the TRIMS study (Figure 3.1)

Participants: Reasons for Surgery

Patient recruitment within the TRIMS cohort is described in Chapter 4: TRIMS Results. Clinicians reason for surgery was recorded by the surgical team who completed the arthroscopy at both clinical sites (Tallaght University Hospital, Dublin and St. James's Hospital, Dublin).

Variables: Reasons for Surgery

Reasons for surgery were recorded on separate occasions by patients and surgeons. This data collection was part of TRIMS standardised data collection forms.

- Patients reasons for surgery

All participants in the TRIMS cohort attended a baseline assessment prior to surgery. As part of the baseline assessment patients responded to a single item open-ended written question: "Reason for surgery: _____". (Appendix 10: TRIMS Injury Mechanism Assessment Form)

This data was collected as an open-ended question in order to capture the participants' perspective on why they were having surgery.

- Surgeons reasons for surgery

At time of surgery, the operating surgeon listed the reason for surgery on the standardised TRIMS arthroscopy form, this form included the tick box question: "Reason for surgery: Persisting Pain / Mechanical Symptoms / Failed Conservative Treatment / Other (please specify): __________ ". (Appendix 12: TRIMS Arthroscopy Form).

This question included optional responses in order to improve compliance with data collection forms from the surgical team. An open-ended option was included in order to capture reasons other than those listed as common reasons for surgery.

Statistical analysis: Reasons for Surgery

Reasons given for surgery are reported according to the frequency that this reason was reported (the percentage of total cohort for which this reason was reported by the participants / surgeons).

Coding of responses

In order to compare reasons given by surgeons and patients undergoing APM, responses were grouped under the four optional headings used by surgeons. Responses given by TRIMS participants to the open-ended question were coded according to these four headings by two researchers (NC, FW). Responses which did not correspond with persisting pain, mechanical symptoms, or failed conservative treatment were coded as 'Other' and are further reported below. A table of all patient responses and coding applied is included as an appendix (Appendix 21: Reasons for Surgery, Coding of Patient Responses).

4.3 Results: Expectations of surgery

4.3.1 Clinician Expectation of Surgery: participant characteristics

Data was collected from a total of 75 clinicians at two clinical sites. After removal of incomplete HSS Questionnaires, analysis was performed on data from 71 clinicians; 19 orthopaedic doctors with a mean of seven years' experience in Orthopaedics, 52 Physiotherapists with a mean of seven years' post-graduate experience. Thirty-three percent of physios specialised in Musculoskeletal / Orthopaedics and this group of physios reported seeing an average of forty APM patients per year. Clinician demographics are summarised in Table 4.1 and Table 4.2.

Characteristics of Physiotherapists: n=52		**n (%)**
Grade	Clinical Specialist	3 (6)
	Senior Physiotherapist	22 (42)
	Basic Grade Physiotherapist	27 (52)
Rotating Post	Yes	27 (52)
	No	25 (48)
Clinical Area	Musculoskeletal	13 (25)
	Orthopaedics	4 (8)
	Respiratory	11 (21)
	Care of the Elderly	8 (15)
	Neurology	5 (10)
	Other	11 (21)

Table 4.1: Characteristics of Physiotherapists

Characteristics of Surgical Team: n=19		n (%)
Grade	Consultant	3 (16)
	Specialist Registrar	6 (32)
	Registrar	7 (37)
	Senior House Officer	2 (11)
	Intern	1 (5)
Rotating Post	Yes	6 (32)
	No	13 (68)

Table 4.2: Characteristics of Orthopaedic Team members

4.3.2 Patients Expectations of Surgery: TRIMS Cohort

Five participants were recruited to the TRIMS cohort during the last month of recruitment. There was a reduction in recruited participants during this period due to infection control issues at the larger clinical site, meaning that non-emergency orthopaedic surgeries were cancelled. One of the five participants did not have a meniscus tear at surgery, and the transformed scores (0-100 expectation of improvement following surgery) for all participants are shown in Figure 4.1. Due to the small sample, patient expectations as reported on the HSS questionnaire were not included in further analysis. The five participants for whom expectation scores were captured had a mean age of 47 and mean BMI of 26.

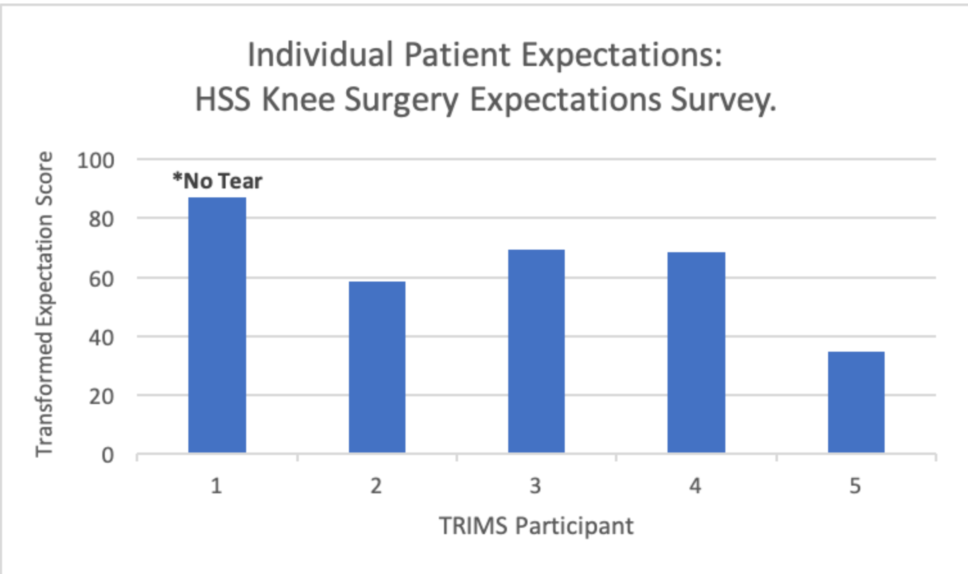

Figure 4.1: Patients' expectations of Surgery

4.3.3 Clinician's Expectation of Surgery: Outcome data

Across all clinicians, the Mean (SD) transformed score (0-100) on HSS Knee Expectation Questionnaire was 54 (21). Mean transformed score for the Orthopaedic team members was 59 (61) and 51 (22) for all Physiotherapists. Physiotherapists working in orthopaedics / musculoskeletal had a similar expectation of improvement to physiotherapists in other specialties; mean transformed score of 55 (24).

The difference in transformed score between clinician groups (surgeons and physiotherapists) was not statistically significant (*P*=0.42). Neither was there a significant difference in expected score between members of the surgical team and physiotherapists specialising in orthopaedics / musculoskeletal (*P* =0.55) nor between orthopaedic / musculoskeletal physiotherapists and other physiotherapists (*P*=0.95). A large variance in expectations between individual clinicians was found, across all clinician groups. The distribution of transformed scores for each discipline is shown in Figure 4.2.

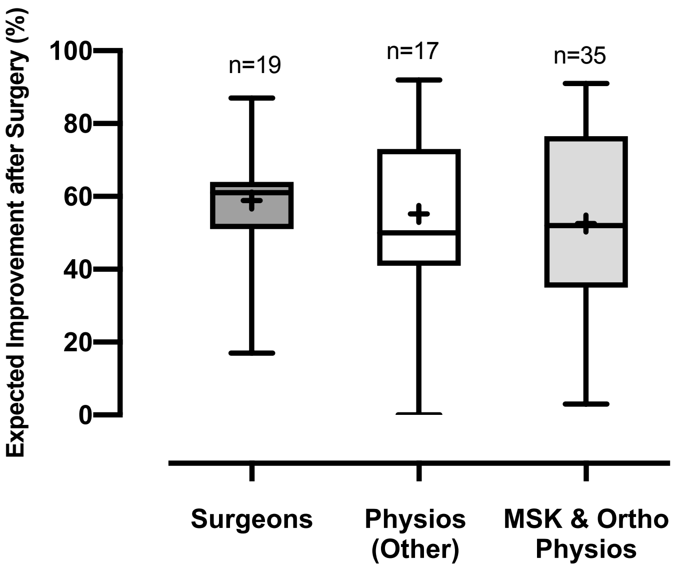

Figure 4.2: Clinician expectations (transformed score on HSS expectation questionnaire) across disciplines.

One way ANOVA revealed no significant effect. [Box = Interquartile Range; Bar = Median; + = Mean,; Whiskers = Range].

Small positive asociations were found between the transformed score and both years' experience (r^2=0.16) and number of patients treated per year (r^2=0.31) by orthopaedic surgical team members, indicating that surgeons who saw more meniscus surgery patients per year may expect a higher improvement score. No association was found for the combined scores of all physiotherapists. (r^2=0.01). Physiotherapists working in orthopaedics / MSK showed a very small and insignificant positive association between years of experience (r^2=0.16) but no association was found between expectation and number of meniscus surgery patients treated per year (r^2=0.00). Correlation coefficients are reported in Table 4.3.

	Number of Years' experience	No. of Meniscus Surgery patients treated per year
Orthopaedic Team Members	r = 0.38	**r = 0.56**
(n=19)	r^2 = 0.16	r^2 = 0.31
Orthopaedic / MSK Physiotherapists	r = 0.40	r = 0.00
(n=17)	r^2 = 0.16	r^2 = 0.00
Physiotherapists	r = 0.09	r = 0.07
(n=52)	r^2 = 0.01	r^2 = 0.01

r^2 = Coefficient of Determination
r =Pearson's correlation coefficient:
(r > 0.40 = moderate correlation, r > .60 = strong correlation r > .80 = very strong correlation).

Table 4.3: Correlation between Transformed Score (HSS Questionnaire) and clinical experience

4.4 Results: Reasons for surgery

4.4.1 TRIMS Cohort: Participant data

Forty-three patients with confirmed meniscus tears at arthroscopy were followed up over one year as part of the TRIMS cohort and included in this analysis of rationale for surgery. This cohort is described in detail in Chapter 4; participants had a Mean (SD) age of 48 (16) years, Mean (SD) BMI was 27.7 (4.9) Kg/m^2 and 35% of the cohort were female.

4.4.2 Reasons for Surgery: Outcome data

Surgeons and patients both reported a combination of reasons for surgery, with more than one reason listed by three patients on their baseline assessment form and eleven surgeons on the arthroscopy form. Reason for surgery was not reported by the surgical team for two participants.

Surgeons' reasons for surgery

Pain was the reason for surgery reported most frequently by the surgical team; pain was selected on 84% of arthroscopy forms. Mechanical symptoms were selected as a reason for 30% of patients in the cohort and surgeons indicated other reasons for seven percent of the cohort. No patients were classified as 'failed conservative treatment' at time of surgery.

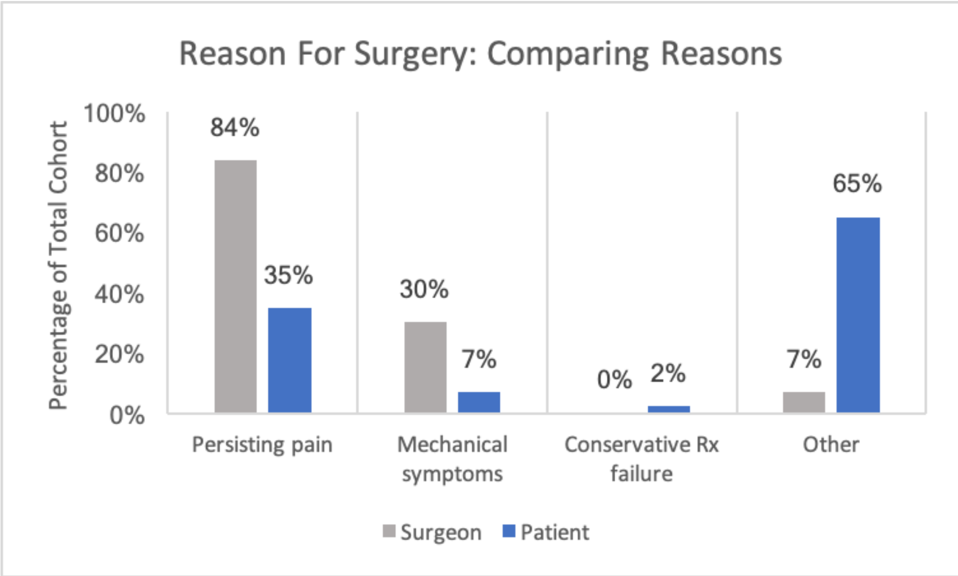

Figure 4.3: Comparing reasons for surgery from surgeons and patients.

Patients' reasons for surgery

Patient responses were coded according to the same three headings as surgeons. Pain was also the most frequent of these reasons given by patients (35% of TRIMS participants). 'Mechanical symptoms' were given as a reason for surgery by seven percent of patients and two percent of patients described 'failed conservative treatment' as their reason for surgery. Sixty-five percent of patients reported other reasons for surgery which were not captured under the three options given to surgeons.

Additional reasons for surgery:

Additional reasons for surgery were reported by seven percent of surgeons and sixty-five percent of patients. Patient reasons not coded under pre-assigned headings were further coded to establish common reasons from patients' perspectives.

- Anatomical diagnosis (33% of cohort)
  One third of all TRIMS participants included responses such as "cartilage tear" and "removal of loose cartilage pieces" as their reason for surgery. These reasons represented what patients perceived to be indications for surgery.
- Functional / personal goals (30% of cohort)

A similar proportion of participants included responses such as "make more comfortable day to day life" and "want to continue playing sport". This category represented personal goals which often corresponded to a functional task that the participant hoped to achieve after surgery.

- Other (2% of cohort)
  One participant listed "exploratory" as their reason for surgery.

Surgical forms which reported other reasons for surgery accounted for seven percent (n=3) of all participants. The reasons given for surgery in these cases were; "traumatic injury, loose body, swelling". Further coding was not carried out for this small number of participants.

Difference between patients and clinicians

The most frequent reason for surgery differed between surgeons and patients. These reasons are compared in Figure 4.3. While persisting pain was the most common reason reported by surgeons, other reasons (primarily anatomical reasons and functional goals) were the most frequently reported reasons by patients.

4.5 Discussion

The aim of this study was to explore current expectations of APM and reasons for selecting APM as a treatment option among clinicians and patients in the TRIMS cohort. Findings of this study have implications for the selection of APM as a treatment option and outline the rationale for current surgical selection in an Irish public hospital cohort of patients and clinicians.

4.5.1 Expectations of surgery: Implications.

An objective of this study was to establish clinicians' mean expectation of change following APM, and whether clinical experience was associated with a different expectation of APM. Expectation of arthroscopic meniscus surgery have not previously been reported for multiple clinician groups. The mean clinician expectation of surgery was found to be similar in orthopaedic surgical and physiotherapy teams. As a score of 100 represents complete improvement or back to normal on all items, this expectation represents an average of 'moderate' improvement across the population of clinicians included in this study. This may reflect a conservative expectation of outcome by clinicians, but contrasts with previously reported expectations of patients, who are known to overestimate the effect of treatments, specifically their expectation of leisure activities following APM (Pihl et al., 2016b).While there was no difference in expectation between disciplines, a large range in response scores reflects the high variability in clinician expectations across all teams. Differing expectations of surgery among clinicians could lead to conflicting education of patients by different members of a multidisciplinary team. Additionally, as there were large differences in expectation within groups, this may reflect a lack of updated knowledge among some team members. Clinicians who are not well informed of current evidence and indications for APM, may be inappropriately selecting or suggesting patients for surgery.

Correlations were found between clinician experience (no. of years and volume of patients) for clinicians who specialise in Orthopaedics / Musculoskeletal; both physiotherapists and members of the surgical team. This indicates that clinicians who see more patients undergoing APM, have a higher expectation of improvement following surgery.

Due to limited numbers, conclusions cannot be made about patient expectations of surgery is this cohort. It was not possible to assess the study objective of establishing whether activity level prior to surgery was associated with a different expectation of APM.

4.5.2 Reasons for surgery: Implications

The continued frequency of APM despite recent guidelines against its primary use for degenerative meniscus tears (Siemieniuk et al., 2017), highlights the complexity of managing patients with meniscus injuries. An additional objective of this study was to compare reasons for APM from both patients' and surgeons' perspectives; establishing frequent reasons for surgery and assessing if these are similar in both groups. Findings of the current study confirm this complexity with both clinicians and patients reporting a combination or reasons for surgery across multiple participants in the TRIMS cohort.

Findings of the current study represent a mixed picture of indications for surgery from a surgeons' perspective, with pain relief being a high priority but many of those participants also classified as having a second reason for surgery. Pain relief was also the most common reason reported by the patient cohort (35% of patients), after further coding of responses under 'other' (33% 'Anatomical Diagnosis', 30% 'Functional / Personal Goals', 2% ‘Other’). In addition to this, a variety of personal goals and hopes for medical / clinical outcomes of surgery formed the majority of reasons for surgery from the perspective of a patient.

Differences in reported reasons for surgery highlights a lack of informed and shared decision making between clinicians and patients. Although direct comparison of responses is limited by slight differences in how the data was collected, the large difference in reported reasons shows that surgeons have a very different perspective on surgical indication to patients in this cohort. Previous research has showed that there are varied factors affecting surgeons’ clinical decision making for APM, with failed conservative treatment, normal radiographic findings and positive physical examinations being most highly influential on decision (Lyman et al., 2012).

Despite the middle aged and mostly degenerative cohort of the current study, a very small percentage of surgeons and patients reported that failed conservative management was the reason for surgery. This may indicate that APM was not used as a treatment option for patients failing conservative treatment in this cohort, or it may indicate that participants had not undergone sufficient conservative treatment prior to surgery. In a middle aged and degenerative knee, APM and has repeatedly been found to be no better than sham surgery (Sihvonen et al., 2013) or exercise therapy (Katz et al., 2013a) for pain relief, as pain was the primary reason for surgery in this cohort, it appears that recent evidence is not yet affecting clinical practice.

4.5.3 Rationale for surgical selection

The inclusion of clinical expertise and patients’ beliefs / expectations is essential in the evidence based decision making process. Clinicians must be cognisant of their own experience as well as patient’s wishes when interpreting current evidence. It appears that the current rationale for selecting APM as a treatment for meniscus tears in middle aged patients did not align with current evidence. The complexity of managing this patient cohort is confirmed by the finding that multiple patients had more than one reason for surgery, from both clinicians and patients’ perspectives.

Patients undergoing APM often see multiple clinicians; varied expectations of surgery across these clinicians could lead to confusion amongst patients and it is essential that clinicians working together in the management of patients are clear on current evidence based guidelines. Conflicting predictors of outcome in previous studies (Eijgenraam et al., 2017, Sofu et al., 2016) and the complexity of this patient population may explain some of the disparity in perspectives of APM, but there must be a clear treatment rationale before considering APM as an option, as there are risks associated with the intervention (Thorlund et al., 2015, Abram et al., 2019).

Both clinician and patient education needs to be consistent in order to maintain standards of consent and shared decision making. Surgeons and participants in the TRIMS cohort displayed a lack of shared understanding surrounding the selection of APM as a treatment option.

4.6 Limitations

A limitation of this study was the manner in which surgeons and patients were asked to give their reason for surgery. The inclusion options given to surgeons may have limited their responses in comparison to patients, although only 7% (n=3) of patients were classified as “Other” by surgeons.

Surgeons and patients may also interpret “reason for surgery” differently. Responses suggested that some patients answered this question with regard to their hopes for surgical outcome, while others responded with what they perceived to be the medical indication for surgery. Further research should look to validate these data collection methods.

Finally, the findings of this study are applicable to a middle aged and degenerative knee population, findings may not reflect expectations or reasons in other populations such as younger patients expecting to return to high level sports participation. Due to the limited number of TRIMS participants who completed expectation questionnaires, the study objective of assessing correlation with activity level was not met.

4.7 Conclusion

There are large variations in clinicians’ expectations of arthroscopic meniscus surgery across disciplines. Patients who undergo APM have a different perspective on the reason for surgery, than the reason that is reported by surgeons.

4.7.1 Further Research

Patient involvement in the clinical decision making process is increasingly complex; patients expectations of surgery and understanding of the reasons for surgery need to be carefully considered. Further qualitative research is needed to investigate the findings of this study particularly using validated measures to assess understanding of surgical indications in more diverse patient and clinician populations. The importance of patients expectations of functional changes following surgery is unclear. Future research should examine the difference in perspectives between orthopaedic clinicians and patients to establish common areas of understanding as a basis for shared decision making.

5 Thesis Discussion & Conclusion

5.1 Current Knowledge on APM outcomes

Recent research in APM populations has provided a new perspective on outcome of surgery and led to guidelines recommending the avoidance of APM in degenerative knees. This thesis highlighted the lack of publications examining objective functional performance and outlined a gap in knowledge on activity levels and their change over time in patients who undergo arthroscopic surgery for a meniscus tear. The relevance of achieving pre-injury activity level and occupational or sports participation in patients with meniscus tears has been discussed. The aim of this thesis was to investigate expectations, functional performance and activity level in a cross sectional population of patients undergoing arthroscopic meniscus surgery of the knee. An initial working hypothesis, was that that objective functional outcome of arthroscopic partial meniscectomy is predicted by pre-operative function and activity level.

Literature review was conducted, comprising two systematic reviews of functional performance, targeting to include publications which reported on younger populations and objective measures of function. Weaknesses in the quality of studies limit the conclusions which can be drawn from systematic review 2; the heterogeneous methods of assessing objective function in knee surgery studies was confirmed by this review. A specific lack of studies examining change in performance from pre-op to post-op was described.

Functional deficits were reported in many studies included in Systematic Review 2, confirming the findings of decreased strength in Systematic Review 1. However, meta-analyses found that there was not a significant difference between functional performance in the surgical leg and controls (matched controls and contralateral leg) pre-operatively or during the first year post-operatively. Both systematic reviews highlighted a need for research in younger populations undergoing meniscus surgery. A lack of data in these cohorts including the lack of PROMs found by Systematic Review 1 and lack of data on meniscus repair outcomes in Systematic Review 2 highlight the fact that current guidelines on the use of APM in degenerative knees cannot be applied to these populations. Lack of reporting on habitual exercise or level of activity in study cohorts also limits the interpretation of findings to clinical cohorts of patients with more specific activity levels, such as athletes or individuals with high levels of occupational activity. Understanding of patients' perspective on surgery or rationale for surgery in this population is also unknown; debate exists over the potential for surgery to improve mechanical symptoms (Thorlund et al., 2019) and preservation of the meniscus is encouraged in order to preserve joint health and improve long-term function (Beaufils et al., 2017b). Mechanism of injury in traumatic tears is often a twisting or turning injury which can occur during sports activities (Rath and Richmond, 2000), this places particular emphasis on the significance of functional performance in younger and more active populations, with further research needed to establish guidelines for management.

Single Leg Hop performance results were pooled in Systematic Review 2 in order to assess this outcome measure individually. Among included studies, SLH was the most frequently reported measure of function; SLH has also been reported as the most reliable and well reported measure of physical function in young and middle aged patients at risk of knee osteoarthritis (Kroman et al., 2014). Better functional performance in APM subjects than controls; while statistically significant, was not clinically significant. Although the minimally important change in SLH is unknown (Hegedus et al., 2015), the minimal detectable change has been reported as 8% of Limb Symmetry Index (Reid et al., 2007). Pooled Mean Difference of SLH performance found a difference of 4.2cm (95% CI: 2.73 – 5.66) while the range of mean scores of APM groups included for SLH analysis was 92cm - 120cm (Figure 2.6).

Limitations due to the quality of included studies and small numbers at each timepoint weakened the findings of meta-analyses in Systematic Review 2. In contrast, narrative summary of included studies in Systematic Review 2 confirm deficits in post-operative APM cohorts, which were also found by systematic reviews and meta-analyses of strength in older adults (Hall et al., 2015b) and younger adults (Systematic Review 1).

Frequency and intensity of habitual physical activity were poorly reported in studies examining APM, despite the relevance of exercise interventions to improve physical function. Strength and function appear to be decreased for up to one year following APM, in younger adults and up to two years in middle aged / older adults. Evidence is lacking on longitudinal performance changes over time from pre-op to post-op in meniscus surgery populations.

5.2 TRIMS Study

The objectives of the TRIMS study were to investigate functional performance and activity level in patients undergoing APM at pre-operative and post-operative timepoints, facilitating analyses of longitudinal change in PROMs and change in functional performance measures post-operatively. The TRIMS study also assessed the relationship between activity level and changes in functional performance following surgery. The null hypothesis of this study was that there would be no difference in variance between groups (surgical leg & control leg) over time (pre-op and post-op) on any performance measures assessed, and that activity level would not be associated with a change in functional performance. Findings of the TRIMS study showed that while there were changes over time in function; difference in change between legs was not demonstrated. Additionally, activity level was not found to be associated with change in function. It was not possible to reject the null hypothesis of this study, findings are discussed further.

Pre-operative assessment revealed deficits in all objective performance measures for middle aged participants 1-2 weeks prior to APM. Participants were moderately active two days per week (SIPAM) and participating in activities similar to light labour (Tegner Score: 3). Post-operatively, participants showed improved self-reported outcome on all measures at three months, excluding the SIPAM (moderately active 2.5 days per week). Improvements from baseline were also found at six-months and twelve-months on all measures excluding the SIPAM. At six months, participants reported that they were moderately active three days per week with a median score of five on the Tegner Scale (Work: Heavy Labour. Recreational sports: jogging on uneven ground at least twice weekly), this was sustained at twelve months.

Analysis of change over time in functional performance measures revealed improvements from pre-op to post-op on all measures excluding 300°.s^{-1} hamstrings. This improvement was only found in the surgical leg for quads strength at 60°.s^{-1}, hamstring 60°.s^{-1} and six metre timed hop. Improvements in both legs were found for 180°.s^{-1} and 300°.s^{-1} quads, 180°.s^{-1} hamstrings, SLH and THD. There was a trend towards greater statistical significance and greater effect sizes of change in the surgical leg compared to the contralateral leg, although effect sizes were small and not clinically significant for any measure. Comparing legs at six-months post-op revealed significant residual deficits in quadriceps strength, hamstring strength (excluding 180°.s^{-1}), Single

Leg Hop and Six-metre timed hop. No difference was found on Triple Hop for Distance at six months post-op.

Subgroup analysis based on activity level / functional status or subgroups of surgical findings were not possible due to the population of participants recruited to the TRIMS study. It was anticipated that a wider age range of participants would be recruited and that patients with non-degenerative meniscus tears would account for a larger proportion of patients undergoing surgery during the recruitment period.

No correlation was found between pre-injury self-reported physical activity level (Tegner Scale) or pre-operative physical activity frequency (SIPAM) and change in any of the recorded objective performance measures from pre-op to six months post-op.

5.2.1 Implications of findings

The TRIMS study showed that while objective and self-reported measures of performance improve in the six months following surgery, deficits in strength and SLH performance still exist at six months compared with the contralateral leg, due to a similar improvement in the control leg.

Previous studies have shown an improvement in strength at both three and twelve months following APM (Kise et al., 2016b). Meta-analysis of post-operative strength outcomes in middle-aged and older adults undergoing APM has shown similar results as observed in the current study with strength deficits persisting at six months, but deficits no longer present at 24months post APM (Hall et al., 2015b). Younger adults have also been reported to have strength deficits up to 12 months post APM (Thorlund et al., 2017b). Improvement in SLH have previously been shown at 24 months following APM (Roos et al., 2018). Although the improvement in the current study was larger than that shown by Roos et al, the difference in timeframe may reflect deterioration in performance over time. The improvement in self-reported function shown in this study, is similar to that of previous studies in similar cohorts (Thorlund et al., 2017a).

Analysis of change over time revealed a trend toward larger improvement in the surgical leg than the control leg. Although effect sizes were small for all measures, this is particularly relevant for the analysis of 6MH and THD; it appeared that there was a larger improvement, favouring the surgical leg in both of these high-level performance outcomes. No improvement over time was found on the control leg for 6MH and a larger effect size was found for improvement of THD in the surgical leg compared to control. Improvement in 6MH more than SLH has previously been shown in this population at both three and twelve months' post APM (Kise et al., 2016b). High performance measures were included in the current study in order to detect change in high level performance in participants who may be more highly active prior to injury. The lack of effect of APM over sham surgery or in addition to exercise therapy in middle-aged patients has been reported (Thorlund et al., 2015, Kise et al., 2016b, Sihvonen et al., 2013), so it was anticipated that this cross-sectional cohort would reflect a younger and more highly active clinical population. The current cohort of patients had a median activity level prior to injury of five on Tegner Scale which includes "competitive sports - cycling, cross country skiing, recreational sports – jogging on uneven ground at least twice weekly", suggesting that they were moderately active prior to injury. Although improvement was detected in high performance on 6MH, this finding should be interpreted carefully, as smaller numbers of participants were able to complete these tests at both baseline and follow up, and outliers in this assessment may have contributed to the interaction effect found.

A number of participants refused to complete hop tests at both baseline and six month assessments. The majority of these participants reported a limitation due to pain at baseline, while an increasing proportion of participants reported at six months that the reason they could not complete hop tests was due to lack of confidence in the knee, rather than pain. It is likely that the observed deficits in hop tests which were observed in the study, were underestimated due to lack of data on these participants who may have worse functional performance. Sensitivity analysis; despite the small sample size, suggested that trends observed for change in functional performance would not differ, if only participants with full datasets on all performance assessments were included. While high level performance assessment has been underreported in this population and may improve based on current data, it is also possible that participants who completed these tests are not representative of the entire cohort, or clinical populations.

This study also found that while habitual exercise (SIPAM) did not improve following surgery, participants were participating in more strenuous activities six months after APM (reported as increase in Tegner scores). There is a current lack of objective data regarding activity participation following APM and difficulties arise in classifying physical activity subjectively. A previous cohort of middle aged APM patients showed that only

12% of patients returned to recreational or competitive sports at three months post-APM and the majority self-reported light household work as their highest level of ranked physical activity (Pihl et al., 2016a). The current study showed a potentially larger improvement in activity at six months post-operatively, as the median Tegner Score (5, IQR: 2-5) includes activities such as heavy labour, recreational jogging on uneven ground at least twice per week and competitive low impact sports such as cycling. The Tegner Score also records self-reported activity level prior to injury; the median score for participants prior to injury (reported at baseline assessment) was five (IQR: 4-7), this indicates that participants returned to the same functional level as pre-injury by six months post-op and sustained this at twelve months.

Changes in pre-operative and post-operative activity level have also been reported across multiple studies in patients undergoing ACL reconstruction. Comparatively; an improvement of two scores on Tegner scale has been found at one year after ACL surgery (Lind et al., 2009), and a systematic review of long term outcomes of ACL reconstruction found similar Tegner Scores to the TRIMS study (range 4 – 7) across multiple studies between five and fifteen years after surgery (Poehling-Monaghan et al., 2017). Long term follow up at close to 10 years post-op reported changes from Tegner Score of eight pre-injury to a score of four prior to surgery and a long-term deficit (Tegner Score: 5) at follow up, close to ten years (Karikis et al., 2018). While findings varied across ACL studies, it appears that the trajectory of functional activity level found in the TRIMS study is similar to that of other arthroscopic knee surgeries, with an initial decreased activity following injury and improvement in the short term following surgery.

The TRIMS study also examined whether self-reported level of physical activity prior to injury, was related to changes in objective measures of physical performance following APM. No clear relationship was found between any of the primary measures; this suggests that being more active prior to surgery does not improve the chance of functional improvement following APM. A skewed distribution of scores on Tegner and SIPAM pre-operatively may have limited this analysis.

Although changes in strength and hop performance were found on both legs, the lack of significant change compared to control (between leg difference) should not be interpreted as a lack of improvement in function. For slower speed of quads and hamstring strength assessment, there was no improvement in control leg and the apparent larger improvement in 6MH and THD over time has been discussed. Whether or not the change in performance can be attributed to surgery, cannot be determined, as bilateral improvement resulted in no effect of treatment leg on ANOVA. It is possible that both legs would improve without surgery, it is also possible that no change in functional performance would have taken place over this period if surgery had not been performed. Recent RCTs have found no benefit of APM over conservative management / sham surgery (Sihvonen et al., 2013, Kise et al., 2016a), although the effects of surgery on activity level were not reported. Findings of bilateral functional improvements following APM, in addition to a significant improvement in high performance measures previously not reported with a restoration of pre-injury functional activity level (Tegner Scale) add weight to calls for further research into objectively measured outcomes of meniscus surgery.

Many clinicians still recommend surgery as a treatment option for patients who are highly active and functionally impaired due to a meniscus tear, findings of the TRIMS study are conflicting with regard to clinical applications for this cohort of patients. Firstly, the TRIMS cohort was a middle aged and overweight cohort with mostly degenerative meniscus tears, findings may not apply to more active cohorts or traumatic meniscus injuries. Secondly, no correlation was found between pre-injury activity level and change in performance measure following surgery, suggesting that activity level may not be a predictor of outcome (a small range of activity levels reported in this study may limit this analysis; baseline Tegner IQR: 1-4, baseline SIPAM IQR: 2-5). Conversely, changes in high-level performance were found following APM, suggesting that more challenging functional tasks may improve with APM. Improvements in high-level hop tests (6MH & THD) were found over time with the complete resolution of deficits in 6MH at six-months post-op. Further research into these previously underreported functional measures is needed in order to establish clinical relevance to all patient cohorts.

5.2.2 Take home message: TRIMS study

While improvement over time was found for measures of functional performance in middle aged participants undergoing APM, deficits in functional performance were found compared to contralateral leg at both pre-operative and post-operative assessments.

No effect of treatment leg (surgical v control) was found when examining each of the performance outcomes, suggesting that although functional performance improves, the improvement may not be due to surgery. In contrast to this, high-level performance assessment (6MH and THD) appeared to improved more in the APM leg, than the contralateral leg over time. At six months post-op, there was no difference between APM and control leg for 6MH assessment, suggesting that the surgical leg had achieved equivalent function to the contralateral leg. A functional deficit was still found for the THD at six months; although performance had improved significantly following APM.

Changes over time in functional performance measures were not correlated with either pre-injury level of functional activity or pre-operative frequency of activity, it does not appear that higher pre-operative function was associated with larger improvements in function following APM.

5.3 Rationale for Surgery

An additional study was undertaken (Chapter 5) to explore the current rationale for APM by comparing both clinician and patient perspectives of arthroscopic meniscal surgery. Unfortunately, conclusions could not be made about patients' expectations of surgery, as only a small number of patients (n=4) with confirmed meniscus tears completed expectation surveys. Responses by clinicians revealed a large variation in expectation of improvement following APM, this variation existed across both surgical teams and physiotherapy teams. Correlation analysis revealed that members of the surgical team who saw a larger volume of APM patients per year, or had more years' experience in Orthopaedics may expect a larger improvement after APM.

Data from the TRIMS study suggested that clinicians have a different understanding of the rationale for treatment than patients undergoing APM. Patients were found to have a different perspective on the reason for surgery, then the reason that was reported by surgeons. Reasons for surgery from a patients' perspective were mostly related to personal / functional goals, or reference at an anatomical injury which required surgical intervention. Shared ownership of decision making is essential in the selection of surgical treatment options; differing expectations of surgery among clinicians could lead to conflicting education of patients by different members of a multidisciplinary team. There were large differences in expectation within groups of this study, variation may reflect a proportion of clinicians who are not aware of recent guidelines on the use of APM.

Surgeons appear to perceive APM to be a treatment strategy for persisting pain in the TRIMS cohort. While pain was also reported as a common reason for surgery from patients' perspectives, functional goals appear to be an equally significant reason for surgery from patients' perspectives. Lack of understanding of patients functional goals may in part reflect the lack of current evidence regarding functional performance measures in APM cohorts and guidelines. While clinicians may be influenced by recent guidelines developed from PROMs and specifically relating to the use of APM for pain management, functional goals appear to be of more significance to patients.

There is considerable evidence that patients receiving treatments want to be consulted about the impacts or outcome of interventions (Frosch and Kaplan, 1999). Patients undergoing Orthopaedic surgery often perceive that they are involved in the decision making process, even overestimating their involvement compared to observational measurements of shared decision making (Mertz et al., 2018). Despite its importance in modern medicine, there is a lack of understanding on how best to optimise shared-decision making among orthopaedic clinicians (Slover et al., 2012).

The TRIMS study found improvements in single leg functional performance bilaterally from pre-op to post-op, although functional deficits persisted. These functional improvements appear to be important to patients and may be a more significant component of their expectation of, and satisfaction with surgical outcomes, than previously considered by clinicians. This is in agreement with findings from a similar Danish cohort of patients who overestimated their expectation of functional improvement following surgery (Pihl et al., 2016a). Clinicians should ensure that functional goals are discussed prior to surgery and that realistic evidence based expectations are set prior to agreeing on either surgical or conservative management of a meniscus injury.

Benefits to patient outcome have been shown with shared decision making; healthcare decisions which reflect patients' goals promote greater patient satisfaction and compliance (Kaplan et al., 1996). Participation in care is particularly import after orthopaedic surgery if rehabilitation and follow up are required, participation in care improves when patients are presented with best evidence on their condition and treatment (Epstein et al., 2004). Improved patient participation in care is essential in achieving post-operative functional improvements following APM, improvements which appear to be important to patients.

In conclusion, clinicians in Ireland appear to have varied expectations of surgery across disciplines; orthopaedic and physiotherapy teams should ensure that management strategies and knowledge on APM outcomes are standardised and evidence based. Surgeons and patients do not currently appear to have a shared understanding of the reason for undergoing surgery. Improvements in shared decision making are needed in order to optimise patient compliance with treatment and optimise functional outcome in APM cohorts.

5.4 Thesis Limitations & Potential Bias

Limitations in the interpretation of literature review findings should be considered. Firstly, lack of data on both self-reported outcomes in younger patients, and outcome of surgery in meniscus repair populations mean that conclusions could not be made, despite the thesis objective to report on these populations. Secondly, heterogeneous reporting of outcome measure methodology in both strength testing and functional performance testing should be noted. This may have led to inconsistencies in how strength or performance was recorded across studies. Finally, a lack of studies reporting change over time was noted. Meta-analyses at multiple timepoints should be interpreted with caution as these analyses were based on low or adequate quality (high risk of bias) studies with small sample sizes, these analyses do not represent a true trajectory of strength or performance over time in any single population.

The TRIMS cohort study is limited by reduced numbers of participants completing all performance measures at both time points, leading to less statistically conclusive results. This study was not powered to stratify and analyse high performance measures according to subgroups of age or activity level. It was anticipated that patients with non-degenerative meniscus tears would account for a larger proportion of patients undergoing surgery during the recruitment period enabling this analysis. Although the TRIMS cohort self-reported a moderate level of activity prior to injury (Tegner Scale: 5), participants were largely middle aged with a high BMI and degenerative meniscus tear. Due to surgical cancellations following an outbreak of multi drug resistant organisms at Tallaght University Hospital, slow recruitment over the last two months of the TRIMS study also resulted in a smaller sample than anticipated.

The use of a contralateral leg as control in a degenerative meniscus injury population is a weakness of the TRIMS study. As degenerative changes in the knee joint are often bilateral, this may have led to decreased performance in the control leg at each time point if degenerative changes were also present. Contralateral knee injury was reported in 35% of the TRIMS cohort with 18% of participants having a history of contralateral knee surgery.

Participation in rehabilitation may have altered functional outcome of APM and was poorly described by TRIMS participants. Both hospital sites provided physiotherapy consultations to patients on the day of APM; patients were reviewed at the surgical unit and prescribed a home exercise program for simple lower limb balance and strengthening, information on adherence to this program was not collected. Participants in the TRIMS study did report the frequency and details of physiotherapy treatments at both pre-op and post-op assessment. This data was difficult to analyse due to a large variety in reported completion of both the post-operative rehab and additional exercise or rehabilitation intervention. Analysis was not adjusted for the potential effect of exercise.

Conclusions regarding clinician and patient reported rationale for surgery should be interpreted with caution. Limited data was gathered on patient expectation of outcome although this was an objective of the study. Limited validity of the methods used to gather information from patients and surgeons should be noted. Patients and surgeons responded to slightly different wording of this question, as patients were not given the tick-box options which were included on the arthroscopy data collection form. These questions were designed to gather exploratory data on the reasons given for surgery, but may not reflect precise reasons for surgery from both perspectives.

Selection bias was addressed in the TRIMS cohort by contacting all participants listed for surgery at two large hospitals in the Dublin area, Ireland. Inclusion criteria was deliberately broad in order to capture high performance data for the first time in a cohort representing a cross section of current clinical populations In Ireland. Assessment bias may be present in this study due to two weaknesses. Firstly, blinding of participants and examiners was not carried out in this study. Blinding to intervention was not possible as all participants were drawn from waiting lists for arthroscopic surgery and were aware of their intervention. Due to the nature of this study as a PhD project, manpower was not available to have additional blinded assessors completing each assessment. Assessment and analysis was performed by the same person (NC). Secondly, the contralateral leg was used as control in this study, which presents problems particularly in an osteoarthritic population who may have bilateral knee symptoms as discussed.

Data was collected on a large number of confounding variables in order to report the study population descriptively with recognition of these confounding factors.

Findings of the TRIMS study are not limited by attrition bias; this was achieved by careful scheduling of follow up with all participants. Phone calls were scheduled weekly to follow up on all participants who were due for follow up. Participants were informed of full participation requirements prior to consenting and reminded of the next stage in participation at each contact point. Participants were contacted by phone in advance of all follow up timepoints and were contacted again if successful response / attendance was not achieved. Excellent rates of follow up were achieved within the TRIMS cohort; 79% of participants returned PROMs at three months, 88% of participants returned for follow up assessment at 6 months and only eighteen percent of participants were lost to follow-up at 12 months.

5.5 Generalisability

Generalising the findings of this thesis to all cohorts of patients should be avoided, the findings of systematic reviews 1 & 2 are applicable to middle aged clinical cohorts of patients with predominantly degenerative meniscus tears only. Similarly, the TRIMS cohort is representative of public sector patients in Irish hospitals; a largely middle aged cohort with degenerative meniscus tears. The inclusion of more than one site and multiple surgeons increases the generalisability of these findings by reducing selection bias.

Cohort demographics from the TRIMS study were similar to cohorts reported at multiple sites in a recent Danish cohort and self-reported outcome measures reported similar trajectory of KOOS score to this cohort (Thorlund et al., 2017a). Similarity in demographics and subjective outcome suggests validity of the TRIMS findings which appear to be further generalisable to international cohorts of middle aged patients.

5.6 Indications for future research

Literature review revealed a lack of objective data in meniscus surgery cohorts and poor quality of studies; the TRIMS study adds longitudinal cohort data and additional measures of performance but further research is required in order to assess these outcomes in varied populations and gather data on additional outcome measures.

Specific subgroups of patients who may have a more significant change in performance measures following APM should be studied. Patients with traumatic tears may present with different clinical cohort which is poorly reported and were not captured by the TRIMS study. Athletes and those who are more highly active through sports or occupational requirements warrant special attention. Comparison can be made with the attention given to functional performance data in athletes who undergo ACL reconstruction; a large battery of assessment tools are reporting which can be used to guide both rehabilitation and clinical decision making. Additional data on performance over time in these cohorts would allow matched reference data by activity level or age – this could aid both clinicians and patients when making a decision about surgery as a treatment option.

Younger patients are poorly studied in current literature and did not account for many participants in the TRIMS study. While joint degeneration is a consequence of meniscus injury and affects all patients with meniscus tears, younger patients with less progressive joint degeneration may have higher functional capacity and may also experience a larger post-injury change in function which they hope to address with treatment. Self-reported outcomes are also lacking in this population; of note no RCTSs examining non-surgical alternatives to APM have been reported in young adults.

In addition to arthroscopic meniscectomy, the effects of arthroscopic meniscus repair also need to be established. Functional performance was only reported in one study with a small same size following meniscus repair. With increased emphasis on preserving meniscus tissue, this population may continue to increase and there is currently a complete lack of longitudinal data on function in this population.

Specific outcome measures should be utilised in future research, particularly measures which record more strenuous functional tasks and remove ceiling effects for populations who are highly active prior to injury. The previous lack of high performance data was addressed in the TRIMS study but plyometric and high speed assessment require research in additional cohorts to validate TRIMS findings of THD and 6MH improvements after APM.

Change over time from pre-op to post-op should be a focus of future study design in order to better analyse the effect of surgery alone. Longitudinal matched control study cohorts should recruit patients with meniscus injuries prior to surgery and assess functional performance longitudinally. Both short term and long-term follow up is required in order to establish if the trajectory of strength and performance which was found in degenerative knees, is applicable to all populations, or represents the progression of osteoarthritis changes at medium follow up in degenerative knees only.

Control data should be gathered from matched healthy populations rather than contralateral leg, particularly in older and degenerative populations. Weaknesses in using contralateral leg due to potential bilateral osteoarthritis can lead to a masking of functional deficits. In populations where matched controls are not easy to find (specific sporting populations etc.) detailed reporting of contralateral injury is required.

Difficulty may arise in assessing high level function pre-operatively in an injured population, although similar numbers of patients in the TRIMS cohort completed these performance tests at both pre-op and post-op. Young and active patients who present with acute injuries are also unlikely to tolerate high performance testing. In order to establish the effect of surgery, conservative management should first be trialled in studies which allow for resolution of acute injury symptoms, followed by surgical intervention and analysis of performance over time.

Additional data on both patient experience of surgery, and clinician perspectives on treatment prescription are needed in order to better understand the rationale for selection of arthroscopic meniscus surgery. Matching reasons for surgery from both perspectives to patient reported outcome measures would help to identify groups of patients whose expectations are met or who report satisfaction with outcome following surgery.

5.7 Thesis Conclusion

Literature review found that objective measures of functional performance are poorly studied across all age groups undergoing arthroscopic meniscus surgery. Strength appears to be decreased for up to one year following APM, in younger adults but there is a complete lack of self-reported outcome data in younger populations. Deficits in functional performance are reported both pre-operatively and post-operatively in middle aged APM cohorts and RCTs, although study quality limited meta-analysis and no pooled difference in functional performance was found pre-op or during the first year post-operatively. Functional performance appeared to improve at two years post-op, equalling control although limited studies were available at this timepoint.

The TRIMS study found deficits in functional performance compared to contralateral leg, both pre-operatively and post-operatively in middle aged patients undergoing APM. These functional deficits were found to improve bilaterally following surgery but no effect of treatment (surgery leg v control leg) was found for any performance measure analysed.. This indicated that deficits still exist following APM, despite bilateral functional improvements.

Change in strength of quads and hamstrings at 60°/sec as well as high-level performance assessments (6MH and THD) appeared to demonstrate greater improvements in the APM leg, compared to the contralateral leg over time in the TRIMS study. This was the first study to assess change over time in thigh performance measures from pre-op to six-months post-op and found that deficits in 6MH had resolved at six-month follow up, deficits still remained in THD despite a significant improvement. Level of self-reported activity prior to injury, or frequency of physical activity pre-op did not correlate with change in functional performance measures for patients undergoing APM in the TRIMS cohort.

Examination of clinician and patient rationale for surgery found that physiotherapists and surgical team members had varied expectations of APM outcome, regardless of clinician discipline. Orthopaedic team members who had a larger yearly caseload of APM patients had a higher expectation of improvement following surgery. Surgeons and patients within the TRIMS cohort reported different perspectives on the reason for surgery, indicating that improvements are need in shared decision making, in order to optimise patient compliance and functional outcome of arthroscopic meniscus surgery. Surgeons frequently reported pain as the reason for surgery, while patients reported functional improvements.

Improvements in functional performance are significant to patients and poorly reported over time in arthroscopic meniscus surgery populations. This thesis examined changes in self-reported and objective function in patients undergoing APM and found that while function improved over time, deficits in functional performance were still present at six-months following surgery.

6 Appendices

Appendix 1: PROSPERO registration: Systematic Review 1

University of York
Centre for Reviews and Dissemination

NHS
National Institute for Health Research

PROSPERO International prospective register of systematic reviews

Self-reported pain and function and knee extensor strength in young adults undergoing arthroscopic meniscal surgery

Jonas Bloch Thorlund, Lasse Østengaard, Nathan Cardy, Carsten Bogh Juhl, Claus Jørgensen

Citation

Jonas Bloch Thorlund, Lasse Østengaard, Nathan Cardy, Carsten Bogh Juhl, Claus Jørgensen. Self-reported pain and function and knee extensor strength in young adults undergoing arthroscopic meniscal surgery. PROSPERO 2015:CRD42015019815 Available from http://www.crd.york.ac.uk/PROSPERO_REBRANDING/display_record.asp?ID=CRD42015019815

Review question(s)

To systematically investigate the time course of self-reported pain and function and knee extensor muscle strength in young adults undergoing arthroscopic meniscal surgery.

Searches

Searches will be performed in MEDLINE, SPORTDiscus, EMBASE, CINAHL, Cochrane Central Register of Controlled Trials (CENTRAL) and Web of Science

Types of study to be included

There will be no restrictions on the types of study design eligible for inclusion.

Condition or domain being studied

Arthroscopic meniscal surgery (i.e. including repair and resection) in young adults.

Participants/ population

Inclusion criteria:

- studies including patients undergoing arthroscopic meniscal surgery (i.e. both meniscal repair and resection)

- studies assessing isometric/isokinetic or eccentric knee extensor muscle strength and/or self-reported pain and/or self-reported function

Exclusion criteria:

- any other concurrent surgical intervention (e.g. ACL reconstruction).

- open surgery.

- complete meniscectomy.

- more than 80% of study sample are older than 30yrs or more than 80% of study sample are younger than 18yrs.

Intervention(s), exposure(s)

Observational studies and intervention studies investigating arthroscopic meniscal surgery.

Comparator(s)/ control

Knee extensor strength (two comparators):

1. Muscle strength in the leg undergoing arthroscopic partial meniscectomy patients vs. muscle strength of a healthy control population (between subjects).

2. Muscle strength in the leg undergoing arthroscopic partial meniscectomy patients vs. muscle strength of the contra-lateral leg of patients (within subjects).

Self-reported pain and function:

1. Self-reported pain and function in the surgery group vs. self-reported pain and function in non-operative control group (or healthy controls).

Outcome(s)

Primary outcomes

Knee extensor strength:

Note: our hierarchy for selecting strength assessments is as follows:

1) Isometric

2) Concentric 60 deg/sec

3) Concentric 30 deg/sec

4) Concentric 120 deg/sec

5) Concentric 180 deg/sec

6) Concentric 240 deg/sec

7) Eccentric 60 deg/sec

8) Eccentric 30 deg/sec

9) Eccentric 120 deg/sec

10) Eccentric 180 deg/sec

11) Eccentric 240 deg/sec

Self-reported pain:

If reports use more than one pain scale we will use the following selection hierarchy for the data extraction:

1. WOMAC-pain or KOOS-pain

2. Pain during activity (VAS)

3. Pain during walking (VAS)

4. Global knee pain (VAS)

5. Pain at rest (VAS)

6. SF-36 (bodily pain (BP) subscale)

7. HAQ (pain subscale), Lequesne algofunctional index (pain subscale), AIMS (pain subscale), Knee-Specific Pain Scale(KSPS), McGill Pain Questionnaire (pain intensity), ASES (pain subscale), SES (Schmerzempfindungsskala)

8. Pain at night (VAS), pain during activity (NRS), pain on walking (NRS), number of painful days (days)

Self-reported function:

Patient-reported physical function (disability). If reports use more than one physical function scale we will use the following selection hierarchy for the data extraction:

1. The physical function scale measuring physical function during the most strenuous activities (i.e. KOOS subscale Sport/Rec)

2. WOMAC subscale for physical function or KOOS subscale for ADL function

3. SF-36 (subscale physical function (PF))

4. Physical composite score (PCS) based on SF-36, SF-12, or SF-8 HAQ (disability subscale), PDI (pain disability index), ASES (disability subscale)

Timing of outcomes:

We propose that time points will be categorized into: pre-surgery, 1 wk post-surgery, 3-4 wks post-surgery, 12 weeks post-surgery, 6 months post-surgery, 12 month post-surgery, 24 months post-surgery and 48 months post-surgery.

Effect measures.

The effect size (Cohens d) will be calculated as the standardized mean difference (SMD) allowing pooling and comparison of the various outcomes assessed in individual trials. The SMD will be estimated as the difference in the mean between the surgery group and the control divided by the pooled standard deviation (SD). The SD will be extracted or estimated from the confidence interval (CI), SE, p-value or other methods recommended by the Cochrane Collaboration. As the Cohens d overestimates the effect size especially in small studies the effect size is adjusted to Hedges g.

Secondary outcomes
All outcomes listed above

Data extraction, (selection and coding)
Two authors (MH and SB will independently screen title and abstracts, and if a study is considered eligible by at least one of the authors, the full text will be screened by both authors. Excluded studies and reasons for exclusion will be recorded, and disagreement will be resolved through discussion with a third reviewer (CJ). The following data will be extracted from the included studies (MH and SB):

1. Study design

2. Country of origin

3. Number of participants at each time point assessed

4. Participant characteristics (i.e. age, gender, body mass index)

5. Knee extensor muscle strength (i.e. peak torque, newton meters, kilograms) for leg of interest, healthy control group leg, contra-lateral leg, isometric strength, isokinetic strength, intervention studies: rehabilitation group and control group

6. Self-reported pain

7. Self-reported physical function

Risk of bias (quality) assessment
Cohort trials will be assessed independently by two reviewers (MH and SB) according to the guidelines from the Scottish International Guideline Network (SIGN50).

1) The study addresses an appropriate and clearly focused question

2) The two groups being studied are selected from source populations that are comparable in all respects other than the factor under investigation. The study indicates how many of the people asked to take part did so, in each of the groups being studied.

3) The likelihood that some eligible subjects might have the outcome at the time of enrolment is assessed and taken into account in the analysis

4) What percentage of individuals or clusters recruited into each arm of the study dropped out before the study was completed

5) Comparison is made between full participants and those lost to follow up, by exposure status

6) The outcomes are clearly defined

7) The assessment of outcome is made blind to exposure status. If the study is retrospective this may not be applicable.

8) Evidence from other sources is used to demonstrate that the method of outcome assessment is valid and reliable

9) The method of assessment of exposure is reliable.

10) Where blinding was not possible, there is some recognition that knowledge of exposure status could have influenced the assessment of outcome

11) Exposure level or prognostic factor is assessed more than once

12) The main potential confounders are identified and taken into account in the design and analysis

13) Have confidence intervals been provided?

Each of these key components of methodological quality will be assessed “yes” or “no” according to the guidelines of SIGN50 and based on this the study are classified as High quality (++), Acceptable (+) or Unacceptable.

Strategy for data synthesis

A meta-analysis will be applied on the SMD of knee extensor muscle weakness, self-reported pain and function. A random effects model (REML) will be applied as large between study variance is expected.

A standard Q-test (Cochran 1954) will be used to test heterogeneity between included studies. Furthermore, I-squared statistics will be calculated (Higgins 2002). This estimate assesses the proportion of variation (i.e. consistency) in the combined estimates due to between-study heterogeneity. Furthermore the Tau-squared value expressing the between study variance will be estimated. Covariates are defined as variables able to reduce the Tau-squared value when included in the analysis.

To improve interpretability of the results the overall SMD values for knee extensor strength will be converted to percentage differences by multiplying the pooled SMD with the SD and dividing by the mean muscle strength estimated in a large cohort.

SMD for self reported pain and disability will be converted into mm on a 0 to 100 scale by multiplying the SMD with the SD from a large cohort.

Analysis of subgroups or subsets

1. Leg (e.g. healthy control leg vs. contra-lateral leg).

2. Rehabilitation (e.g. no formal rehabilitation vs. formal rehabilitation).

3. Surgery type (i.e. repair vs. resection)

Dissemination plans
We intend to publish the results in an international peer-reviewed journal.

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Anticipated or actual start date
27 April 2015

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31 December 2015

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None

Conflicts of interest
None known

Language
English

Country
Denmark

Subject index terms status
Subject indexing assigned by CRD

Subject index terms
Adult; Arthroscopy; Humans; Knee; Knee Joint; Pain; Self Report

Stage of review
Ongoing

Date of registration in PROSPERO
23 April 2015

Date of publication of this revision
02 March 2016

DOI
10.15124/CRD42015019815

Stage of review at time of this submission	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	No
Data extraction	No	No
Risk of bias (quality) assessment	No	No
Data analysis	No	No

Appendix 2: Search Strategy for Systematic Review 2

Self-reported pain and function and knee extensor strength in young adults undergoing arthroscopic meniscal surgery

Search strategy:

(Menisci, Tibial/surgery[Mesh] OR Menisci, Tibial/injuries[Mesh] OR Degenerative meniscal tear[TIAB] OR ((Arthroscopic lavage[TIAB] OR Arthroscopic debridement[TIAB] OR Arthroscopic[TIAB])) AND menisc*[TIAB]) OR arthroscopic meniscectomy[TIAB] OR (Arthroscopy[TIAB] AND Knee[TIAB])

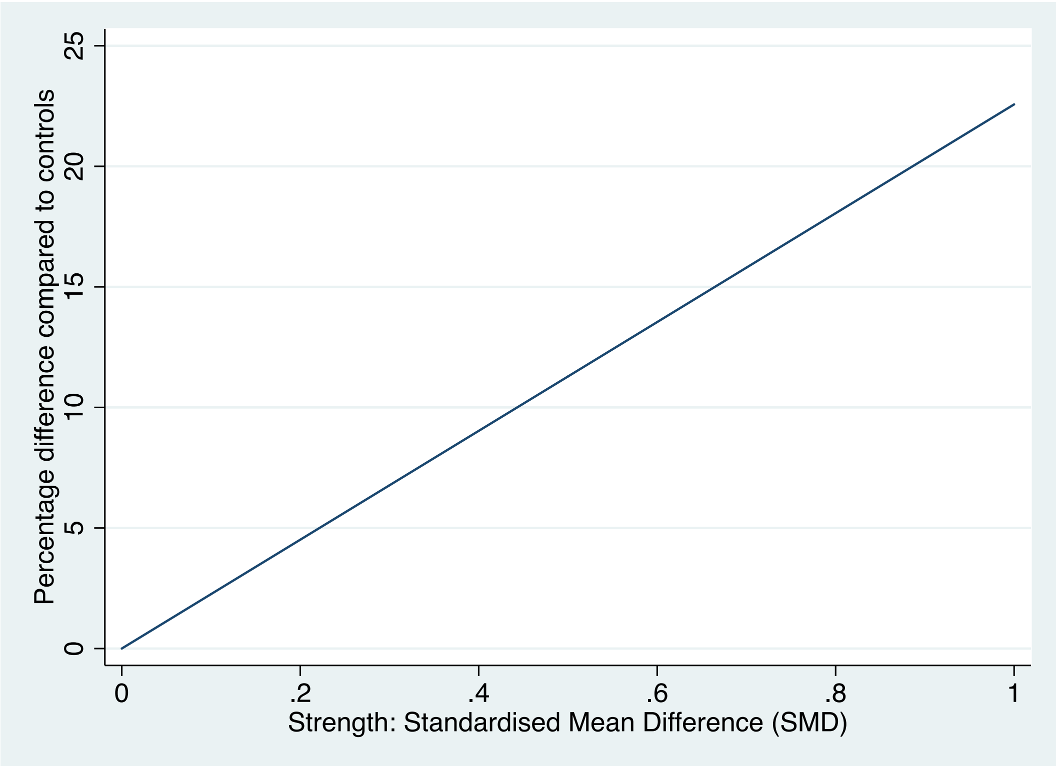
AND

(Pain[Mesh] OR Pain[TIAB]) OR (Physical function[TIAB] OR Disability[TIAB]) OR ((Knee[Mesh] OR Knee[TIAB]) AND (muscle strength[MeSH] OR Resistance Training[MeSH] OR strength*[TIAB] OR strength[TIAB] OR function*[TIAB] OR function[TIAB] OR isometric[TIAB] OR isokinetic[TIAB] OR concentric[TIAB] OR eccentric[TIAB] OR torque[TIAB]))

Appendix 3: Conversion of SMD to percentage differences

A converter between standardized mean differences (SMDs) and percentage difference between healthy controls (SMD into % difference = SMD X 0.226* X 100%) (Bliddal and Christensen, 2009) was used to improve interpretability and approximate the overall SMD values for knee extensor weakness in Systematic Review 1.

*SD/mean knee extensor strength calculated frim values in three previous studies (Danneskiold-Samsøe et al., 2009, Santos et al., 2010, Bolgla et al., 2015), weighted by study size (n).



BLIDDAL, H. & CHRISTENSEN, R. 2009. The treatment and prevention of knee osteoarthritis: a tool for clinical decision-making. *Expert Opinion on Pharmacotherapy,* 10**,** 1793-1804.

BOLGLA, L. A., EARL-BOEHM, J., EMERY, C., HAMSTRA-WRIGHT, K. & FERBER, R. 2015. Comparison of hip and knee strength in males with and without patellofemoral pain. *Physical Therapy in Sport,* 16**,** 215-221.

DANNESKIOLD-SAMSØE, B., BARTELS, E. M., BÜLOW, P. M., LUND, H., STOCKMARR, A., HOLM, C. C., WÄTJEN, I., APPLEYARD, M. & BLIDDAL, H. 2009. Isokinetic and isometric muscle strength in a healthy population with special reference to age and gender. *Acta Physiologica,* 197**,** 1-68.

SANTOS, H. H., ÁVILA, M. A., HANASHIRO, D. N., CAMARGO, P. R. & SALVINI, T. F. 2010. The effects of knee extensor eccentric training on functional tests in healthy subjects. *Brazilian Journal of Physical Therapy,* 14**,** 276-283.

Appendix 4: SIGN 50, risk of bias criteria for Systematic Review 1

Risk of bias assessment according to the SIGN50 criteria, including specific interpretation (guidelines) used for each domain for this specific study and scoring for each of the included studies.

SIGN50 criteria:	Guidelines for risk assessment:	deSouza et al. 1992	Eller et al. 1999	Gapeyeva et al. 2000	Gapeyeva et al. 2000	Ford et al. 2011	Huber et al. 2013
1) The study addresses an appropriate and clearly focused question	Adequate study question relevant in relation to the conducted systematic review	**I**	**I**	**A**	**A**	**I**	**A**
2) The two groups being studied are selected from source populations that are comparable in all respects other than the factor under investigation. The study indicates how many of the people asked to take part did so, in each of the groups being studied.	Adequate if the study contained a properly matched reference group or used the contra-lateral leg for comparison	**A**	**A**	**A**	**A**	**A**	**I**
3) The likelihood that some eligible subjects might have the outcome at the time of enrolment is assessed and taken into account in the analysis	Adequate if subjects were unlikely to have reduced muscle strength prior to meniscal injury	**I**	**I**	**I**	**I**	**I**	**I**
4) What percentage of individuals or clusters recruited into each arm of the study dropped out before the study was completed	Adequate if over 80% was retained in the study	**I**	**U**	**A**	**A**	**A**	**A**
5) Comparison is made between full participants and those lost to follow up, by exposure status	Adequate if drop-out analysis was conducted and showed minimal risk of selective drop-out	**I**	**U**	**A**	**A**	**A**	**A**
6) The outcomes are clearly defined	Adequate if outcome was clearly defined (i.e. type of muscle strength	**A**	**I**	**A**	**A**	**A**	**A**

	assessment, units of measurement given, etc.)						
7) The assessment of outcome is made blind to exposure status. If the study is retrospective this may not be applicable.	Adequate if assessors blinded to leg status (i.e. surgery or control leg using sleeve or other type of masking)	**I**	**I**	**I**	**I**	**I**	**I**
8) Evidence from other sources is used to demonstrate that the method of outcome assessment is valid and reliable	Adequate if validity/reliability testing in study or properly referenced	**I**	**I**	**I**	**I**	**A**	**I**
9) The method of assessment of exposure is reliable.	Adequate if type of surgery was specified (i.e. repair/resection, open or arthroscopic, etc.)	**I**	**A**	**A**	**A**	**A**	**A**
10) Where blinding was not possible, there is some recognition that knowledge of exposure status could have influenced the assessment of outcome	Not applicable as measures of blinding could have been employed	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
11) Exposure level or prognostic factor is assessed more than once	Not possible as exposure was surgery	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
12) The main potential confounders are identified and taken into account in the design and analysis	Adequate if major potential confounders discussed and/or employed in statistical analysis	**I**	**I**	**I**	**I**	**I**	**I**
13) Have confidence intervals been provided?	Adequate if measures of dispersion on estimates is given in table format (95% CI, SD or SE)	**A**	**I**	**A**	**I**	**A**	**I**

A=adequate, U=unclear, I=inadequate (N/A=not applicable)

Appendix 5 PROSPERO registration: Systematic Review 2

PROSPERO
International prospective register of systematic reviews

National Institute for Health Research

Systematic review and meta-analysis of objective functional performance prior to and following arthroscopic meniscal surgery

Nathan Cardy, Jonas Bloch Thorlund, John Quinlan, Niall Hogan, Kate MacNulty, Aisling Brennan, David Mockler, Fiona Wilson

Citation

Nathan Cardy, Jonas Bloch Thorlund, John Quinlan, Niall Hogan, Kate MacNulty, Aisling Brennan, David Mockler, Fiona Wilson. Systematic review and meta-analysis of objective functional performance prior to and following arthroscopic meniscal surgery. PROSPERO 2017 CRD42017050313 Available from:
http://www.crd.york.ac.uk/PROSPERO/display_record.php?ID=CRD42017050313

Review question

Do functional performance limitations exist in patients scheduled for arthroscopic meniscus surgery?
Do functional performance limitations exist in patients who have undergone arthroscopic meniscus surgery?
What is the timeline of functional performance changes in patients who have undergone arthroscopic meniscus surgery?
Does participation in structured rehabilitation (physiotherapy, group exercise, home exercise programs) influence objective measures of functional performance in patients before or after arthroscopic meniscus surgery?

Searches

Searches will be performed in MEDLINE, EMBASE, CINAHL, Cochrane Central Register of Controlled Trials (CENTRAL) and Web of Science. A grey literature search of conference proceedings will be carried out. Searches will be limited to English language publications. No start date restriction will be applied, and all articles to date of search will be included. The search strategy will be repeated prior to publication to ensure no recent articles are missed.

Search strategy

https://www.crd.york.ac.uk/PROSPEROFILES/50313_STRATEGY_20170017.pdf

Types of study to be included

There will be no restriction on type of study design eligible for inclusion.

Case reports and commentaries / reviews of other studies will not be included.

Condition or domain being studied

Arthroscopic meniscal surgery (including partial & total meniscectomy, meniscal suture, meniscal repair etc).

Participants/population

Inclusion:
Studies including patients of any age over 18 years old, undergoing arthroscopic meniscal surgery.
Studies where the primary or secondary outcome measure is an objective performance test.
Exclusion:
Studies where the primary surgical procedure is a ligament reconstruction (ACL / PCL) combined with meniscectomy.
Studies where the surgical procedure is arthroscopy assisted, but not true arthroscopy (eg. Meniscal Allograft Transplantation).

Intervention(s), exposure(s)

Objective functional performance measures – objective tests designed to assess functional ability of the knee joint, excluding self-reported measures. These measures will include both clinically driven and research based outcome measures, Studies on functional performance (i.e. Jump tests, running tests, agility tests, etc.) will be included, for this study tests of biomechanical kinetics/kinematics or tests of proprioception will

not be considered as functional performance tests.
Inclusion:
Validated or clinically relevant objective measures of physical function or performance.
Exclusion:
Measures of self-reported physical function.
Measures of knee strength as an indicator of function, rather than an objective measure of function.

Comparator(s)/control

Acceptable comparators / controls will be either a healthy leg (within participants) or a healthy control subject. The hierarchy of preference for controls will be healthy control over contralateral leg. Studies with contralateral limb as control will be included (within participant design) but a sub-group analysis will be done excluding these, as a sensitivity analysis to see if this is an influencing factor.
For studies which do not include a comparator / control group, results of functional performance will still be extracted for meta-analysis of functional performance at various time points before / after surgery (this will allow an investigation of timeline, to assess for functional trajectory in this population)

Context

The purpose of the systematic review is to review current literature regarding objective functional measures, to compliment current knowledge of patient reported outcomes and function following meniscus surgery. In order to capture all published data of this nature, the inclusion & exclusion criteria are deliberately broad and inclusive.

Main outcome(s)

Due to the heterogenous nature of functional assessment and the multitude of functional measures in use by clinicians and researchers, a single primary outcome measure has not been selected prior to article screening.
As previously published reviews of functional measures in this population (Kroman et al, 2014) have pointed to functional hop tests as the most reliable measure of function in a knee injured population, it is hoped that performance in functional hop tests will be available for meta analysis. A number of Hop Tests are commonly used in clinical practice and published in the literature for this population, the following (non-exhaustative) hierarchy of hop tests will be taken as the primary outcome measure:
1. One legged hop for distance
2. 6m timed hop
3. Crossover hop for distance
4. Triple hop for distance
5. Vertical Jump.

Timing and effect measures

Timing of outcome measure will be extracted from each included study, and where multiple studies report at the same timepoint, a meta-analysis will be performed at these time points using the SMD of each measure, to establish aggregated data at clinically relevant time points.
Effect measures.
The effect size (Cohens d) will be calculated as the standardized mean difference (SMD) allowing pooling and comparison of the various outcomes assessed in individual trials. The SMD will be estimated as the difference in the mean between the surgery group and the control divided by the pooled standard deviation (SD). The SD will be extracted or estimated from the confidence interval (CI), SE, p-value or other methods recommended by the Cochrane Collaboration. As the Cohens d overestimates the effect size especially in small studies the effect size is adjusted to Hedges g.

Additional outcome(s)

Secondary measures will include objective functional knee tests and other physical performance assessments.The following (non-exhaustive) hierarchy of tools will be used:
Functional Knee Tests:
1. Single leg bend reps in 30 secs
2. One leg rise
3. Stairs hopple test
Other Physical Performance:
1. 6 minute walk test

2. Timed Up and Go test
3. Figure of 8
4. Chair Stand Test
5. Get up and go test
6. Stairs running test
7. Stair-climb test
8. Functional Assessment system.

Timing and effect measures

Timing of outcome measure will be extracted from each included study, and where multiple studies report at the same timepoint, a meta-analysis will be performed at these time points using the SMD of each measure, to establish aggregated data at clinically relevant time points.
Effect measures.
The effect size (Cohens d) will be calculated as the standardized mean difference (SMD) allowing pooling and comparison of the various outcomes assessed in individual trials. The SMD will be estimated as the difference in the mean between the surgery group and the control divided by the pooled standard deviation (SD). The SD will be extracted or estimated from the confidence interval (CI), SE, p-value or other methods recommended by the Cochrane Collaboration. As the Cohens d overestimates the effect size especially in small studies the effect size is adjusted to Hedges g.

Data extraction (selection and coding)

Two authors (NC and FW) will independently screen title and abstracts, and if a study is considered eligible by at least one of the authors, the full text will be screened by both authors. Excluded studies and reasons for exclusion will be recorded, and disagreement will be resolved through discussion with a third reviewer(JT). The following data will be extracted from the included studies:
Study design
Country of study origin
No. of participants at each time point assessed
Study participant characteristics (eg. Mean age of participants, Percentage of participants who are female, Mean BMI of participants, Activity level of participants).
Category of control subjects (healthy controls / contralateral limb / nil)
Timepoint of Functional Performance Assessment
Mean score on objective functional performance assessment at all timepoints
Details of rehabilitation at each time point.

Risk of bias (quality) assessment

Cohort trials will be assessed independently by two reviewers (NC and FW). Randomised Controlled Trials will be assessed using the Cochrane Risk Of Bias Tool. Cross sectional studies will be assessed using the Appraisal Tool for Cross-Sectional Studies (AXIS).

Strategy for data synthesis

A meta-analysis will be applied on the SMD of functional performance measures at each time point. A random effects model (REML) will be applied as large between study variance is expected. I-squared statistics will be calculated (Higgins 2002) in order to assess hetrogeneity between studies. This estimate assesses the proportion of variation (i.e. consistency) in the combined estimates due to between-study heterogeneity. Furthermore the Tau-squared value expressing the between study variance will be estimated. Covariates are defined as variables able to reduce the Tau-squared value when included in the analysis.

Analysis of subgroups or subsets

Subgroups of participants, as well as subsets of functional performance will be analysed if sufficient data is available.
Participants will be subgrouped by:
Age
Gender
Classification of meniscus injury as traumatic or degenerative
Participation in rehabilitation and type of rehabilitation (supervised physio / home exercises / group exercise / not specified).
Functional Performance will be analysed in subsets of:

Knee specific function
Overall physical function
If enough data is available; performance on specific outcome measures, as outlined in the hierarchy of primary and secondary outcome measures, will be analysed.

Contact details for further information

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Trinity College Dublin

Review team members and their organisational affiliations

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Mr Niall Hogan. St. James's Hospital, Dublin
Ms Kate MacNulty. St. James's Hospital, Dublin
Ms Aisling Brennan. Adelaide and Meath Hospital Incorporating the National Children's Hospital, Dublin
Mr David Mockler. Trinity College Dublin
Dr Fiona Wilson. Trinity College Dublin

Type and method of review

Meta-analysis, Systematic review

Anticipated or actual start date

01 November 2016

Anticipated completion date

10 February 2017

Funding sources/sponsors

Trinity College Dublin; PhD Studentship

Conflicts of interest

None known

Language

English

Country

Denmark, Ireland

Stage of review

Review Ongoing

Subject index terms status

Subject indexing assigned by CRD

Subject index terms

Arthroscopy; Humans; Menisci, Tibial; Meniscus

Date of registration in PROSPERO

17 January 2017

Date of publication of this version

10 July 2018

Details of any existing review of the same topic by the same authors

Stage of review at time of this submission

Stage	Started	Completed
Preliminary searches	Yes	Yes
Piloting of the study selection process	Yes	Yes
Formal screening of search results against eligibility criteria	Yes	No
Data extraction	No	No
Risk of bias (quality) assessment	No	No
Data analysis	No	No

Versions

17 January 2017
10 July 2018

Appendix 6: Search Strategy for Systematic Review 2

Systematic Review and Meta-analysis of Objective Functional Performance prior to and following arthroscopic meniscal surgery

EMBASE

1. 'meniscal surgery'/exp
2. 'knee meniscus rupture'/exp
3. meniscectom* OR menisectom*:ti,ab
4. (menisc* NEAR/2 (surger* OR transplant* OR sutur* OR allograft* OR implant* OR repair OR debridement)):ab,ti
5. #1 OR #2 OR #3 OR #4
6. 'knee function'/exp
7. 'functional assessment'/exp
8. 'functional status'/exp
9. 'range of motion'/exp
10. 'ergometry'/exp
11. 'exercise test'/exp
12. (function* NEAR/2 (outcome* OR capacity OR status OR assessmen* OR knee OR activity)):ti,ab
13. (physical* NEAR/2 (function* OR performance* OR capacity* OR status OR assess*)):ti,ab
14. (test NEAR/2 (exercise OR bicycle OR step OR treadmill OR knee OR hop* OR jump*)):ti,ab
15. (‘range of motion’ OR gait OR walk* OR flexion OR laxity OR extension OR ‘observed function’ OR ‘task performance’):ti,ab
16. ((Performance OR objective OR observational) NEAR/3 (measure OR test* OR instrument* OR evaluation)):ab,ti
17. #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR #16
18. #5 AND #17

Medline (EBSCO)

1. MH "Menisci, Tibial/SU/TR"
2. TI (meniscectom* OR menisectom*) OR AB (meniscectom* OR menisectom*)
3. TI (menisc* N2 (surger* OR transplant* OR sutur* OR allograft* OR implant* OR repair OR debridement)) OR AB (menisc* N2 (surger* OR transplant* OR sutur* OR allograft* OR implant* OR repair OR debridement))
4. S1 OR S2 OR S3
5. MH "Gait"
6. MH "Muscle Strength+"
7. MH "Range of Motion, Articular+"
8. MH "Ergometry+"
9. TI (function* N2 (outcome* OR capacity OR status OR assessmen* OR knee OR activity)) OR AB (function* N2 (outcome* OR capacity OR status OR assessmen* OR knee OR activity))
10. TI (physical* N2 (function* OR performance* OR capacity* OR status OR assess*)) OR AB (physical* N2 (function* OR performance* OR capacity* OR status OR assess*))
11. TI (test N2 (exercise OR bicycle OR step OR treadmill OR knee OR hop* OR jump*)) OR AB (test N2 (exercise OR bicycle OR step OR treadmill OR knee OR hop* OR jump*))
12. TI (‘range of motion’ OR gait OR walk* OR flexion OR laxity OR extension OR ‘observed function’ OR ‘task performance’) OR AB (‘range of motion’ OR gait OR walk* OR flexion OR laxity OR extension OR ‘observed function’ OR ‘task performance’)
13. TI ((Performance OR objective OR observational) N3 (measure OR test* OR instrument* OR evaluation)) OR AB ((Performance OR objective OR observational) N3 (measure OR test* OR instrument* OR evaluation))
14. S5 OR S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13
15. S4 AND S14

CINAHL

1. MH "Meniscectomy"
2. MH "Menisci, Tibial/SU/IN"
3. TI (meniscectom* OR menisectom*) OR AB (meniscectom* OR menisectom*)
4. TI (menisc* N2 (surger* OR transplant* OR sutur* OR allograft* OR implant* OR repair OR debridement)) OR AB (menisc* N2 (surger* OR transplant* OR sutur* OR allograft* OR implant* OR repair OR debridement))
5. S1 OR S2 OR S3 OR S4
6. MH "Functional Status"
7. MH "Range of Motion"
8. MH "Exercise Test"
9. MH "Functional Assessment"
10. MH "Gait"
11. MH "Gait Analysis"
12. MH "Muscle Strength"
13. MH "Exercise Test, Muscular"
14. TI (function* N2 (outcome* OR capacity OR status OR assessmen* OR knee OR activity)) OR AB (function* N2 (outcome* OR capacity OR status OR assessmen* OR knee OR activity))
15. TI (physical* N2 (function* OR performance* OR capacity* OR status OR assess*)) OR AB (physical* N2 (function* OR performance* OR capacity* OR status OR assess*))
16. TI (test N2 (exercise OR bicycle OR step OR treadmill OR knee OR hop* OR jump*)) OR AB (test N2 (exercise OR bicycle OR step OR treadmill OR knee OR hop* OR jump*))
17. TI (‘range of motion’ OR gait OR walk* OR flexion OR laxity OR extension OR ‘observed function’ OR ‘task performance’) OR AB (‘range of motion’ OR gait OR walk* OR flexion OR laxity OR extension OR ‘observed function’ OR ‘task performance’)
18. TI ((Performance OR objective OR observational) N3 (measure OR test* OR instrument* OR evaluation)) OR AB ((Performance OR objective OR observational) N3 (measure OR test* OR instrument* OR evaluation))

19. S6 OR S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S18
20. S5 AND S19

Cochrane

1. [mh "Menisci, Tibial"/IN,SU]
2. meniscectom* or menisectom*:ti,ab,kw
3. (menisc* NEAR/2 (surger* OR transplant* OR sutur* OR allograft* OR implant* OR repair OR debridement)): ti,ab,kw
4. #1 OR #2 OR #3
5. [mh "Gait"]
6. [mh "Muscle Strength"]
7. [mh "Range of Motion, Articular"]
8. [mh "Ergometry"]
9. (function* NEAR/2 (outcome* OR capacity OR status OR assessmen* OR knee OR activity)):ti,ab,kw
10. (physical* NEAR/2 (function* OR performance* OR capacity* OR status OR assess*)):ti,ab,kw
11. (test NEAR/2 (exercise OR bicycle OR step OR treadmill OR knee OR hop* OR jump*)):ti,ab,kw
12. ('range of motion' OR gait OR walk* OR flexion OR laxity OR extension OR 'observed function' OR 'task performance'):ti,ab,kw
13. ((Performance OR objective OR observational) NEAR/3 (measure OR test* OR instrument* OR evaluation)):ab,ti,kw
14. (OR #5 - #13)
15. #4 AND #14

Web of Science

1. TS= (menisc* NEAR/2 (surger* OR transplant* OR sutur* OR allograft* OR implant* OR repair OR debridement)) OR TS= (meniscectom* OR menisectom*)
2. TS= (function* NEAR/2 (outcome* OR capacity OR status OR assessmen* OR knee OR activity)) OR TS= (physical* NEAR/2 (function*

OR performance* OR capacity* OR status OR assess*)) OR TS= (test NEAR/2 (exercise OR bicycle OR step OR treadmill OR knee OR hop* OR jump*)) OR TS= (‘range of motion’ OR gait OR walk* OR flexion OR laxity OR extension OR ‘observed function’ OR ‘task performance’) OR TS= ((Performance OR objective OR observational) NEAR/3 (measure OR test* OR instrument* OR evaluation))

3. #1 AND #2

Appendix 7: SIGN 50 Criteria, Systematic Review 2

SIGN50 criteria:	Guidelines for risk assessment:	Ericsson et al. 2006	Ericsson et al. 2008	Huber et al. 2013	Malliou et al. 2012	Morrissey et al. 2006	Naimark et al. 2014	Thorlund et al. 2010	Thorlund et al. 2011
1) The study addresses an appropriate and clearly focused question	Adequate study question relevant in relation to the conducted systematic review	**A**	**A**	**A**	**I**	**A**	**A**	**A**	**A**
2) The two groups being studied are selected from source populations that are comparable in all respects other than the factor under investigation. The study indicates how many of the people asked to take part did so, in each of the groups being studied.	Adequate if the study contained a properly matched reference group or used the contra-lateral leg for comparison	**A**	**N/A**	**A**	**A**	**A**	**N/A**	**A**	**A**
3) The likelihood that some eligible subjects might have the outcome at the time of enrolment is assessed and taken into account in the analysis	Adequate if subjects were unlikely to have reduced functional performance prior to meniscal injury	**I**	**I**	**A**	**A**	**I**	**I**	**I**	**I**
4) What percentage of individuals or clusters recruited into each arm of the study dropped out before the study was completed	Adequate if over 80% was retained in the study	**A**	**A**	**A**	**A**	**U**	**I**	**A**	**A**
5) Comparison is made between full participants and those lost to follow up, by exposure status	Adequate if drop-out analysis was conducted and showed minimal risk of selective drop-out	**I**	**I**	**I**	**I**	**I**	**U**	**I**	**I**
6) The outcomes are clearly defined	Adequate if outcome was clearly defined (i.e. type of functional	**A**	**A**	**A**	**A**	**I**	**A**	**A**	**A**

	performance, units of measurement given, etc.)								
7) The assessment of outcome is made blind to exposure status. If the study is retrospective this may not be applicable.	Adequate if assessors blinded to leg status (i.e. surgery or control leg using sleeve or other type of masking)	**I**	**N/A**	**I**	**I**	**U**	**N/A**	**I**	**I**
8) Evidence from other sources is used to demonstrate that the method of outcome assessment is valid and reliable	Adequate if validity/reliability testing in study or properly referenced	**A**	**A**	**A**	**U**	**I**	**I**	**A**	**A**
9) The method of assessment of exposure is reliable.	Adequate if type of surgery was specified (i.e. repair/resection, open or arthroscopic, etc.)	**A**	**A**	**A**	**I**	**A**	**A**	**A**	**A**
10) Where blinding was not possible, there is some recognition that knowledge of exposure status could have influenced the assessment of outcome	Not applicable as measures of blinding could have been employed	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
11) Exposure level or prognostic factor is assessed more than once	Not possible as exposure was surgery	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**
12) The main potential confounders are identified and taken into account in the design and analysis	Adequate if major potential confounders discussed and/or employed in statistical analysis	**I**	**I**	**I**	**I**	**A**	**I**	**A**	**A**
13) Have confidence intervals been provided?	Adequate if measures of dispersion on estimates is given in table format (95% CI, SD or SE)	**A**	**I**	**I** **	**A**	**A**	**A**	**A**	**A**

A=adequate, U=unclear, I=inadequate (N/A=not applicable)

Appendix 8: TRIMS Patient Information Leaflet

Stopping the study:

You understand that your doctor or investigator may stop your participation in the study at any time without your consent.

Permission:

This trial has hospital Research Ethics Committee approval.

Further information:

You can get more information or answers to your questions about the study, your participation in the study, and your rights, from your lead investigator Mr. Nathan Cardy who can be telephoned at 0863786414. If your doctor or lead investigator learns of important new information that might affect your desire to remain in the study, he or she will tell you.

Coláiste na Tríonóide, Baile Átha Cliath
Trinity College Dublin
Ollscoil Átha Cliath | The University of Dublin

SDU
UNIVERSITY OF SOUTHERN DENMARK

ST. JAMES'S HOSPITAL

The Adelaide and Meath Hospital, Dublin
Incorporating the National Children's Hospital

TRIMS: Trinity Meniscus Study.

Patient Information Leaflet

Title of Study:

An investigation of predictors of functional outcome following meniscus surgery of the knee.

Introduction:

This study aims to examine the knee joint before and after meniscus surgery. Assessments of strength, tests of physical function and reports of physical activity & knee function will be assessed on both knees, before surgery and after surgery. Participants will be required to attend a Physiotherapy assessment on two occasions for testing. Participants will also be required to complete questionnaires on two separate occasions

Procedures:

Criteria for selection for participation in the study are:

- Age 18 years and above
- Scheduled for meniscus surgery of the knee
- Available for follow-up assessment 6 months after surgery

The participant will undergo initial tests prior to surgery, and will proceed for their knee surgery as normal. The participant will then complete questionnaires 3 months after surgery and will have a return visit to the Physiotherapist for repeat examinations at 6 months after the surgery. Finally, the participant will compete questionnaires again at 12 months after surgery.

Benefits:

The study will have no direct benefit to the individual participant but the results may benefit subsequent patients.

Risks:

Participants may experience discomfort in their knee or muscles following physical function testing and strength testing.

Exclusion from participation:

You cannot participate in this study if any of the following are true:

- You have had a recent fracture to your leg
- You have a cognitive disability that may hinder following instructions

Alternative treatment:

You do not have to be a part of this study to be treated. You may choose to go for surgery without participating in this study.

Confidentiality:

Your identity will remain confidential. Your name will not be published and will not be disclosed to anyone outside the research team.

Compensation:

Your Physiotherapist is covered by standard professional liability insurance. Nothing in this document restricts or curtails your rights.

Voluntary Participation:

You have volunteered to participate in this study. You may quit at any time. If you decide not to participate, or if you quit, you will not be penalised and will not give up any benefits which you had before entering the study.

Appendix 9: TRIMS Consent Form

CONSENT FORM

An investigation of predictors of functional outcome following meniscus surgery of the knee.

This study and this consent form have been explained to me. The lead investigator has answered all my questions to my satisfaction. I believe I understand what will happen if I agree to be part of this study. I have read, or had read to me, this consent form. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I freely and voluntarily agree to be part of this research study, and allow the processing of my data for research purposes though without prejudice to my legal and ethical rights. I have received a copy of this agreement.

PARTICIPANT'S NAME:

____

PARTICIPANT'S SIGNATURE:

____

Date:

____

Date on which the participant was first furnished with this form:

____

Statement of investigator's responsibility:
I have explained the nature, purpose, procedures, benefits, risks of, or alternatives to, this research study. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

Principal Investigator's signature:

____

Date:

____

Appendix 10: TRIMS Injury Mechanism Assessment Form

Trinity Meniscus Study: TRIMS
Physiotherapy Assessment Form

Participant ID:

Mechanism of injury:

Previous Knee injury before current complaint: Yes ☐ No ☐
Details:____

Date of current injury onset (month):

____
(The knee pain / problem for which you are now having surgery)

Date of initial medical review (month):_____________________

How did the knee pain/problems for which you are now having surgery develop (choose the answer that best match your situation)?
☐ The pain/problems have slowly evolved over time.
☐ As a result of a specific incident (ie, kneeling, sliding and/or twisting of the knee or the like).
☐ As a result of a violent incident (ie, during sports, a crash, collision or the like)

How often have you experienced the following sensations, in the knee which is now undergoing surgery:

Catching of the knee
Never ☐ Monthly ☐ Weekly ☐ Several Times a week ☐ Daily ☐

Locking of the knee
Never ☐ Monthly ☐ Weekly ☐ Several Times a week ☐ Daily ☐

Giving way of the knee
Never ☐ Monthly ☐ Weekly ☐ Several Times a week ☐ Daily ☐

Reason for surgery: ____

Management to date:

Pre-op X-ray: Yes ☐ No ☐
Pre-op MRI: Yes ☐ No ☐
Where performed: ____________________________
Date of MRI: ____________________________

Supervised Physio: Pre-op: Yes ☐ No ☐
Post-op: Yes ☐ No ☐ N/A ☐

Appendix 11: TRIMS Physiotherapy Assessment Form

ST. JAMES'S HOSPITAL

THE ADELAIDE & MEATH HOSPITAL, DUBLIN INCORPORATING THE NATIONAL CHILDREN'S HOSPITAL

Trinity College Dublin The University of Dublin

SDU UNIVERSITY OF SOUTHERN DENMARK

Trinity Meniscus Study: TRIMS

Physiotherapy Assessment Form

Participant ID:

Knee Surgery Leg: **Left ☐ Right ☐**
Assessment date: ____________
Pre-op: ☐ Post-op: ☐

Date of Birth: ________________________
Gender: ________________________
Height: ________________________
Weight: ________________________
BMI: ________________________

Details of Physiotherapy management to date: (Pre-op ☐ Post-op ☐)
Where Performed: ____________________________________
Duration of Physio: ____________________________________
No. of sessions: ____________________________________
Components of Physio treatment: Pain Modalities ☐ Strengthening Exercises ☐
Aerobic Exercises ☐ Functional / Agility training ☐ Other ☐______________

<u>Physical Assessment:</u>
Infrapatellar swelling: <1cm difference ☐ 1-2cm difference ☐ >2cm difference☐
PFJ Crepitus: Yes ☐ No ☐
Knee Alignment: Normal ☐ Valgus ☐ Varus ☐
Joint Line tenderness: Medial ☐ Lateral ☐ Details:__________________
McMurray's: Positive ☐ Negative ☐ Details:__________________

<u>Performance Assessment:</u>
AROM: Left_________ Right________

Biodex Scores: (see Biodex print out attached)

<u>Hop tests:</u>
Single Leg Hop for distance: (measured in cm)
Left_________ Right________
Left_________ Right________
Left_________ Right________
LSI: ______ ______ ______/______ ______

6m Speed Hop: (measured in seconds)

Left_________ Right________

Left_________ Right________

Left_________ Right________

LSI: ______ ______ ______/______ ______

Triple Hop for distance: (measured in cm)

Left_________ Right________

Left_________ Right________

Left_________ Right________

LSI: ______ ______ ______/______ ______

<u>Session Summary:</u>

PAR-Q collected: Yes ☐ No ☐

10minute Warm-up (cycle) performed: Yes ☐ No ☐

Stretching advice given at end of session: Yes ☐ No ☐

Appendix 12: TRIMS Arthroscopy Form

ST. JAMES'S HOSPITAL

THE ADELAIDE & MEATH HOSPITAL, DUBLIN
INCORPORATING THE NATIONAL CHILDREN'S HOSPITAL

Trinity College Dublin
The University of Dublin

SDU
UNIVERSITY OF SOUTHERN DENMARK

Trinity Meniscus Study: TRIMS

Patient Sticker

Surgery date: ____________________

Knee Surgery Leg: Left ☐ Right ☐

Previous meniscus surgery:
None ☐ Medial ☐ Lateral ☐
Repair ☐
Resection: 0-20% ☐ 21-50% ☐ >51% ☐

Reason for meniscus surgery: Persisting pain ☐ Mechanical Symptoms ☐
Conservative Rx failure ☐
Other (Please specify) ☐ ________________________________

Combined Surgery: Nil ☐ ACLR ☐ PCLR ☐ Other ☐ ____________________
Knee Joint stability at surgery: No laxity ☐ Light-slight laxity ☐ Pronounced laxity ☐

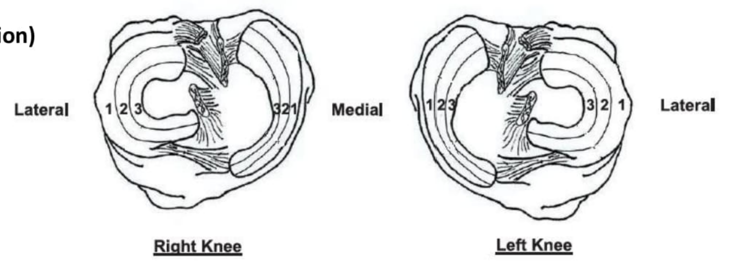
Meniscus Tear Location:
☐ Medial
☐ Lateral
☐ No Tear

Meniscus Tear Depth:
☐ Partial
☐ Complete

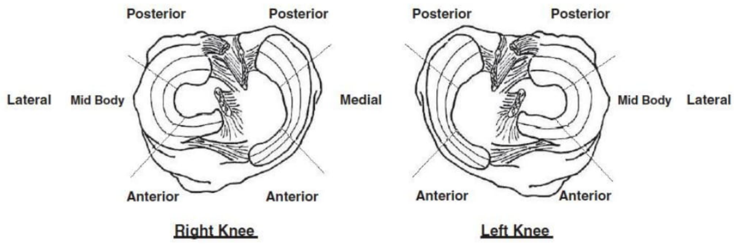
Ligamentous Injury:

ACL	☐ No Tear	☐ Partial Tear	☐ Rupture
PCL	☐ No Tear	☐ Partial Tear	☐ Rupture
MCL	☐ No Tear	☐ Partial Tear	☐ Rupture
LCL	☐ No Tear	☐ Partial Tear	☐ Rupture

Rim width (circumferential location)
☐ Zone1
☐ Zone 2
☐ Zone 3



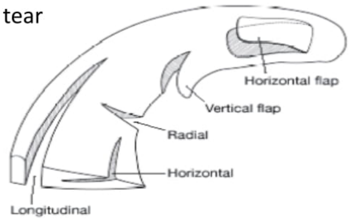
Radial location
☐ Posterior
☐ Mid Body
☐ Anterior



Central to the popliteal hiatus? Yes ☐ No ☐
Degree of Synovitis: Mild ☐ Moderate ☐ Severe ☐

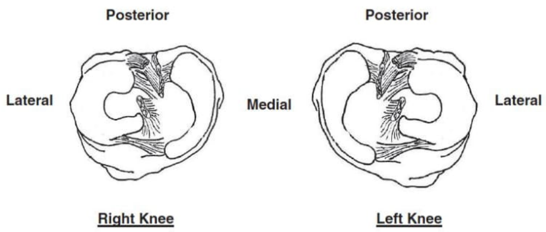
Tear Pattern:

- ☐ Longitudinal - vertical: extension is a bucket handle tear
- ☐ Horizontal
- ☐ Radial
- ☐ Vertical flap
- ☐ Horizontal Flap
- ☐ Complex
- ☐ Root Tear (not shown)



Quality of tissue: Non-degenerative ☐ Degenerative ☐ Undetermined ☐
Length of tear: _____ mm

Indicate the amount of meniscus that was excised by drawing on the diagram and crosshatching the part that was removed.



What Percentage of the meniscus was excised?
Medial: 0-20%☐ 21-50%☐ >51%☐
Lateral: 0-20%☐ 21-50%☐ >51%☐

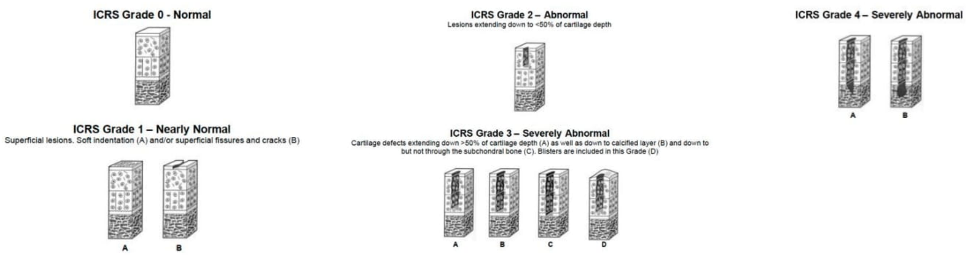
Meniscal Repair Reporting **(Not Applicable ☐)**

Type of Surgery: Rasping ☐ Suture ☐ Arrow ☐ Anchor & Suture ☐
Surgical Technique: All Inside ☐ Inside-Out ☐ Outside-In ☐
Number of sutures/stiches: _______
Company and device name: _________________________
Placement of repair: Use drawing above

Grading of Cartilage Deficits (ICRS)

Cartilage defects are evaluated separately for the medial and lateral compartment of the knee. Please indicate grade (0-4) according to the worst area in each compartment (see figures).

Medial Compartment:	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
Lateral Compartment:	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐
Patellofemoral Compartment:	0 ☐	1 ☐	2 ☐	3 ☐	4 ☐



Treatment of Cartilage Defects: No Treatment ☐ Debridement ☐ Chondroplasty ☐ Microfracture ☐

Plica Present: Yes ☐ No ☐
Plica Removed: Yes ☐ No ☐

Appendix 13: TRIMS Physical Activity Form.

ST. JAMES'S HOSPITAL

THE ADELAIDE & MEATH HOSPITAL, DUBLIN INCORPORATING THE NATIONAL CHILDREN'S HOSPITAL

Trinity College Dublin
The University of Dublin

SDU
UNIVERSITY OF SOUTHERN DENMARK

Participant ID:	Date of Assessment:

TEGNER ACTIVITY LEVEL SCALE

Please indicate in the spaces below the HIGHEST level of activity that you participated in BEFORE YOUR INJURY and the highest level you are able to participate in CURRENTLY.

BEFORE INJURY: Level___________

CURRENT: Level___________

See scale below

Level 10	**Competitive sports- soccer, football, rugby (national elite)**
Level 9	**Competitive sports- soccer, football, rugby (lower divisions), ice hockey, wrestling, gymnastics, basketball**
Level 8	**Competitive sports- racquetball or bandy, squash or badminton, track and field athletics (jumping, etc.), down-hill skiing**
Level 7	**Competitive sports- tennis, running, motorcars speedway, handball** **Recreational sports- soccer, football, rugby, bandy, ice hockey, basketball, squash, racquetball, running**
Level 6	**Recreational sports- tennis and badminton, handball, racquetball, down-hill skiing, jogging at least 5 times per week**
Level 5	**Work- heavy labor (construction, etc.)** **Competitive sports- cycling, cross-country skiing,** **Recreational sports- jogging on uneven ground at least twice weekly**
Level 4	**Work- moderately heavy labor (e.g. truck driving, etc.)**
Level 3	**Work- light labor (nursing, etc.)**
Level 2	**Work- light labor** **Walking on uneven ground possible, but impossible to back pack or hike**
Level 1	**Work- sedentary (secretarial, etc.)**
Level 0	**Sick leave or disability pension because of knee problems**

Single Item Physical Activity Measure:

In the past week, on how many days have you done a total of 30 min or more of physical activity, which was enough to raise your breathing rate?
This may include sport, exercise, and brisk walking or cycling for recreation or to get to and from places, but should not include housework or physical activity that may be part of your job

1 2 3 4 5 6 7 (circle number of days in the past week)

Appendix 14 KOOS questionnaire

KOOS KNEE SURVEY

Today's date: ____/_____/_____ Date of birth: ____/_____/_____

Name: ____

INSTRUCTIONS: This survey asks for your view about your knee. This information will help us keep track of how you feel about your knee and how well you are able to perform your usual activities.
Answer every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can.

Symptoms
These questions should be answered thinking of your knee symptoms during the **last week**.

S1. Do you have swelling in your knee?

Never	Rarely	Sometimes	Often	Always
□	□	□	□	□

S2. Do you feel grinding, hear clicking or any other type of noise when your knee moves?

Never	Rarely	Sometimes	Often	Always
□	□	□	□	□

S3. Does your knee catch or hang up when moving?

Never	Rarely	Sometimes	Often	Always
□	□	□	□	□

S4. Can you straighten your knee fully?

Always	Often	Sometimes	Rarely	Never
□	□	□	□	□

S5. Can you bend your knee fully?

Always	Often	Sometimes	Rarely	Never
□	□	□	□	□

Stiffness
The following questions concern the amount of joint stiffness you have experienced during the **last week** in your knee. Stiffness is a sensation of restriction or slowness in the ease with which you move your knee joint.

S6. How severe is your knee joint stiffness after first wakening in the morning?

None	Mild	Moderate	Severe	Extreme
□	□	□	□	□

S7. How severe is your knee stiffness after sitting, lying or resting **later in the day**?

None	Mild	Moderate	Severe	Extreme
□	□	□	□	□

Pain

P1. How often do you experience knee pain?

Never	Monthly	Weekly	Daily	Always
☐	☐	☐	☐	☐

What amount of knee pain have you experienced the **last week** during the following activities?

P2. Twisting/pivoting on your knee

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P3. Straightening knee fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P4. Bending knee fully

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P5. Walking on flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P6. Going up or down stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P7. At night while in bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P8. Sitting or lying

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

P9. Standing upright

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, daily living

The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A1. Descending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A2. Ascending stairs

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A3. Rising from sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A4. Standing

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A5. Bending to floor/pick up an object

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A6. Walking on flat surface

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A7. Getting in/out of car

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A8. Going shopping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A9. Putting on socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A10. Rising from bed

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A11. Taking off socks/stockings

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A12. Lying in bed (turning over, maintaining knee position)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A13. Getting in/out of bath

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A14. Sitting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A15. Getting on/off toilet

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

For each of the following activities please indicate the degree of difficulty you have experienced in the **last week** due to your knee.

A16. Heavy domestic duties (moving heavy boxes, scrubbing floors, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

A17. Light domestic duties (cooking, dusting, etc)

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Function, sports and recreational activities

The following questions concern your physical function when being active on a higher level. The questions should be answered thinking of what degree of difficulty you have experienced during the **last week** due to your knee.

SP1. Squatting

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP2. Running

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP3. Jumping

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP4. Twisting/pivoting on your injured knee

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

SP5. Kneeling

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Quality of Life

Q1. How often are you aware of your knee problem?

Never	Monthly	Weekly	Daily	Constantly
☐	☐	☐	☐	☐

Q2. Have you modified your life style to avoid potentially damaging activities to your knee?

Not at all	Mildly	Moderately	Severely	Totally
☐	☐	☐	☐	☐

Q3. How much are you troubled with lack of confidence in your knee?

Not at all	Mildly	Moderately	Severely	Extremely
☐	☐	☐	☐	☐

Q4. In general, how much difficulty do you have with your knee?

None	Mild	Moderate	Severe	Extreme
☐	☐	☐	☐	☐

Thank you very much for completing all the questions in this questionnaire.

Appendix 15 IKDC Subj questionnaire

IKDC Subjective Knee Evaluation

SYMPTOMS*:
*Grade symptoms at the highest activity level at which you think you could function without significant symptoms, even if you are not actually performing activities at this level.

1. What is the highest level of activity that you can perform without significant knee pain?
   - 4❑ Very strenuous activities like jumping or pivoting as in gymnastics or football
   - 3❑ Strenuous activities like heavy physical work, skiing or tennis
   - 2❑ Moderate activities like moderate physical work, running or jogging
   - 1❑ Light activities like walking, housework or gardening
   - 0❑ Unable to perform any of the above activities due to knee pain

2. During the past 4 weeks, or since your injury, how often have you had pain?

	0	1	2	3	4	5	6	7	8	9	10	
Never	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Constant

3. If you have pain, how severe is it?

	0	1	2	3	4	5	6	7	8	9	10	
No pain	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	Worst pain imaginable

4. During the past 4 weeks, or since your injury, how stiff or swollen has your knee been?
   - 4❑ Not at all
   - 3❑ Mildly
   - 2❑ Moderately
   - 1❑ Very
   - 0❑ Extremely

5. What is the highest level of activity you can perform without significant swelling in your knee?
   - 4❑ Very strenuous activities like jumping or pivoting as in gymnastics or football
   - 3❑ Strenuous activities like heavy physical work, skiing or tennis
   - 2❑ Moderate activities like moderate physical work, running or jogging
   - 1❑ Light activities like walking, housework or gardening
   - 0❑ Unable to perform any of the above activities due to knee swelling

6. During the past 4 weeks, or since your injury, has your knee locked or caught?

   0❑Yes 1❑No

7. What is the highest level of activity you can perform without significant giving way in your knee?
   - 4❑ Very strenuous activities like jumping or pivoting as in gymnastics or football
   - 3❑ Strenuous activities like heavy physical work, skiing or tennis
   - 2❑ Moderate activities like moderate physical work, running or jogging
   - 1❑ Light activities like walking, housework or gardening
   - 0❑ Unable to perform any of the above activities due to giving way of the knee

SPORT ACTIVITIES:

8. What is the highest level of activity you can participate in on a regular basis?

- 4❑ Very strenuous activities like jumping or pivoting as in gymnastics or football
- 3❑ Strenuous activities like heavy physical work, skiing or tennis
- 2❑ Moderate activities like moderate physical work, running or jogging
- 1❑ Light activities like walking, housework or gardening
- 0❑ Unable to perform any of the above activities due to knee

9. How does your knee affect your ability to:

		Not difficult at all	Minimally difficult	Moderately Difficult	Extremely difficult	Unable to do
a.	Go up stairs	4❑	3❑	2❑	1❑	0❑
b.	Go down stairs	4❑	3❑	2❑	1❑	0❑
c.	Kneel on the front of your knee	4❑	3❑	2❑	1❑	0❑
d.	Squat	4❑	3❑	2❑	1❑	0❑
e.	Sit with your knee bent	4❑	3❑	2❑	1❑	0❑
f.	Rise from a chair	4❑	3❑	2❑	1❑	0❑
g.	Run straight ahead	4❑	3❑	2❑	1❑	0❑
h.	Jump and land on your involved leg	4❑	3❑	2❑	1❑	0❑
i.	Stop and start quickly	4❑	3❑	2❑	1❑	0❑

FUNCTION:

10. How would you rate the function of your knee on a scale of 0 to 10 with 10 being normal, excellent function and 0 being the inability to perform any of your usual daily activities which may include sport?

FUNCTION PRIOR TO YOUR KNEE INJURY:

Couldn't perform daily activities	0	1	2	3	4	5	6	7	8	9	10	No limitation in daily activities
	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	

CURRENT FUNCTION OF YOUR KNEE:

Cannot perform daily activities	0	1	2	3	4	5	6	7	8	9	10	No limitation in daily activities
	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	❑	

Appendix 16: Ethical Approval letter TRIMS

THIS NOTEPAPER MUST NOT BE USED FOR PRESCRIPTIONS OR INVOICING PURPOSES

SJH/AMNCH Research Ethics Committee Secretariat
Claire Hartin Ph: 4142199
email: claire.hartin@amnch.ie

THE ADELAIDE & MEATH HOSPITAL, DUBLIN
INCORPORATING
THE NATIONAL CHILDREN'S HOSPITAL

TALLAGHT, DUBLIN 24, IRELAND
TELEPHONE +353 1 4142000

Mr. Nathan Cardy
Physiotherapist
Department of Physiotherapy
Trinity Centre for Health Sciences
St. James's Hospital
Dublin 8

6th July 2016

Re: Trinity Meniscus Study: TRIMS

REC Reference: 2016-07 Chairman's Action (12)
(Please quote reference on all correspondence)

Dear Mr. Cardy,

Thank you for your recent application to SJH/AMNCH Research Ethics Committee in which you requested ethical approval for the above named study.

The Chairman, Dr. Peter Lavin, on behalf of the Research Ethics Committee, has reviewed your correspondence and grants ethical approval.

Yours sincerely,

Claire Hartin
Secretary
SJH/AMNCH Research Ethics Committee

The SJH/AMNCH Joint Research and Ethics Committee operates in compliance with and is constituted in accordance with the European Communities (Clinical Trials on Medicinal Products for Human Use) Regulations 2004 & ICH GCP guidelines.

NSV Code: WPA 00486

Appendix 17: Amendment to Ethical Approval TRIMS

THIS NOTEPAPER MUST NOT BE USED FOR PRESCRIPTIONS OR INVOICING PURPOSES

THE ADELAIDE & MEATH HOSPITAL, DUBLIN
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SJH/AMNCH Research Ethics Committee Secretariat
Claire Hartin Ph: 4142199
email: claire.hartin@amnch.ie

Mr. Nathan Cardy
Senior Sports Physiotherapist
Trinity College
Dublin 2

28th February 2017

Re: TRIMS Trinity Meniscus Study

REC Reference: 2016/09/04/ 2017-02 List 5 (18)
(Please quote reference on all correspondence)

Dear Mr. Cardy,

Thank you for your recent correspondence to SJH/AMNCH Research Ethics Committee in which you requested an amendment in relation to the above referenced study.

The Chairman, Dr. Peter Lavin, on behalf of the Research Ethics Committee, has reviewed this request and grants permission for this amendment.

Yours sincerely,

Claire Hartin
Secretary
SJH/AMNCH Research Ethics Committee

The SJH/AMNCH Joint Research and Ethics Committee operates in compliance with and is constituted in accordance with the European Communities (Clinical Trials on Medicinal Products for Human Use) Regulations 2004 & ICH GCP guidelines.

NSV Code: WPA 00486

Appendix 18: HSS Knee Surgery Expectation Survey

HOSPITAL FOR SPECIAL SURGERY
KNEE SURGERY EXPECTATIONS SURVEY

Please circle the number that best describes your response to each question.

How much relief or improvement do you expect in the following areas as a result of your knee surgery?

	Back to normal or complete improvement	Not back to normal, but… a lot of improvement	a moderate amount of improvement	a little improvement	I do not have this expectation, or this expectation does not apply to me
Relief of pain	1	2	3	4	5
Improve ability to walk * short distance (indoor, 1 block)	1	2	3	4	5
* medium distance (take a walk, up to 1 mile)	1	2	3	4	5
* long distance (more than 1 mile)	1	2	3	4	5
Increase knee stability	1	2	3	4	5
Increase knee mobility	1	2	3	4	5
Improve ability to go up and down stairs	1	2	3	4	5
Improve ability to squat	1	2	3	4	5
Improve ability to kneel	1	2	3	4	5
Stop knee from catching or buckling	1	2	3	4	5
Stop knee from giving way when coming to a quick stop while running	1	2	3	4	5
Stop knee stiffness or swelling	1	2	3	4	5
Be employed for monetary reimbursement	1	2	3	4	5
Improve ability to run (for example, across the street, to catch the bus)	1	2	3	4	5
Improve ability to perform daily activities (for example, daily routine, household chores)	1	2	3	4	5
Improve ability to exercise or participate in recreational sports	1	2	3	4	5
Improve ability to participate in professional sports	1	2	3	4	5
Have confidence in knee	1	2	3	4	5
Avoid future degeneration of knee	1	2	3	4	5
Improve ability to maintain general health	1	2	3	4	5
Improve ability to interact with others (for example, take care of someone, play with children)	1	2	3	4	5
Improve psychological well-being	1	2	3	4	5
For knee to be back to the way it was before this problem started	1	2	3	4	5

Appendix 19: HSS Knee Surgery Expectation Survey: Clinician Version

HOSPITAL FOR SPECIAL SURGERY
KNEE SURGERY EXPECTATIONS SURVEY

Physician Response Version

Please circle the number that best describes your response to each question.

How much relief or improvement do you expect your patient will have in the following areas as a result of this knee surgery?

		Not back to normal, but…			
	Back to normal or complete improvement	a lot of improvement	a moderate amount of improvement	a little improvement	I do not have this expectation, or this expectation does not apply
Relief of pain	1	2	3	4	5
Improve ability to walk					
* short distance (indoor, 1 block)	1	2	3	4	5
* medium distance (take a walk, up to 1 mile)	1	2	3	4	5
* long distance (more than 1 mile)	1	2	3	4	5
Increase knee stability	1	2	3	4	5
Increase knee mobility	1	2	3	4	5
Improve ability to go up and down stairs	1	2	3	4	5
Improve ability to squat	1	2	3	4	5
Improve ability to kneel	1	2	3	4	5
Stop knee from catching or buckling	1	2	3	4	5
Stop knee from giving way when coming to a quick stop while running	1	2	3	4	5
Stop knee stiffness or swelling	1	2	3	4	5
Be employed for monetary reimbursement	1	2	3	4	5
Improve ability to run (for example, across the street, to catch the bus)	1	2	3	4	5
Improve ability to perform daily activities (for example, daily routine, household chores)	1	2	3	4	5
Improve ability to exercise or participate in recreational sports	1	2	3	4	5
Improve ability to participate in professional sports	1	2	3	4	5
Have confidence in knee	1	2	3	4	5
Avoid future degeneration of knee	1	2	3	4	5
Improve ability to maintain general health	1	2	3	4	5
Improve ability to interact with others (for example, take care of someone, play with children)	1	2	3	4	5
Improve psychological well-being	1	2	3	4	5
For knee to be back to the way it was before this problem started	1	2	3	4	5

Appendix 20: HSS Knee Surgery Expectation Survey: Scoring Instructions

HOSPITAL FOR SPECIAL SURGERY
KNEE SURGERY EXPECTATIONS SURVEY

Scoring

Thank you for your interest in the Hospital for Special Surgery Knee Surgery Expectations Survey.

The scoring for the survey is as follows:

1. Record responses in reverse order so that:
    - 4 = back to normal or complete improvement
    - 3 = a lot of improvement
    - 2 = a moderate amount of improvement
    - 1 = a little improvement
    - 0 = I do not have this expectation, or this expectation does not apply to me

2. Sum all responses.

The summed raw score ranges from 0 to 92.

3. Transform the score to range from 0 to 100.

Transformed score = (raw score / 92) x 100.

4. Report the transformed score.

Higher score indicates expecting more improvement for more items.

Please cite the following when referring to the Hospital for Special Surgery Knee Surgery Expectations Survey.

Mancuso CA, Sculco TP, Wickiewicz TL, Jones EC, Robbins L, Warren RF, Williams-Russo P. Patients' expectations of knee surgery. J Bone Joint Surg 2001;83-A:1005-1012.

Appendix 21: Reasons for Surgery: Coding of Patient Responses

Reason for surgery (patient)		
Persisting Pain	Mechanical Symptoms	Conservative Rx failure
pain in joint	pain and swelling in right knee, frequently 'gives'	physio did not relieve pain
To improve soreness and movement	Stop dislocations and pain	
out of pain	swelling and locking of joint	
pain in knee		
pain and swelling in right knee, frequently 'gives'		
pain relief		
Remove Pain in Knee		
Pain / Having a normal working knee		
Pain		
Stop dislocations and pain		
pain relief and being able to walk		
for some relief from pain		
hoping to reduce pain and continue walking		
The constant pain and hurt		
remove pain and free up knee (back to normal)		

Reason for surgery (patient)		
Functional / Personal Goal	Anatomical Diagnosis	Other
Betterment	meniscus injury	exploritory
Make more comfortable day to day life	meniscus tear and ACL damage	
Pain / Having a normal working knee	tear meniscus	
Feel better	Tear of the meniscus. Scop.Bakers Cyst	
Unable to walk properly	lump/swelling on top pf knee as a result of fall	
To be able to train / run - marathon training	removal of loose cartilage pieces	
to regain mobility	cartilage tear	
pain relief and being able to walk	Torn ACL cartilage problem	
to see if I can improve how I walk up and down stairs and generally	damaged cartilage / ligament	
want to continue playing sport	Osteochondral repair (cartilage repair also)	
to improve life quality walking	tear in meniscus	
walking, tennis	my tear is causing problems	
sort problems within knee	pinching and cartilage not stable	
	to correct meniscus tear	

Appendix 22: Publication Systematic Review 1

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Review

Trajectory of self-reported pain and function and knee extensor muscle strength in young patients undergoing arthroscopic surgery for meniscal tears: A systematic review and meta-analysis

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ABSTRACT

Objectives: To investigate the trajectory of patient reported pain and function and knee extensor muscle strength over time in young individuals undergoing arthroscopic meniscal surgery.
Design: Systematic review and meta-analysis
Methods: Six databases were searched up to October 13th, 2016. Patients and intervention: People aged 30 years or younger undergoing surgery for a meniscal tear. Outcomes: and comparator: (1) Self-reported pain and function in patients undergoing meniscal surgery compared to a non-operative control group (2). Knee extensor strength in the leg undergoing surgery compared to a healthy control group or the contra-lateral leg. Methodological quality was assessed using the SIGN 50 guidelines.
Results: No studies were found on patient reported pain and function. Six studies, including 137 patients were included in the analysis on knee extensor muscle strength. Knee extensor muscle strength was impaired in the injured leg prior to surgery and was still reduced compared with control data up to 12 months after surgery (SMD: −1.16) (95% CI: −1.83; −0.49). All included studies were assessed to have a high risk of bias.
Conclusions: No studies were found comparing the trajectory of self-reported pain and function in patients undergoing arthroscopic surgery compared with non-operative treatments for young patients with meniscal tears. Knee extensor strength seemed to be impaired up to 12 months after surgery in young patients undergoing surgery for meniscal tears. The results of the present study should be interpreted with caution due to a limited number of available studies with high risk of bias including relatively few patients.

1. Introduction

Recent systematic reviews and meta-analysis have reported no better effect of arthroscopic partial meniscectomy on patient reported pain and function compared to placebo or in addition to exercise for middle-aged and older individuals with degenerative meniscal tears.[1,2] In addition, these patients show impaired knee extensor muscle strength up to 4 years after arthroscopic partial meniscectomy.[3]

In contrast to degenerative meniscal tears, traumatic tears typically occur in younger adults as a result of an acute injury.[4] However, knowledge about the trajectory of self-reported pain and function in young patients with meniscal tears as well as the recovery of muscle strength after surgery is not well understood. This is largely due to most previous studies including mixed cohorts of young and old patients as well as poor recording of symptom onset. Furthermore, no randomized trials exist that have investigated the effect of surgery in comparison to non-surgical treatment alternatives for young patients with meniscal tears.[2]

Patient-reported outcomes are generally considered most appropriate to assess the patient's perspective of their own health status. However, recovery of muscle strength is also considered to be important for young individuals in order to regain capacity

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to participate in sports or other activities as both pre- and post-operative knee extensor strength have been reported to predict better functional outcome of knee surgery.[5,6]

Thus, the aim of this study was to conduct a systematic review and meta-analysis to investigate the trajectory of patient reported pain and function and knee extensor muscle strength over time in young individuals undergoing arthroscopic meniscal surgery.

2. Methods

This systematic review and meta-analysis was performed according to the recommendations in The Cochrane Handbook for Systematic Reviews of Interventions,[7] and the findings were reported according to the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) guidelines.[8] The study protocol was registered in PROSPERO (http://www.crd.york.ac.uk, ID: CRD # 42015019815).

Search Strategy: Electronic searches were performed in MEDLINE via PubMed, SPORTDiscus via EBSCO, CINAHL via EBSCO, EMBASE via Ovid, Cochrane Central Register of Controlled Trials (CENTRAL) and Web of Science up to November 2nd 2015 and updated on October 13th 2016 by one of the authors (CBJ). A manual search of reference list from relevant articles was also conducted. Key search terms were searched as keywords and text words in title and abstracts to create two separate filters; which were then combined. These filters were: (i) Population: 'meniscus'; 'arthroscopic surgery' (ii) Outcome: 'muscle strength'; 'function' and 'pain'. The complete search strategy is presented in detail in Supplementary appendix. No restriction on language or year of publication was applied.

Eligibility Criteria: Studies of any design, were included if they met the following criteria:

Population and intervention: young adults (in this study defined as a mean age of the included participants between 18 and 30 years) undergoing arthroscopic surgery (i.e. repair or partial resection) for a meniscal tear.

Outcomes: (1) Self-reported pain and/or function reported on a separate subscale (i.e. not aggregate score) or (2) Muscle strength: isometric or isokinetic knee extensor muscle strength measured in the leg undergoing surgery.

Comparator: (1) Self-reported pain and/or function in a non-operative control group (or healthy controls). (2) isometric or isokinetic knee extensor muscle strength assessed in either a healthy control group or in the contralateral leg of the meniscal patient.

We only included full text studies published as original articles.

Selection of studies: Following omission of duplicates from the initial search, two authors (LØ and CJ) independently screened the articles by title and abstract to exclude irrelevant studies. Full-text of all articles considered relevant by either of the two reviewers, was obtained and screened for eligibility by both reviewers.

Data Extraction: To describe the time course of self-reported pain and function and muscle strength deficits the following seven time points were decided a priori for data extraction: pre-surgery; 1 week post-surgery, 3–4 weeks post-surgery, 12 weeks post-surgery, 6 month post-surgery, 24 months post-surgery and 48 months post-surgery. Data extraction was performed independently by two authors (NC and FW) on published data only. The following information was extracted: authors; publication year; number of participants in surgery group and control group (if applicable); gender; age; technique used to measure strength; outcome measure used for assessing pain and function, mean and standard deviation of the pain scores, function scores and the assessment of knee extensor muscle strength, and time point for measurement. Predefined hierarchies were used to extract data from studies that had used more than one approach to assess patient reported outcomes and muscle strength. The hierarchy for selection of pain and function has previously been published.[9] The hierarchy for knee extensor muscle strength comparison was: (1) healthy controls, and (2) contralateral leg. The hierarchy for technique used to assess knee extensor muscle strength was: (1) isometric strength, (2) isokinetic strength at 60°/s, (3) isokinetic strength at 30°/s, (4) isokinetic strength at 120°/s, (5) isokinetic strength at 180°/s and (6) isokinetic strength at 240°/s. For isokinetic strength, concentric strength scores were extracted in the case where eccentric scores were also available.

Data synthesis: Effects were calculated as the standardized mean difference (SMD) to allow pooling of the various outcomes assessed in individual studies. The SMD was estimated as the difference between the surgical leg and the contra-lateral and/or healthy control leg divided by the pooled standard deviation. Standard deviations were extracted or estimated from standard errors, p-value, 95% confidence intervals, or extracted from figures when numbers were not available. In case of lacking or incomplete data, attempts to contact authors were made.

A meta-analysis was applied on the SMD of pain, function and knee extensor muscle strength. Random effect models were used as large heterogeneity was expected due to the different approaches used to compare (i.e. controls or contralateral leg) and assess knee extensor muscle strength (i.e. isometric or isokinetic) as well as different pain and function scores. A standard Q-test was used to test the heterogeneity between studies,[10] and the I^2 statistic measuring the proportion of variance attributable to inconsistency was subsequently calculated.[11,12] An I^2 equal to 0% indicate minimal inconsistency and an I^2 equal to 100% indicate maximal inconsistency between individual study results. Furthermore the Tau^2 value expressing the between study variance was estimated. Covariates are defined as variables able to reduce the Tau-squared value when included in the analysis.

SMD Interpretation: A SMD of 0.2 was considered small, 0.5 moderate and greater than 0.8 was considered large.[13] Although, the SMD permits inclusion of studies using various approaches to assess strength, the SMD is not easily interpreted. Therefore, to improve interpretability and approximate the overall SMD values for knee extensor weakness, we applied an algorithm using previously described methods to convert SMD values to percentage differences.[14] This conversion was based on descriptive knee extensor strength data obtained from 3 studies on a total of 74 young healthy controls (20–30 years of age) (Supplementary Fig. 1).[15–17]

Risk of Bias Assessment: Two reviewers (JBT and CBJ) independently assessed study quality with regard to risk of bias based on guidelines from the Scottish Intercollegiate Guidelines Network (SIGN50).[18] Prior to assessing the risk of bias of the studies, two authors (JBT and CBJ) set guidelines for scoring each of the criteria in the checklist as detailed in Supplementary Table 2. Each of the criteria listed in Supplementary Table 2 was scored 'Adequate', 'Unclear' or 'Inadequate'. Disagreement was solved by discussion. As described in SIGN50[18], the overall risk of bias was judged as 'low' if the majority of the criteria were appropriately met, moderate if most criteria were met (i.e. some flaws in the study associated with risk of bias), overall risk of bias was judged as high if most criteria were not met or significant flaws relating to key aspects of the study design was not met (i.e. for this study validity and reliability of outcome assessment and blinding of outcome assessors was considered key aspects).

3. Results

Our search strategy identified 10,604 articles after exclusion of duplicate records (Fig. 1). No studies fulfilled the eligibility crite-

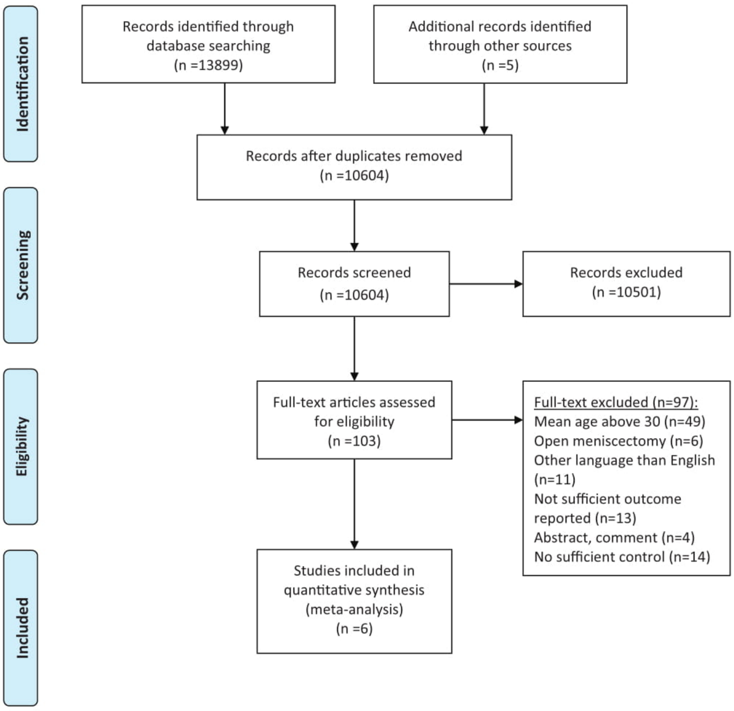

Fig. 1. Flow chart of the search and final inclusion of studies.

Table 1
Characteristics of included studies.

Author and Year	Study-design	Group age at baseline, mean ± SD	Number of participants, n (%, male)	Comparator	Strength assessment	Units	Time points
deSouza et al.[19]	Observational	APM 29 years	26 (85%)	Contralateral leg	Isometric	Nm	PRE surgery
Eller et al.[20]	Observational	APM 24 years	13 (61%)	Contralateral leg	Isometric	N	6 mths post-APM
Gapeyeva et al.[21]	Observational	APM 26 ± 9 years	21 (100%)	Contralateral leg	Concentric at 60°/sec	Nm	2–4 wks post-APM 3 mths post-APM 6 mths post-APM
Gapeyeva et al.[22]	Observational	APM 26 ± 9 years	14 (100%)	Contralateral leg	Isometric	N	PRE surgery 2–4 wks post-APM 3 mths post-APM 6 mths post-APM
Ford et al.[24]	Observational	APM 20 ± 3 years Controls 20 ± 3 years	9 (78%) 9 (78%)	Healthy control leg	Concentric at 60°/sec	Nm/kg	3 mths post-APM
Huber et al.[23]	Observational	APM 26 ± 5 years Repair 23 ± 9 years Controls 25 ± 4 years	15 (40%) 15 (53%) 15 (Not available)	Healthy control leg	Isometric	Nm	12 mths post-APM

APM = arthroscopic partial meniscectomy.

ria on patient reported pain and function. Six studies fulfilled the eligibility criteria for inclusion in the analysis on trajectory of knee extensor muscle strength.[19–24]

Studies included 137 participants who were predominately male, with the mean age in individual studies ranging from 20 to 29 years (Table 1). Only one study included patients that underwent meniscal repair,[23] the remaining studies included only patients undergoing arthroscopic partial meniscectomy.[19–22] Between 35 and 53 patients were assessed at each time point and no studies assessed knee extensor strength after 12 months. In 4 studies the contra-lateral leg was used a the comparator and in 2 studies healthy controls acted a the comparator (Table 1).

Knee extensor muscle strength seemed to be impaired up to 12 months after meniscal surgery (Fig. 2 and supplementary Table 1 for specific estimates). At 12 months legs undergoing meniscal surgery were around 25% weaker compared with control legs (SMD: −1.16; 95% CI: −1.83, −0.49 – for conversion of SMD to % see supplementary Fig. 1). Sensitivity analyses excluding patients with meniscal repair (n = 15) at the 12 months time point demonstrated similar

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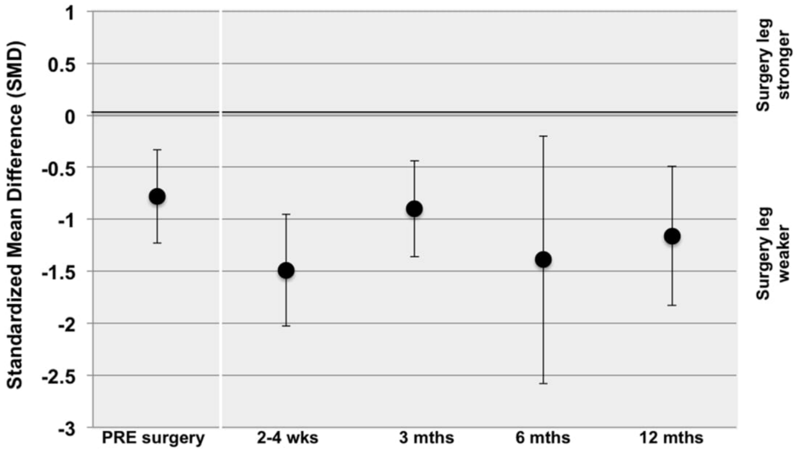

	PRE surgery	2-4 wks	3 mths	6 mths	12 mths
No. of studies	2	2	3	3	1
Patients (n)	40	35	53	48	45
I^2 (%)	0	0	7	84	-
p-value (I^2)	0.63	0.34	0.34	0.002	-

Fig. 2. Standardized mean difference (SMD) with 95% confidence intervals in knee extensor muscle strength between individuals undergoing meniscal surgery and controls over time. Positive values indicate that the surgery leg is stronger than controls, and negative values indicate that the surgery leg is weaker than controls. Where applicable, each time point represents an individual meta-analysis.

SMD as when these where included in the analysis (SMD: −1.31; 95% CI: −2.10, −0.51).

The overall risk of bias was judged as high across all studies, as several items in the SIGN 50 was not appropriately met (Supplementary Table 2). Especially, none of the included studies reported any effort in blinding the outcome assessors and the validity and reliability of the outcome measurements were not stated. None of the included studies addressed that participants could have had lower muscle strength in the operated leg before surgery. Lastly, the influence of potential confounders was not addressed in any of the included studies.

4. Discussion

In this systematic review and meta-analysis we found no randomized trials comparing the trajectory of patient reported pain and function for young patients undergoing meniscal surgery compared with non-operative treatment. Nor did we find studies comparing the trajectory of pain and function after surgery to a healthy control group. We included 6 studies in the analysis on the trajectory of knee extensor muscle strength over time compared to healthy controls or the contra-lateral leg of the included patients. Impaired muscle strength was observed up to 12 months after meniscal surgery. However, given the risk of bias assessment, the observational nature and the limited amount of patients in the included studies the certainty of estimates should be interpreted with caution.

In the present study we aimed to include young individuals with traumatic meniscal tears, as most previous systematic reviews have focused on assessing pain, function and knee extensor strength in middle-aged and older patients with degenerative meniscal tears.[1–3,25] As recently reported,[2] no randomized trials comparing arthroscopic surgery to non-operative treatments were found for young adults. Such trials are critically needed to assess the effectiveness of surgery compared with non-operative treatments for young patients with meniscal tears. As lack of randomized trials was anticipated we also allowed for non-randomized comparative studies including either a non-operative comparative group or a healthy control group to assess the trajectory of patient reported pain and function. However, no such studies were found. Furthermore, most studies that included some form of patient reported outcome used the Lysholm score, but none of the studies included a control group for comparison. A priori we had decided to include only studies that presented separate patient reported outcomes of pain and function. Several knee scores exist that use composite scores of 'knee function', and arbitrarily aggregate and differently weighted items assessing sometimes related, but commonly distinctly different, constructs such as swelling, instability, and ability to walk one block into one overall score. It is generally accepted that distinct outcomes should be reported separately at the different levels according to the World Health Organization (WHO) International Classification of Functioning. According to this classification, pain belongs to the "Body function and structure" and physical function to the "Activity" level.[26]

Our analyses suggest that reduced knee extensor muscle strength is present in young patients with meniscal tears before surgery and seem to increase within the first 2–4 weeks after surgery. This is likely caused by an inevitable surgery induced trauma. It is unclear why reduced knee extensor strength is present before surgery, and why it persists up to 12 month following surgery. Possible explanations may be reduced physical activity or muscle atrophy and/or arthrogenic muscle inhibition, which have been suggested to be caused by injury and/or surgery and thought to affect knee extensor muscle function for extended periods of time.[27] Knee extensor muscle strength impairment seemed to be impaired up to 12 months after surgery. Patients in all included

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studies[19–23] received some form of post-operative rehabilitation. These rehabilitation protocols may have been of too poor quality (i.e. low intensity and/or frequency, lack of progression, etc.) to elicit improvements in muscle strength. Specifics of rehabilitation protocols were not well described thus no firm conclusions can be drawn on this. Nevertheless, a recent systematic review did not find any difference in effect of rehabilitation after meniscal surgery, regardless of rehabilitation type (though the included patients were somewhat older than in the present study).[25]

A recent study on knee extensor strength in middle-aged and older patients with degenerative tears found that knee extensor strength was impaired up to 48 months after arthroscopic partial meniscectomy.[3] From the available data it is unknown how the trajectory of knee extensor muscle strength proceeds after 12 months in young patients with meniscal tears. Nevertheless, 25% lower knee extensor strength in the surgery leg 12 months post surgery is considered clinically relevant as return to sport criteria for patients with knee injuries such as anterior cruciate ligament injury is often considered to be less than 10% strength difference between legs.[28]

The 6 studies included in this review were all considered to have a high risk of bias, as none of the studies scored 'adequate' on all applicable criteria. The main methodological considerations that influence the quality of the studies in the current review relate to all studies failing to blind the outcome assessor to which leg had the meniscal tear. Furthermore, no studies tried to handle the potential influence of any confounders, such as sex in their analysis. Another consideration relates to units of strength, where two studies failed to adequately report strength as Nm. We consider strength as the generation of muscle force in combination with the moment arm of the muscle. As such, strength is optimally reported as the product of the force (N) and the distance (m) from axis of rotation to where the transducer attaches to the limb.[29] Clinicians and researchers should be aware of these methodological considerations when designing future studies and interpreting strength related measures.

Limitations of this study warrant consideration. Firstly, it is important to consider that the described trajectory is a combination of data from individual studies at each time point and do not represent longitudinal data. Secondly, our findings and point estimates should be interpreted with caution due to high risk of bias (i.e. low study quality), the size of the individual studies and the small number of studies available for meta-analysis at each time point. Furthermore, only one study was available at 12 months and the SD had to be estimated for this study as we failed to get additional data from the authors. Thirdly, our aim was to primarily include young patients with traumatic meniscal tears. However, symptom onset was not reported in the included studies, thus some patients may have had non-traumatic injuries. In addition, the results of this study cannot be generalized to middle-aged and older individuals with degenerative meniscal tears. Lastly, we had to deviate from the registered study protocol on 2 accounts. We decided to adjust the age criteria from "more than 80% of study sample are older than 30 years or more than 80% of study sample are younger than 18 years" to "studies with a mean age between 18–30 years" in order to include more studies in the analysis. Thus, some studies include a smaller proportion of patients above 30 years of age. The time point "3–4 weeks" was adjusted to "2–4 weeks" to be able to include 2 studies for analyses at this time point.

5. Conclusion

No randomized trials were found comparing the trajectory of patient reported pain and function for young patients undergoing meniscal surgery with non-operative treatments. Neither did we identify any studies comparing the trajectory of pain and function to a healthy control group. Knee extensor strength seemed to be impaired up to 12 months after surgery in young patients undergoing surgery for meniscal tears. The results of the present study should be interpreted with caution due to a limited number of available studies with high risk of bias including relatively few patients. This systematic review highlights the need for randomized trials comparing the effectiveness of arthroscopic meniscal surgery for young adults to non-operative treatment as well as longitudinal studies to better appreciate the trajectory of muscle strength recovery over time.

Practical Implications

- Inferences about improvements in pain and function after meniscal surgery in young adults are based on data with no comparison to non-surgical treatments or reference groups as no such studies were identified.
- Knee extensor strength seems to be impaired in young patients undergoing meniscal surgery up to 1 year after surgery.
- These results indicate a potential for rehabilitation of muscle strength within the first year after surgery.
- Results from this study should be interpreted with caution due to a small number of studies including few patients and having a high risk of bias.

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None.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jsams.2017.02.004.

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Appendix 23: Publication: Poster Presentation Chapter 4. TRIMS early findings

Changes in isokinetic strength and single-leg hop test performance following arthroscopic meniscus surgery: A Cohort Study

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[2]Department of Sports Science and Clinical Biomechanics, University of Southern Denmark
[3]Department of Orthopaedics, Tallaght Hospital, Dublin
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SDU
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Introduction:

- The benefit of arthroscopic meniscal surgery has been questioned, based primarily on patient reported outcome measures[1,2]. Less is known about objective performance in patients who undergo meniscus surgery.
- The Trinity Meniscus Study (TRIMS) investigated changes in objectively measured performance in a cohort of patients from before, to 6 months after arthroscopy.
- The primary aim of the TRIMS study was to quantify change in objective physical performance measures, from before to 6 months after arthroscopic meniscus surgery.

Pre-operative
Physical Assessment
Isokinetic Strength
Single Leg Hop Tests

Surgery

+6 months
Physical Assessment
Isokinetic Strength
Single Leg Hop Tests

Materials and Methods:

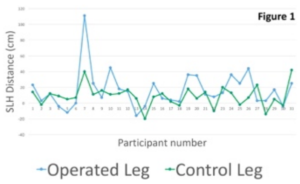
- Participants were recruited from scheduled elective surgical lists at 2 orthopaedic departments in Dublin, Ireland over a 6 month period.
- All eligible patients were contacted prior to surgery and consenting participants were scheduled for pre-operative assessments.
- 53 participants were tested pre-operatively. 43 were available for follow up at 6 months. 40 participants completed strength assessments (60 deg/sec quadriceps and hamstrings: concentric/concentric) at both time points, and 31 participants were able to complete single leg hop for distance (SLH) at both time points. Patients underwent standard care of home exercises following surgery.

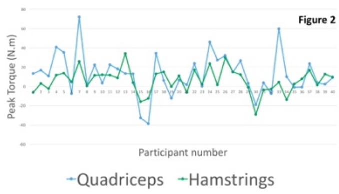
Results:

- Pre-operatively, there were significant deficits in the injured leg in all performance measures ($p<0.05$). At 6 months, deficits persisted in all tests compared to the contralateral leg; quads strength: Mean Difference (MD) 20.99Nm (95%CI; 12.85,29.12. $p<0.001$), hamstring strength MD 4.83Nm (1.19,8.48. $p=0.013$), SLH MD 12.28cm (4.33,20.44. $p<0.005$).
- When comparing change over time in injured and contralateral leg performance, no significant difference was found between legs. MD in change score for quads strength was 6.35Nm (-14.06,1.35. $p= 0.114$), hamstring strength was 1.22Nm (-5.23,2.79. $p=0.61$), and SLH was -7.61cm (-14.46,-0.76. $p=0.04$).

Figure 1:
Change in SLH performance (centimeters) from pre-operatively to 6 months post-operatively

Figure 2:
Change in isokinetic strength (peak torque: newton metres) from pre-operatively to 6 months post-operatively.





Conclusions:

- Following arthroscopic meniscus surgery, deficits in strength and objective performance are still present at 6 months when compared to the contralateral leg. As performance improves in both legs similarly, current management does not eliminate performance deficits.

Further Research:

- Further research is needed to determine predictors of superior outcome in select populations. The Trinity Meniscus Study continues to follow patients to 12 months post operatively, and will report further objective measures of function from this 6 month cohort.

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Trinity Meniscus Study (TRIMS) Clinical Sites:

The Adelaide and Meath Hospital, Dublin
Incorporating the National Children's Hospital

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Appendix 24: Publication: Poster Presentation Chapter 5: Expectations of Surgery

Large Variability in Clinician Expectations of Arthroscopic Partial Meniscectomy; a Study of Physiotherapists and Orthopaedic Surgical Teams.

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Nathan Cardy[1], Jonas Bloch Thorlund[2], Fiona Wilson[1]

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[2]Department of Sports Science and Clinical Biomechanics, University of Southern Denmark

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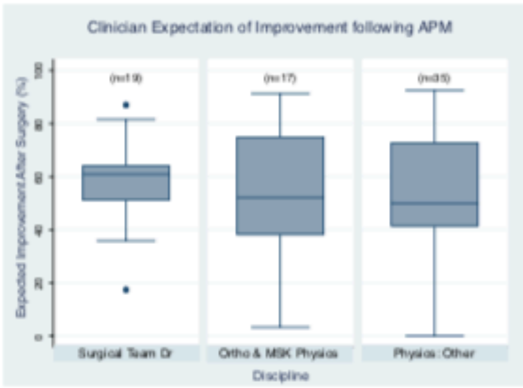
Introduction:

- The aim of this study was to explore current expectations of Arthroscopic Partial Meniscectomy (APM) among Irish clinicians.
- Recent guidelines state that APM is no better than exercise interventions for degenerative meniscus tears of the knee. However, APM remains a frequently performed procedure in Ireland & Europe. This study examined the expectations of physiotherapists across multiple disciplines and doctors within orthopaedic surgical teams.
- Our objectives were to establish the mean expectation of change following APM, and to examine if clinical experience was associated with a different expectation of APM.



Materials and Methods:

- The Hospital for Special Surgery (HSS) Knee Surgery Expectations Survey (Clinician Version) is a questionnaire designed to grade a clinician's expectation of how a patient will improve following arthroscopic knee surgery. Clinicians grade 23 items from one to five based on how much relief or improvement they expect a patient will have in each area as a result of knee surgery. Scores are transformed to a 0-100% Scale, with higher scores indicating that clinicians expect more improvement from more items.
- In March 2017, questionnaires were distributed to all team members at physiotherapy and orthopaedic department meetings in two Dublin teaching hospitals. Clinicians were advised to respond while considering the average patient undergoing arthroscopic meniscus surgery. Clinicians also reported: their job grade; number of years' experience; current specialty and average number of arthroscopic meniscus surgery patients treated in a year
- Total scores for the HSS survey were calculated and reported for different clinical groups, as Means (SD). Correlations between the expectation (total score for change) and clinical experience (job grade / years' experience / number of patients per year) were also assessed.

Results:

- Questionnaires were completed by 72 clinicians; 19 orthopaedic doctors with a mean of 6.8 years' experience in Orthopaedics, 52 Physiotherapists with a mean 7.4 years' post-graduate experience (32% specialising in Musculoskeletal / Orthopaedics).
- Mean (SD) improvement expected was 59% Improvement(16) for the Orthopaedic team members and 51% Improvement (22) for Physiotherapists. The difference between clinician groups was not statistically significant ($P = 0.36$).
- Physiotherapists working in orthopaedics / musculoskeletal had a similar expectation of improvement to other specialties: 55% Improvement (24). There was no correlation between years of experience and clinician expectation of improvement ($r = 0.08$). A large variance in expectation scores was found, for all clinician groups.

Conclusions:

- The mean clinician expectation of surgery was found to be similar in orthopaedic surgical and physiotherapy teams, this expectation represents an average of 'moderate' improvement across the population of clinicians included in this study.
- **A large range in response scores reflects the high variability in clinician expectations across both teams.**
- **Differing expectations of surgery among clinicians could lead to conflicting education of patients by and poor selection of patients for surgery within the Irish healthcare system.**

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Appendix 25: Publication: Oral Presentation Chapter 5: Reasons for Surgery

Trinity College Dublin
Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

Surgeons and Patients Report Different Reasons for Surgery; Examination of an Arthroscopic Partial Meniscectomy Cohort

Nathan Cardy BSc, PGC, PGC, MISCP
Dr. Jonas Thorlund: University of Southern Denmark
Dr. Fiona Wilson: Trinity College Dublin

ISCP Conference 2018: Musculoskeletal Track
09/11/18 11:10 – 11:30

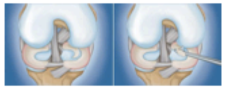
1

Arthroscopic Partial Meniscectomy
Current Evidence

Keyhole surgery: removal of damaged meniscus tissue.

Two varied patient populations:

1. Degenerative Knees
2. Traumatic Tears



2017 guidelines:
Strong recommendation against the use of arthroscopy for patients with a degenerative knee, regardless of radiographic osteoarthritis.

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2

Clinician Expectations of Surgery

- Clinicians have varied expectation of recovery time following arthroscopic meniscectomy.
- The average expected recovery time reported by surgeons: 5 weeks following isolated meniscus tear (Roos et al., 2000).
- This expectation does not match the trajectory of functional performance found in systematic review of younger or older patients undergoing meniscectomy (Hall et al., 2015, Thorlund et al., 2017).

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3

Patient Expectation of Surgery

- Systematic review has shown that patients frequently overestimate the benefits of treatments (Hoffmann and Del Mar, 2015).
- Patient expectations of demanding physical activities following knee joint surgery are often not met (Nilsdotter et al., 2009)
- Fulfilment of pre-operative expectations of surgery is one of the main determinants of patient satisfaction (Bourne et al., 2010).

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4

Study Objective

Compare reasons for APM from both patients' and surgeons' perspectives.

1. Establish frequent reasons for surgery from both perspectives
2. Assess if these reasons are similar / different
3. Encourage reflection on Evidence Based Practice

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5

Methods
Overview TRIMS

TRIMS: Trinity Meniscus Study

- Observational cohort study
  Examined objective functional and self-reported outcomes in patients undergoing APM at two Dublin teaching hospitals.
- Patients recruited from September 2016 - March 2017
  Followed up for one year

Trinity Meniscus Study (TRIMS) Clinical Sites: The Adelaide and Meath Hospital, Dublin, Incorporating the National Children's Hospital; St. James's Hospital

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6

Methods
Patient data collection

Prior to surgery, patients responded to a single item open-ended question: "Reason for surgery".

Physio assessment pre-operatively
- Questionnaires and Objective measures
- Open-ended to gather qualitative data on the perceived reason for undergoing surgery

Reason for surgery: ______________________

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Methods
Surgeon data collection

At time of surgery, the operating surgeon completed a data collection form

Included the tick box question:
"Reason for surgery: Persisting Pain / Mechanical Symptoms / Failed Conservative Treatment / Other (please specify)".

Reason for meniscus surgery: Persisting pain ☐ Mechanical Symptoms ☐
Conservative Rx failure ☐
Other (Please specify) ☐ ______________

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Results
Overview

1. Forty three patients followed up over one year.
2. Responses from patients were coded and compared to the responses given by surgeons.
3. Responses reported as percentages of the total cohort for which that reason was given.

Surgeons and patients both reported a combination of reasons for surgery, with more than one reason for a number of patients in the cohort.

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Results
Surgeon reasons for surgery

- Pain was the reason for surgery reported most frequently by surgical team (84% of patients).
- Mechanical symptoms were selected as a reason for 30% of patients.
- Other: 7% (N=3) ("traumatic injury, loose body, swelling").
- No patients were classified as 'failed conservative treatment' at time of surgery.

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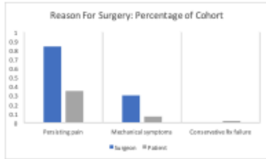
10

Results
Patient Reasons for Surgery

Patient responses were coded according to the same three headings.

- Pain (35%)
- Mechanical symptoms (7%)
- Failed conservative management (2%)



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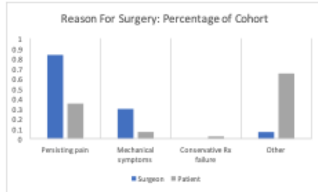
11

Results
Difference in reported reasons for surgery

Other Reasons reported by patients:



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12

Results
Other Reasons reported by patients

- **Functional / personal goals (30%)**
  Included responses such as "make more comfortable day to day life" and "want to continue playing sport".
- **Anatomical diagnosis (33%)**
  Included responses such as "cartilage tear" and "removal of loose cartilage pieces".
- **Other (2%)**
  "Exploratory".

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13

Discussion

- Some of these differences may be due to the close-ended question offered to surgeons, although only 7% of patients were classified as "Other".
- Patients reporting personal / functional goals may reflect their hopes for outcome of surgery rather than reason for needing the surgery.
- Although direct comparison of responses is limited, the large difference in reported reasons shows that surgeons have a very different perspective on surgical indication to patients in this cohort.

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14

Conclusion

- There is a lack of shared ownership / understanding surrounding the selection of APM as a treatment option for patients in this cohort.
- Patients may not understand why their surgeon or physiotherapist is suggesting surgical treatment.
- Further qualitative and quantitative research is needed to further investigate these findings.

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15

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Q&A

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Funding source: Trinity College Dublin PhD Stipend

Appendix 26: Contralateral and Mechanical Symptoms

ST. JAMES'S HOSPITAL

THE ADELAIDE & MEATH HOSPITAL, DUBLIN
INCORPORATING THE NATIONAL CHILDREN'S HOSPITAL

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The University of Dublin

SDU
UNIVERSITY OF SOUTHERN DENMARK

Trinity Meniscus Study: TRIMS

Participant ID:

<u>How often have you experienced the following sensations, in the knee which has now undergone surgery 3-months ago:</u>

Catching of the knee
Never ☐ Monthly ☐ Weekly ☐ Several Times a week ☐ Daily ☐

Locking of the knee
Never ☐ Monthly ☐ Weekly ☐ Several Times a week ☐ Daily ☐

Giving way of the knee
Never ☐ Monthly ☐ Weekly ☐ Several Times a week ☐ Daily ☐

The following questions relate to your opposite knee (the knee which <u>did not</u> undergo surgery 3months ago):

Have you ever had an injury on this (opposite) knee?
Yes ☐ No ☐

Have you ever seen a doctor due to problems with this (opposite) knee?
Yes ☐ No ☐

Have you ever had surgery on this (opposite) knee?
Yes ☐ No ☐
Details:

____

Appendix 27: TRIMS Arthroscopy Form Instructions

Arthroscopy Form Instructions

Review the below instructions before filling out each part of the Arthroscopy form:

- <u>Please double-check that all sections are fully completed – missing data is much easier to prevent than remedy; many thanks.</u>
- For tick box questions, please select the most appropriate answer. If more than one box is applicable, please tick both.

Surgery Date:
Date of Surgery.

Knee Surgery Leg:
Note surgery leg (Left or right)

Previous meniscus surgery:
Note if previous surgery to the medial and/or lateral meniscus was performed (none / medial / lateral). Note type of surgery (repair or resection) and amount of meniscus removed (0-20%, 21-50% or >51%).

Reason for meniscus surgery:
Indicate the reason for which arthroscopic meniscus surgery is performed. If other, please specify.

Combined Surgery:
Indicate if meniscus surgery was performed along with ACL / PLC reconstruction, or other arthroscopic procedure (please specify).

Knee Joint stability at surgery:
Indicate result of clinical looseness/laxity test for knee joint stability at surgery (i.e. prior to entering the knee).

Meniscus Tear Location:
Medial or Lateral or indicate if no tear.

Tear depth:
The partial tear extends through either the superior or inferior surface of the meniscus. A horizontal tear may also be a partial tear. The complete tear extends through both the superior and inferior surfaces of the meniscus.

Ligamentous Injury:
Indicate integrity of each collateral and cruciate ligaments based on physical assessment and arthroscopic findings.

Rim width:
In the zone classification, tears may involve more than one zone. The tears should be graded based on how far the tear extends into the meniscus. For example, a complete radial tear that extends through zones 3, 2 and 1 should be graded as a zone 1.
Zone 1 tears have a rim width of < 3 mm
Zone 2 tears have a rim width of 3 to < 5 mm
Zone 3 tears have a rim width of ≥ 5 mm.

Radial location:
Indicate whether the tear is posterior, mid body, or anterior in location. Tears should be graded according to all the zones in which they are located. For example, complete bucket-handle medial meniscus tear would be in the posterior, mid body and anterior zones.

Central to the popliteal hiatus:
A tear of the lateral meniscus that extends partially or completely in front of the popliteal hiatus should be graded as central to the popliteal hiatus.

<u>Please Turn Over:</u>

Arthroscopy Form Instructions

Degree of Synovitis:
Indicate the level of synovitis evident on arthroscopic examination.

Tear pattern:
The tear should be graded according to the patterns demonstrated at the drawing (except root tear). Tears should be graded on the predominant tear pattern. Complex tears include 2 or more tear patterns.

Quality of tissue:
Degenerative characteristics include cavitations, multiple tear patterns, softened meniscus tissue, fibrillation, or other degenerative changes.

Length of tear:
This should be measured by the arthroscopic ruler or other device in millimeters (as precise as possible). The length of a radial tear is the distance the tear extends into the meniscus.

Indicate the amount of meniscus that was excised by drawing on the diagram and crosshatching the part that was removed:
Only for meniscus resection/debridement/meniscectomy. If meniscus repair performed, please indicate repair site.

What percentage of the meniscus was excised:
For meniscus resection/debridement/meniscectomy, indicate the percentage of the meniscus (surface area) that was removed.

Meniscal Repair Reporting:
If meniscus repair is performed, indicate type of surgery and surgical technique. Record number of stitches/sutures if applicable. Please also indicate company and device name of suture together with placement of repair on drawing (Only for meniscus REPAIR)

Grading of Cartilage Deficits (ICRS):
Cartilage defects are evaluated separately for the medial and lateral and patella-femoral compartment of the knee. Please indicate grade (0-4) according to the worst area in each compartment (see figures).

Treatment of Cartilage Defects:
Please indicate if any action where taken for cartilage defects – if no cartilage defects where found choose the "No treatment" option.

Plica Present:
Please indicate if a Plica was present (yes/no).

Plica Removed:
If present please indicate if the Plica was removed or not (yes/no).

Appendix 28: Summary Data and T-tests, Six-month Functional Assessments.

6 months n=34	Surgery Leg Mean (SD)	Contralateral Leg Mean (SD)	Mean Difference (SD) (95% CI), p-value	*P*-value
Strength Quadriceps 60°/sec (Nm)	116 (54)	135 (61)	-19.1 (23) (-27.2, 11.1)	***P*<.001**
Strength Quadriceps 180°/sec (Nm)	87 (39)	99 (44)	-9 (11) (-13, -5)	***P*<.001**
Strength Quadriceps 300°/sec (Nm)	69 (26)	78 (33)	-9 (11) (-80, -52)	***P*<.001**
Strength Hamstrings, 60°/sec (Nm)	69 (32)	73 (31)	-4.0 (12) (-8.0, 0.04)	***P*=.052**
Strength Hamstrings, 180°/sec (Nm)	55 (24)	56 (24)	-.97 (9) (-4, 2)	*P=.537*
Strength Hamstrings, 300°/sec (Nm)	53 (23)	57 (24)	-4 (9) (-7, -1)	***P*=.023**
Single Leg Hop (cm) n=27	108 (43)	118 (45)	-10.2 (-17.4, -2.9)	***P*=.008**
Six Metre Hop (s) n=24	3.3 (1.5)	3.0 (0.8)	0.2 (-0.2, 0.7)	*P=.235*
Triple Hop, (cm) n=25	391 (118)	421 (122)	-30.6 (-58.6, -2.7)	***P*=.033**

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