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Outcomes in Patients with Degenerative vs. Non-Degenerative Meniscus Tears

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OUTCOMES IN PATIENTS WITH DEGENERATIVE VS. NON-DEGENERATIVE MENISCUS TEARS

By

Eryn Apanovitch

A DISSERTATION

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OUTCOMES IN PATIENTS WITH DEGENERATIVE VS. NON-DEGENERATIVE MENISCUS TEARS

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Meniscus tears are the second most common orthopedic injury of the knee with an incidence of 12% to 14% and a prevalence of 61 cases per 100,000 persons. Physical therapy (PT) is a standard of care for these patients post-meniscectomy, but research is conflicting on the benefits and the most appropriate outcome measures to use when assessing activity levels in these patients.

The main purpose of this dissertation was to explore 5 performance-based outcome measure (single-limb single hop test for distance (SLHT), single-limb crossover hop test for distance (CHT), Edgren side step test (ESST), Illinois agility test (IAT), and stair measure test (SMT)), 3 of which were recommended by the clinical practice guidelines (CPGs) for meniscal lesions, in order to provide information on the reliability and validity of these measures for patients after meniscectomy. A secondary purpose of this dissertation was to identify the differences in outcomes between patients with degenerative meniscus tears and non-degenerative meniscus tear by investigating recovery post-arthroscopic partial meniscectomy.

A convenience sample of patients who underwent an arthroscopic partial meniscectomy were recruited from the University of Miami Hospital sports medicine
Subjects were categorized into one of two groups based on whether their meniscus tear was degenerative or not. Subjects were treated by one of five physical therapists. The rehabilitation protocol consisted of 45 minutes to 1 hour of PT 2-3x/week for a total of 8 weeks. A general protocol was followed for the first 4 weeks of rehabilitation and an individualized protocol was incorporated into the final 4 weeks of rehabilitation. Assessments were performed at initial PT evaluation (week 0), at four weeks post-meniscectomy (week 4), and 8 weeks post-meniscectomy (week 8). Comparisons were made in terms of impairments, activity limitations, and participation restrictions using both patient-reported outcomes (IKDC, Tegner) and performance-based outcomes.

This work provides information on the reliability and validity of 5 activity level performance-based outcome measures for patients after arthroscopic partial meniscectomy. Additionally, it discusses the importance of making sure these outcome measures are appropriate to the population of patients being examined. Because there are two different subpopulations of patients with meniscus tears, patients with degenerative meniscus tear and patients with non-degenerative meniscus tears, different activity level outcome measures should be considered when studying and treating these different types of patients with meniscus tears. Finally, this work demonstrates similar patterns of recovery in patients with degenerative and non-degenerative meniscus tears. Both groups nearly recover to their pre-morbid level of activity after 8-weeks of PT.
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Chapter 1 - Introduction

In the United States, the American Academy of Orthopedic Surgeons (AAOS) estimates 850,000 patients each year undergo surgery for a meniscus tear. The most commonly performed surgery is an arthroscopic partial meniscectomy. After meniscectomy, patients initially experience knee swelling, pain, and loss of range of motion (ROM). Physical therapy may be implemented post-meniscectomy to treat these impairments and subsequent knee related activity limitations and participation restrictions. However, literature to support the effectiveness of physical therapy is limited, conflicting, or of poor quality. Two possible explanations for conflicts in this literature are the variability in the use of outcome measures to describe recovery after arthroscopic partial meniscectomy and the variability of patients undergoing this procedure.

Patients with meniscus tears have a large variability in age, pre-morbid activity, and participation. Meniscus tears may be caused by an acute traumatic event or constant wear and tear over time as in chronic degenerative articular disease. The current research typically does not distinguish between these two populations of patients with meniscus tears, but does recommend caution when selecting older individuals for surgical intervention. The limited research that does compare outcomes after arthroscopic partial meniscectomy for patients with acute and degenerative meniscus tears, demonstrates that patients with degenerative tears present with worse outcomes. Englund et al reported that patients with degenerative tears had significantly worse knee function based on the Knee Injury and Osteoarthritis Outcome Score (KOOS) and poorer quality of life because of their knee compared to those with traumatic/acute tears. Patients with degenerative
tears had significantly lower scores on both knee-specific outcomes and the Short Form Health Survey (SF-36), when compared to those with traumatic tears. In this article, self-report measures are used to describe outcomes post-meniscectomy. Minimal research on outcomes post-meniscectomy includes the use of performance-based measures.

With growing emphasis on outcomes-based reimbursement, research on the effectiveness of rehabilitation interventions is crucial. Outcome measures should be used to measure the impact of PT and these outcome measures should be specific and appropriate to the population being investigated, in this case patients undergoing meniscectomy. The Orthopedic Section of the American Physical Therapy Association (APTA) has published CPG, which help to guide the use of outcome measures in PT patient management, and to reduce variability in the use of these outcomes.

One of the aims of this dissertation was to investigate the psychometric properties of activity limitations and participation restriction measures recommended by the CPG for patients with meniscal lesions and other performance-based activity limitations measures. A second aim of this dissertation was to investigate recovery in patients with degenerative meniscus tears compared to patients with non-degenerative meniscus tears.

The first chapter will provide an overview of the anatomy and function of the meniscus, the incidence and prevalence of meniscus tears, the importance of outcomes and PT, and recommendation based on the CPG developed by the Orthopedic Section of the APTA, and also will provide a detailed description of the research methodology used in this study.
Anatomy and Physiology of the Meniscus

The menisci are fibrocartilaginous wedge-shaped structures that convert the relatively flat articular surface of the tibial plateau into a more contoured area for contact with the femoral condyles. The medial meniscus is C-shaped, with the posterior horn larger than the anterior horn in the antero-posterior direction. Recent studies have investigated anatomic variations in the attachment site of the anterior horn of the medial meniscus and in doing so, the role the transverse meniscal ligament plays in medial meniscus stability. In the majority of specimens, a firm anterior bony attachment of the medial meniscus was observed. The remainder of the medial meniscus is firmly attached to the joint capsule. The posterior bony attachment lies anterior to the insertion of the posterior cruciate ligament. The lateral meniscus is also anchored anteriorly and posteriorly through bony attachments, but has nearly a circular configuration. The anterior and posterior horns attach closer to each other, with the anterior horn inserting adjacent to the anterior cruciate ligament (ACL) and the posterior horn inserting behind the intracondylar eminence anterior to the posterior horn of the medial meniscus. The remaining attachments of the lateral meniscus to the tibia are through the capsule, but are not as well developed as the attachments on the medial side. This lack of development allows for increased translation of the lateral meniscus throughout motion at the knee joint. The lateral meniscus also covers a larger portion of the tibial articular surface compared to the medial meniscus and therefore may theoretically contribute more to load bearing.

Joint space narrowing and osteophyte formation after total meniscectomy suggests that the meniscus is important in joint protection and have led to investigations
of the role of the meniscus in joint function. An intact meniscus is essential to normal structure and function of the knee. With removal of part of the meniscus, as in an arthroscopic partial meniscectomy, stress acting on the joint surfaces increases significantly. Radin et al demonstrated that removal of the medial meniscus results in a 50% to 70% reduction in femoral condyle contact area and a 100% increase in contact stress. Total lateral meniscectomy causes a 40% to 50% decrease in contact area and increases contact stress in the lateral compartment to 200% to 300% of normal. This increased stress can lead to the progression of osteoarthritis (OA).

The menisci function as shock absorbers, secondary stabilizers, and provide proprioception, joint lubrication, and nutritional support to the articular cartilage thereby contributing to both load transmission and stability of the knee. Many of these functions are achieved through the ability of the menisci to transmit and distribute load over the tibial plateau.

The importance of the role of the menisci in shock absorption has been demonstrated in compression studies. Using bovine menisci, studies have demonstrated that meniscal tissue is approximately one half as stiff as articular cartilage. In a study by Voloshin and Wosk, the shock absorption capacity of the normal knee was reduced by 20% after meniscectomy.

The menisci also play a key role in enhancing joint stability. Medial meniscectomy in the ACL-intact knee has little effect on antero-posterior motion, but in the ACL-deficient knee, it results in an increase in anterior tibial translation of up to 58% at 90 degrees of flexion. Shoemaker and Markolf demonstrated that the posterior horn of the medial meniscus is the most important structure resisting an applied anterior tibial
force in an ACL-deficient knee. Allen et al showed that the resultant force in the medial meniscus of the ACL-deficient knee increased by 52% in full extension and by 197% at 60 degrees of flexion under a 134-N load. Although the inner two thirds of the meniscus is important in maximizing joint contact area and increasing shock absorption, the integrity of the peripheral one third is essential for both load transmission and stability.

The anatomical features of the medial and lateral meniscus result in load bearing differences across the medial and lateral compartments of the knee joint. These differences become more apparent after removal of part of the meniscal tissue as in an arthroscopic partial meniscectomy reinforcing the importance of the meniscus in maintaining normal health and function of the knee joint.

**Scope of the Problem**

Meniscus tears are the second most common orthopedic injury of the knee with a prevalence of 61/100,000 in the United States each year. The ratio of meniscus tears in males versus females is 2.5:1 with the peak incidence between 31-40 years old in males and 11-20 years old in females. Tears often occur secondary to mechanical or degenerative causes and result from non-contact forces acting across the knee joint.

A meniscal tear can be classified in various ways: by anatomic location, by proximity to blood supply, and by cause of tear. Cause of tear is one of the most useful ways to categorize patients with meniscus tears and can be further classified as degenerative versus non-degenerative tears.

Non-degenerative tears result from excessive force applied to a normal knee and meniscus. Younger patients are more likely to have an acute traumatic event as the
cause of their meniscal pathology. Commonly, these tears occur while cutting, decelerating, or landing from a jump when a mechanical non-contact force creates excessive rotation, hyper-flexion, and/or hyperextension of the knee. Non-degenerative meniscal tears may be radial, vertical-circumferential or horizontal-cleavage in orientation. The central portion of a circumferential tear may be unstable, and can displace inwards within the medial and/or lateral compartment of the knee. When this occurs, it is referred to as a bucket-handle tear, which frequently causes mechanical locking of the knee.

Degenerative tears result from repetitive normal forces acting on the meniscus over time. They generally have a complex tear pattern and are predominantly found in the posterior horn and mid-body of the meniscus. These tears occur in multiple planes and are more common in older age groups (>40 years). Degenerative tears commonly occur in men in their fourth, fifth, and sixth decades of life. These tears are often associated with degenerative changes of articular cartilage in the knee and represent part of the pathology of degenerative arthritis. As described above, patients with non-degenerative tears and degenerative tears are two distinctly different populations of patients.

The AAOS estimates 10-20% of all orthopedic surgeries each year are a result of a meniscus tear with annual direct medical costs estimated at 4 billion dollars. Several options exist for treatment of a torn meniscus. Conservative treatment includes elements of bracing and/or a structured rehabilitation program. When conservative methods fail to produce improvement, surgical intervention is the next step. The standard surgical
procedure performed is a partial meniscectomy, but additional options include meniscal repair or transplantation.

Selection of surgical technique requires the consideration of patient’s age, health, lifestyle, and willingness to undergo major surgery as well as the location and type of meniscal tear. The major determinants of whether a meniscal tear is amenable to surgical repair are the vascular supply related to the tear, the type of lesion, and the location of the tear. Studies have shown that 10-30% of the periphery of the medial meniscus and 10-25% of the lateral meniscus receives vascular supply. The remainder receives nutrition from the synovial fluid via passive diffusion and mechanical pumping. Three zones, based on extent of vascularization, determine the healing prognosis for meniscal lesions and optimal surgical procedure: red-red, red-white, and white-white. For example, longitudinal tears occur parallel to the circumferential fibers and if such a tear occurs in the red-red or red-white zone then healing potential is good and ideal for repair. Flap or radial tears, however, are more amenable to debridement.

**Outcomes and Physical Therapy**

Physical therapy is the standard of care after arthroscopic partial meniscectomy. The main goals of post-meniscectomy rehabilitation are to control the pain and inflammation associated with surgery, maintain ROM and general conditioning, restore or maintain isolated muscle function, and optimize integrated lower extremity neuromuscular coordination in order to return patients to their previous level of activity and participation. Current research related to the efficacy of PT for patients with meniscal injury is not extensive, and there is controversy related to the benefits of PT following injury and surgery. When arthroscopy and conservative treatment were
compared, arthroscopic partial medial meniscectomy combined with exercise did not lead to greater improvements than exercise alone. After the intervention, both groups reported decreased knee pain, improved knee function and a high satisfaction rate.29

Meniscus tears are a common orthopedic diagnosis treated by physical therapists. Patients are seen after injury and after surgery, but unfortunately the effectiveness of PT interventions has not been established in the literature. This may be due to weakness in the methodology of the current literature and may also relate to how patients with meniscus tears are categorized. When investigated, patients with meniscus tears are typically all grouped together and this may explain why current research studies have difficulty demonstrating the benefits of PT. There are two distinctly different groups of patients with meniscus tears; patients with degenerative tears and patients with non-degenerative tears, and these groups should be investigated separately.

Another weakness in current methodology is the improper utilization of outcomes. In order to prove the effectiveness of treatment, outcomes need to be chosen that are appropriate to the population and constructs assessed. Finally, the lack of standardization of a protocol for treating patients with meniscus tears results in a lack of consensus on what treatment is best for these patients.

Research on the effectiveness of rehabilitation interventions after meniscectomy is needed, especially in the current era of accountability in healthcare where there is an increasing emphasis on health outcomes. Outcomes are used to assess quality of care, make decisions about patient management, describe the results of interventions, and to demonstrate effectiveness in research. Health-related outcomes should be incorporated
into all aspects of rehabilitation, and movement related outcomes (activity level
performance-based measures) are of particular interest to the physical therapist.

Self-reported outcome measures are frequently used in orthopedic rehabilitation
due to their practicality, low cost, low participant burden, and general acceptance.\textsuperscript{30}
Self-report measures are also useful in assessing quality of life. They allow for the quick
retrieval of information on impairments, activity limitations, and participation
restrictions, but they have potential for recall and response bias.\textsuperscript{30} Performance-based
outcomes measures are more direct measures of activity limitations that provide precise
information about movement and remove many of the issues of recall and response bias
seen in self-report measures.\textsuperscript{30} Performance-based measures can be used both to assess
outcomes of treatment and to assist in developing an appropriate plan of care.
Performance-based activity level measures allow clinicians an opportunity to observe
movement and therefore paint a clear picture of impairments and functional limitations.
This helps guide specific components of the PT plan of care after meniscectomy. As
recommended by the CPG for patients with meniscal lesions, performance-based
measures should be used in addition to self-report measures to assess change in patient’s
post-meniscectomy. In conflict with this recommendation, a current meta-analysis
demonstrates the majority of outcome measures used to assess outcomes post-
arthroscopic partial meniscectomy are self-report measures. Out of 6 articles analyzed,
only 2 actually used performance-based measures. The performance-based measures
used in these 2 studies were a timed walk test, the SMT, single-leg stance, and squatting.\textsuperscript{4}
Clinical Practice Guidelines for Patients with Meniscal Lesions

The Orthopedic Section of the APTA is engaged in a continuing effort to create evidence-based practice guidelines for orthopedic physical therapy management of patients with musculoskeletal impairments as described in the World Health Organization’s International Classification of Functioning, Disability, and Health (ICF). The purposes of these clinical guidelines are to describe evidence-based PT practice including diagnosis, prognosis, intervention, and assessment of outcome for musculoskeletal disorders commonly managed by orthopedic physical therapists, identify appropriate outcome measures to assess changes resulting from PT interventions, and create a reference publication for orthopedic PT clinicians, academic instructors, clinical instructors, students, interns, residents, and fellows regarding the best current practice of orthopedic PT.

The CPG for meniscal lesions is combined with that for articular cartilage lesions and state that clinicians should use a validated patient-reported outcome measure, a general health questionnaire, and a validated activity scale for patients with knee pain and mobility impairments. Clinicians should also utilize easily reproducible physical therapy performance measures to assess activity limitation and participation restrictions associated with their patient’s knee pain or mobility impairments and to assess changes in the patient’s level of function. These recommendations are the basis for the outcome measures used in this study.

The outcome measures recommended by the CPG include; the Medical Outcomes Study 36-item Short Form (SF-36), the Knee Outcome Survey – Activities of Daily Living Scale (KOS – ADL), the Knee Injury and Osteoarthritis Outcome Score (KOOS),
the International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC), Lysholm Knee Scale, Cincinnati Knee Rating Scale, Tegner Activity Scale, and the Marx Activity Scale. Physical impairment measures recommended by the clinical practice guideline are the modified stroke test, bulge sign, knee passive ROM, knee active ROM, maximum voluntary isometric quadriceps strength, isokinetic muscle strength, and knee joint line tenderness. The activity limitation and participation restriction measures recommended are the single-limb hop tests, 6-minute walk test, timed up-and-go test, and stair measure test.

The IKDC and Tegner Activity Scale were the self-report outcome measures utilized in this study. The IKDC includes multiple sections that can either be used in combination or individually and is therefore comprehensive and includes a general health questionnaire. The Tegner Activity Scale is an activity level and participation restriction outcome measure that is widely used in the literature and is reliable and valid for knee injuries. The primary impairment level outcome measures selected were pain, active ROM of the knee, and isokinetic muscle strength. The IKDC subjective knee evaluation form also contains a symptoms sub-section, which assesses at the impairment level.

The activity level outcome measures selected for this study were the single-limb single hop test for distance (SLHT), single-limb crossover hop test for distance (CHT), stair measure test (SMT), Illinois agility test (IAT), and Edgren side step test (ESST). The SLHT, CHT, and SMT were recommended in the CPGs. The IAT and ESST were additions that were included because they assess lateral and multi-directional movements, additional components of activity not addressed in the hop tests or the SMT. They are also safe to use in an injured population with patients of all ages. The IKDC subjective
knee evaluation form and the Tegner Activity Scale also measure activity limitations.
The IKDC captures these in its sport activities and function sub-sections. **Table 1.1** lists the outcome measures used in this study based on ICF category.

**Table 1.1 – Outcome Measures by ICF Category**

<table>
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<th>Impairment</th>
<th>Activity Limitation</th>
<th>Participation Restrictions</th>
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<td>IKDC subjective knee evaluation form*</td>
<td>IKDC subjective knee evaluation form*</td>
<td>IKDC subjective knee evaluation form*</td>
</tr>
<tr>
<td>Pain*</td>
<td>Tegner Activity Scale*</td>
<td>Tegner Activity Scale*</td>
</tr>
<tr>
<td>Range of motion*</td>
<td>Single-limb single hop test for distance (SLHT)*</td>
<td></td>
</tr>
<tr>
<td>Isokinetic muscle strength*</td>
<td>Single-limb crossover hop test for distance (CHT)*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Edgren side step test (ESST)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Illinois agility test (IAT)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Stair measure test (SMT)*</td>
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</tr>
</tbody>
</table>

* recommended by the CPG

**Outcome Measures**

**Self-Report Outcome Measures**

**International Knee Documentation Committee Form (IKDC)**

The IKDC was created by a committee of international knee experts and includes; a demographic form, a health assessment form, subjective knee evaluation form, knee history form, surgical documentation form, and a knee examination form (**Appendix A**).
These forms are meant to be used together or separately. The IKDC was initially designed to assess ligament injuries of the knee, but has more recently been validated for use in meniscal injuries. The demographic form of the IKDC is a self-report form that includes age, gender, height, weight, and past medical history. The current health assessment form of the IKDC is another self-report measure that provides information on the patient’s current health status including a general measure of the patient’s activity level. The subjective knee evaluation form is composed of three subcategories: symptoms, sports activities, and function. This section is scored from 0-100 with 100 representing no limitations. A higher score represents a better outcome. The subcategories were scored in the same manner, by adding the appropriate questions related to each subcategory and calculating a percentage based on the maximum possible score of that subcategory.

The IKDC has been studied in people with meniscus injuries and was found to be reliable and valid. The intraclass correlation coefficient (ICC) was 0.95 demonstrating excellent test-retest reliability. Criterion validity was established by a significant correlation between the pre-operative IKDC score and the physical component of the SF-12 scale (r = 0.60). Floor effects and ceiling effects were determined for the overall IKDC score (<30%), as well as for each domain, and were acceptable. Pre-operative IKDC scores were compared with postoperative scores 12 months after treatment of a meniscus tear in order to calculate effect size and the MDC. A large effect size (2.11) was determined for the overall score and the MDC was 8.8 points with a standard error of 3.19.
**Tegner Activity Scale**

The Tegner Activity Scale (Appendix A.4) is a single item outcome measure that uses a scale from 0-10 based on activities performed. It is frequently used to assess a patient’s perceived level of participation following treatment of knee injuries. The Tegner has also been validated in a meniscus population with acceptable test re-test reliability, floor and ceiling effects, criterion and construct validity, and responsiveness to change.\(^{35,36}\)

The Tegner requires that each subject estimate their current activity level based on an ordinal scale from 0-10 where 0 represents sick leave or disability because of knee problems and 10 represents competitive sports. A higher score represents a higher level of activity.

**Impairment Level Outcome Measures**

**Pain**

A numerical rating scale was used to assess pain in this study. The pain scale used ranged from 0-10 where 0 was representative of no pain and 10 was representative of extreme pain. Subjects were asked to verbalize their pain level based on this scale.

**Active Range of Motion (AROM)**

Knee active ROM is the amount of active knee extension and flexion measured using a goniometer and therefore is measured on a continuous scale using degrees.\(^{8}\) The process of measuring knee active ROM has been investigated and results indicate good validity as well as intra-rater reliability (ICC\(_{\text{extension}} = 0.85\), ICC\(_{\text{flexion}} = 0.95\)).\(^{37}\) The standard error of measurement was determined to be 2.37 degrees.\(^{38}\)
**Isokinetic Muscle Strength (IMS)**

Isokinetic muscle strength is a measurement of the power of isolated muscles and muscle groups. Strength is measured as the quadriceps torque, work, and/or quadriceps index and is therefore measured on a continuous scale. The test-retest reliability for isokinetic muscle strength using an isokinetic dynamometer is good to excellent with an ICC of 0.94 for concentric extension and eccentric flexion.

**Activity Level Outcome Measures**

**Activity Level Components of the Self-Report Measures**

The Tegner Activity Scale and the sport activities and function sub-sections of the subjective knee evaluation form of the IKDC measure the construct of activity level. The sport activities sub-section of the IKDC lists 9 activities (going up stairs, going down stairs, kneeling on the front of your knee, squatting, sitting with knee bent, rising from a chair, running straight ahead, jumping and landing on involved leg, and starting and stopping quickly) and asks patients to subjectively report how difficult it is for them to perform these tasks from not difficult at all (score of 4) to unable to do (score of 0). The function portion of the IKDC includes 2 questions asking patients to rate the function of their knee prior to knee injury and currently on a scale of 0 to 10 with 10 being normal and 0 being the inability to perform any of your usual daily activities.

**Single-limb Single Hop Test for Distance (SLHT)**

The SLHT is a measurement of the distance a patient travels when a single hop on one limb is performed. The test-retest reliability was investigated in both a healthy population and in a population of individuals with ACL reconstruction. In healthy individuals, the ICC was 0.92, SEM as 4.61 cm, and MDC as 12.78 cm. The mean
distance traveled was 208.08-208.24 cm. In patients who had undergone an ACL reconstruction, the ICC was 0.92 and the MDC was calculated as a limb symmetry index score of 8.09% representing the ratio of the distance hopped on the operated limb to the reference limb where 100 represents perfect symmetry.

Single-limb Crossover Hop Test for Distance (CHT)

The CHT measures the distance a patient travels when three maximal crossover hops forward are performed. Crossover hops are defined as a single-limb hop from one side of a long jump tester mat to the other. The test-retest reliability was also investigated in a healthy population and population of individuals with ACL reconstruction. In healthy individuals the ICC was 0.93, SEM as 17.74 cm, and MDC as 49.17 cm. The mean distance traveled was 637.40-649.19 cm. For patients who had undergone an ACL reconstruction, the ICC was 0.84 and the MDC as a limb symmetry index score of 12.25%.

Edgren Side Step Test (ESST) and Illinois Agility Test (IAT)

The ESST was first introduced in the literature to assess lateral mobility in basketball players, and off-ice lateral agility in hockey players. As a popular test of agility in athletes, there is a need to establish the ESST’s consistency and validity with specific diagnostic groups.

The IAT is a test of motor ability, particularly running and dodging agility in healthy individuals. Distinct characteristics of the IAT test include a prone start position with a rapid transition to standing, followed by a combination of multi-directional maneuvers around obstacles. Excellent within-day reliability (r = 0.98, p < 0.001) was established with a variation of the IAT in semi-professional rugby players
using a shorter course, unknown surface of performance, and without the prone to
standing start and was found to be excellent. Numerous authors have described the IAT
as a measure of multi-directional agility for a variety of sports without establishing the
prerequisite performance metrics.

The inter-rater reliability of the ESST and IAT have been found to be excellent
suggesting that different clinicians, with proper training, can administer these tests with
confidence that their scores are precise and accurate. The ICC values for inter-rater
reliability for the agility tests ranged from 0.92 for the ESST to 0.99 for the IAT. The
implementations of the tests require simple equipment such as cones, tape, a stopwatch,
and counter. The test-rest reliability of the ESST and IAT was moderate to good for a
population of male service members. The ICC for test-retest reliability of the agility tests
ranged from 0.62 for the ESST to 0.68 for the IAT. The standard error of measurement
(SEM) for the ESST and IAT was small because of the homogeneity of the group tested
in the above research study with respect to age, gender, fitness level, and physical
occupational demands. The SEM values were 1.41 m for the ESST and 0.65 seconds for
the IAT. The responsiveness or minimal detectable change of the ESST and IAT
represents the minimum amount of performance improvement required to detect or
demonstrate true change in agility capabilities for healthy, fit, males between the ages of
18 and 40 years of age. The MDC for the ESST was 3.91 m and for the IAT was 1.80
seconds.

*Stair Measure Test (SMT)*

The SMT is a timed test that assesses how well a person can ascend and descend a
flight of stairs. The test-retest reliability of this measure has been investigated in patients
with total knee and hip arthroplasty and results indicate that is it a reliable measure in this population. The ICC was 0.90, SEM was 2.35 seconds, and the MDC was 5.49 seconds.56

Statement of Intent

A main purpose of this dissertation is to explore performance-based outcome measures (activity limitations and participation restriction measures) recommended by the clinical practice guideline for meniscal lesions in order to provide information on the reliability and validity of these measures for patients after meniscectomy, discuss the importance of these measures in treatment planning and assessing change after a PT intervention, and explore the feasibility and safety in different populations of patients with meniscus tears.

A secondary purpose of this dissertation is to identify the differences between patients with degenerative meniscus tears and non-degenerative meniscus tear by investigating recovery post-arthroscopic partial meniscectomy. Comparisons were made in terms of impairments, activity limitations, and participation restrictions utilizing both patient-reported outcomes and performance-based outcomes. These comparisons were made within 1-week of surgery, at 4-weeks post-op, and at 8-weeks post-op. Groups were also compared based on the extent to which each of these outcome measures changed between week 0 and week 8 post-meniscectomy and/or week 4 and week 8 post-meniscectomy.

Chapter 2 describes the psychometric properties of five performance-based measures in a population of patients with meniscal tears who underwent partial meniscectomy surgery. Chapter 3 reports the difference in outcomes (self-report,
impairment, and performance-based) in patients with degenerative meniscus tears versus patients with non-degenerative tears.

Specific Aim 1:

To determine the reliability, validity, and responsiveness of 5 performance-based measures (SLHT, CHT, ESST, IAT, and SMT) for patients after arthroscopic partial meniscectomy.

Hypothesis 1A:

The 5 performance-based measures (SLHT, CHT, ESST, IAT, and SMT) will demonstrate an ICC greater than 0.70 representing acceptable test-retest reliability.

Hypothesis 1B:

The 5 performance-based measures (SLHT, CHT, ESST, IAT, and SMT) will show a moderate to high correlation with the IKDC subjective knee evaluation form and the Tegner Activity Scale thus demonstrating the construct validity of these performance-based tests. These same 5 performance-based measures will also be correlated to the subscales of the IKDC subjective knee evaluation form (sports activities and function).
Specific Aim 2:

To identify demographic and pre-surgical differences between patients with non-degenerative versus degenerative meniscus tears.

Hypothesis 2A:

Patients with degenerative meniscus tears will be older and will have a higher BMI at week 0 when compared to patients with acute meniscus tears.

Hypothesis 2B:

Patients with degenerative meniscus tears will demonstrate lower scores (lower scores are worse) on both self-report measures (IKDC subjective knee evaluation form, Tegner Activity Scale) at week 0 when compared to those with acute meniscus tears.

Hypothesis 2C:

Patients with degenerative meniscus tears will demonstrate more pain and less AROM at week 0 when compared to patients with acute meniscus tears.

Hypothesis 2D:

Patients with degenerative meniscus tears will demonstrate less isokinetic strength at week 4 when compared to patients with acute meniscus tears.
Hypothesis 2E:

Patients with degenerative meniscus tears will demonstrate lower scores on the SLHT, CHT, and ESST and higher scores on the IAT and SMT indicating worse function at week 4 when compared to patients with acute meniscus tears.

Specific Aim 3:

To identify differences in post-meniscectomy recovery in patients with degenerative and non-degenerative meniscus tears. Self-report, impairment, and performance-based activity measures will be compared in patients with degenerative meniscus tears and patients with acute meniscus tears.

Recovery for all outcome measures is defined in three ways. First, recovery is based on absolute recovery and therefore the outcomes achieved at 8-weeks post-meniscectomy. Second, recovery is described as the magnitude of change between two time intervals (week 0-week 8 or week 4-week 8). Recovery for the self-report measures is defined as the change in score of the IKDC subjective knee evaluation form and Tegner Activity Scale from week 0 post-op to week 8 post-op. The same definition applies for recovery of impairments. Recovery for pain and AROM is the change from week 0-week 8. Recovery for strength is the change from week 4-week 8 because the first measurement of strength was not taken until 4-weeks post-op. This was reported as the percent difference between the involved and uninvolved limb. Recovery for the performance-based measures is defined as the change in score of the SLHT, CHT, ESST, IAT, and SMT from week 4 post-op to week 8 post-op. Finally, recovery is defined as
return to pre-morbid activity level as described by the Tegner Activity scale and the IKDC Question number 10.

Hypothesis 3A:

Patients with degenerative meniscus tears will demonstrate lower scores on the IKDC and Tegner at week 8 and will demonstrate less improvement in their IKDC and Tegner scores from week 0-week 8 when compared to patients with acute tears.

Hypothesis 3B:

Patients with degenerative meniscus tears will demonstrate more impairment at week 8 and will also demonstrate less improvement in impairments from week 0-week 8 when compared to patients with acute tears.

Hypothesis 3B.1:

Patients with degenerative meniscus tears will demonstrate more pain at week 8 and will demonstrate less of a change in pain from week 0 to week 8 when compared to patients with acute tears.

Hypothesis 3B.2:

Patients with degenerative meniscus tears will demonstrate less flexion and will be lacking more extension compared to patients with acute tears at week 8 and will demonstrate less improvement in flexion and extension from week 0 to week 8 when compared to patients with acute tears.
Hypothesis 3B.3:

Patients with degenerative meniscus tears will demonstrate less strength at week 8 and will demonstrate less improvement in strength from week 4 to week 8 when compared to patients with acute tears.

Hypothesis 3C:

Patients with degenerative meniscus tears will demonstrate scores on the performance-based measures with more activity limitations at week 8 and less of an improvement in these scores from week 4-week 8 when compared to patients with acute tears.

Hypothesis 3C.1:

Patients with degenerative meniscus tears will hop a shorter distance at week 8 and will demonstrate less of a change from week 4 to week 8 on the SLHT and CHT when compared to patients with acute tears.

Hypothesis 3C.2:

Patients with degenerative meniscus tears will demonstrate lower scores at week 8 and will demonstrate less improvement in their ability to side step on the ESST when compared to patients with acute tears.
Hypothesis 3C.3:

Patients with degenerative meniscus tears will take more time at week 8 and will demonstrate less of a change in their ability to perform agility activities on the IAT when compared to patients with acute tears.

Hypothesis 3C.4:

Patients with degenerative meniscus tears will demonstrate slower stair ascent and descent at week 8 and will demonstrate less improvement on the SMT when compared to patients with acute tears.

Hypothesis 3D:

Patients with degenerative meniscus tears will have a larger difference between pre-morbid activity levels and activity levels after 8 weeks of physical therapy as measured by the Tegner and the IKDC compared to patients with non-degenerative tears.

Methods

Sample

A convenience sample of patients who underwent an arthroscopic partial meniscectomy was recruited from the University of Miami Hospital (UMH) sports medicine clinic. Male and female patients who underwent a partial meniscectomy from March 1, 2013 to May 1, 2014 and were between the ages of 18-60 years old were
included in this study. Professional athletes, patients with a bilateral injury and/or a neurological impairment that limited their mobility and patients with other musculoskeletal pathology not related to a meniscal injury which limited their mobility (ex: ACL reconstruction) were excluded.

Subjects were categorized into one of two groups based on whether their meniscus tear was degenerative or not, based upon review of the arthroscopic images. The surgeon or the surgeon’s assistant reviewed the arthroscopic images for all subjects and categorized each subject’s tear based on the following categories; bucket handle tear, radial tear, oblique tear, longitudinal tear, undersurface tear, or complex degenerative tear. At this time they also filled out the IKDC surgical documentation form to provide additional information on the meniscus tear and articular cartilage damage present at the time of surgery. The categories of meniscus tear were further collapsed into two groups for ease of comparisons and statistical analysis. Complex degenerative tears and all other tears that could not be categorized into only one group easily were placed into the degenerative group. All other tears were placed into the non-degenerative/acute meniscus tear group.

Recruitment

Participants were recruited on their initial physical therapy (PT) visit, which was scheduled within 1-week postarthroscopic partial meniscectomy. The principal investigator (PI) asked each patient if they were willing to participate in this study. The PI explained the purpose and the design of the study and those who agreed to participate signed an informed consent. In addition, the following additional documentation was completed: the demographic form (Appendix A.1), current health assessment form
(Appendix A.2), the subjective knee evaluation form of the International Knee Documentation Committee Form (IKDC, Appendix A.3) and the Tegner Activity Scale (Appendix A.4). At this time a standard PT initial evaluation was also performed (Appendix B). Figures A.1-A.4 are located in Appendix A, which includes all self-report measures utilized during the course of this study. Appendix B includes the documentation for the PT initial evaluation used for the knee at UMH.

Assessments

Assessments were performed at initial PT evaluation (week 0), at four weeks post-meniscectomy (week 4), and 8 weeks post-meniscectomy (week 8). The week 0 assessment included a standard PT initial evaluation, which included measurements of impairments, and completion of the self-report measures. The week 4 and 8 assessments included a PT re-assessment (impairments), documentation of the same self-report measures that were filled out at initial PT evaluation, and an assessment of activity level, which included all 5 performance-based measures. In addition, isokinetic muscle strength of the involved and uninvolved quadriceps muscle was evaluated at three different velocities (60 degrees/sec, 180 degrees/sec, and 300 degrees/sec) using the Biodex system. Each re-assessment was performed at the University of Miami Hospital outpatient physical therapy clinic by the PI or the evaluating therapist. All procedures were discussed with the evaluating physical therapist before measurements were taken. If any measurements or procedure were unfamiliar to the patient, the PI demonstrated and reviewed these with each physical therapist.

Table 1.2 provides a timeline for all outcome measures used in this study. As recommended by the CPG for meniscal pathology, performance-based outcome measures
were used to assess function in this study. The following 5 previously described performance-based measures were used; the single-limb single hop test for distance (SLHT), single-limb crossover hop test for distance (CHT), Illinois agility test (IAT), Edgren side step test (ESST), and stair measure test (SMT). Both the involved lower extremity and the uninvolved lower extremity were assessed for the SLHT and CHT, but only data from the involved limb was used during this study. Three trials for each test were performed. This functional assessment was completed at UM’s Medical Wellness Center. The performance-based activity measures were recorded. Videos were used by the PI to assess the quality of movement and establish guidelines for each individual’s 4-8-week rehabilitation protocol.

<table>
<thead>
<tr>
<th>Table 1.2 – Assessment Timetable</th>
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<tbody>
<tr>
<td>Test</td>
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<tr>
<td>Standard Initial PT Evaluation</td>
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<td>Standard PT Re-assessment</td>
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<tr>
<td>Tegner Activity Scale</td>
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<td>IKDC</td>
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<td>Subjective Knee Evaluation</td>
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<td>Pain</td>
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<tr>
<td>Knee AROM (flexion, extension)</td>
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<td>Isokinetic Muscle Strength</td>
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<td>SLHT</td>
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<td>CHT</td>
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<td>ESST</td>
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<td>IAT</td>
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<tr>
<td>SMT</td>
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</table>
Self-Report Outcome Measures

*International Knee Documentation Committee Form (IKDC)*

The IKDC surgical documentation form was completed at week 0 (within 1 week post-op) by the operating surgeon. The IKDC demographic form and current health assessment form were completed by the patient at week 0. These three forms were completed only once during each subject’s course of rehabilitation. The IKDC subjective knee evaluation form was completed at three different time intervals; week 0, week 4, and week 8. A score of 100 on the IKDC was the maximum possible score and depicted optimal recovery as this indicates that the patient reports no symptoms or functional limitations related to their knee.

*Tegner Activity Scale*

The Tegner Activity Scale was completed at the same intervals as the IKDC subjective knee evaluation form: week 0, week 4, and week 8 post-op. During the first completion, each subject was also required to report their activity level before they were injured, and this was used to determine the level of recovery of the patient by comparing the scores at 8 weeks post-operatively to the previous level of activity on these two measures.

*Impairment Level Outcomes*

*Pain*

Subjects were asked to verbally rate their knee pain from 0-10 at week 0, week 4, and week 8. The goal of PT was to achieve a score of 0 using the VAS for pain by 8-weeks post-op.
**Active Range of Motion (AROM)**

Active knee flexion and extension ROM were measured at initial PT evaluation week 0, week 4 and week 8. Measurements were taken with a standard goniometer with the subject in a supine position, as recommended by the CPG. The goal of rehabilitation was to regain full active and passive ROM, which is defined as a ROM equal to the uninvolved lower extremity.

**Isokinetic Muscle Strength (IMS)**

Strength using the Biodex was assessed at week 4 and week 8. A quadriceps index was calculated as a strength test score after testing was completed by calculating (involved side maximum force/uninvolved side maximum force) x 100. The score calculated is a percentage and represents the amount of strength (work in ft./lbs.) of the involved quadriceps as it relates to the strength of the uninvolved quadriceps.

The procedure for each subject was as follows. The patient was seated on a dynamometer (Biodex) with hips positioned in 90° of flexion. The distal tibia was secured to the dynamometer force arm just proximal to the lateral malleolus, and Velcro straps were used to stabilize the thigh and pelvis. The axis of rotation was adjusted to align with the lateral condyle of the femur. To ensure that the patient is exerting a maximal effort, he/she was familiarized with the procedure and received verbal encouragement from the tester and visual feedback from the dynamometer’s real time force display.

Strength was first assessed on the uninvolved limb then the same procedure was completed for the involved limb. Instructions given to the subjects were to “kick out and pull back as fast and as hard as you can for the entire time period.” Subjects were
instructed to stop only if they had significant pain that restricted them from performing the full range of motion. The test was performed at three different speeds; 60, 180, and 300 degrees/second. The percent difference between the involved quadriceps and the uninvolved was calculated for each speed.

*Activity Level Outcome Measures*

*Single-limb Single Hop Test for Distance (SLHT)*

Subjects were allowed one practice trial to test for pain associated with jumping. If a subject experienced pain during this practice, the test was terminated. If they did not experience pain with their first jump, they were instructed to complete the hopping test. Each participant started by standing on the uninvolved limb with his or her heel in line with a starting line. They were instructed to hop as far as they could and land safely on the same leg. Once the patient hopped, a piece of tape was placed at the heel of the uninvolved limb. The distance from the starting line to the tape was measured with a measuring wheel and the total distance hopped was recorded in inches. *Figure 2.1* in Chapter 2 is an illustration of the SLHT. Each patient was then asked to complete the same task on the involved limb. Three trials were performed on both the uninvolved and involved limb, but only the second and third trials were used for psychometric testing. Each trial was video recorded so that the PI could view it at a later time in order to make decisions about treatment planning.

*Single-limb Crossover Hop Test for Distance (CHT)*

The procedure for this test was the same as the single limb hop test for distance described above, however the instructions were slightly different. Subjects started on the uninvolved leg and were required to jump for three consecutive hops for as far as they
could jump crossing from one side of a standard long jump mat to the other. **Figure 2.2** in Chapter 2 is an illustration of the CHT. Participants were also asked to perform a practice jump to assess for pain and ability to perform three trials on the involved limb. The total distance was recorded in inches as described above.

*Edgren Side Step Test (ESST)*

The course was 4m in length with four 1 m (3.28 ft.) increments identified by cones. Subjects were asked to start with their right foot in line with the first cone. This start position is a modification from how the ESST was originally described, but is consistent with current literature by Raya et al.**\(^55\)** **Figure 2.3** in Chapter 2 is an illustration of the ESST. Subjects were instructed not to cross their feet while sidestepping. On the command “Go”, the subject sidestepped to the left until their left foot touched or crossed the outside cone. The participant then sidestepped to the right until the right foot touched or crossed the right outside cone. The subject was timed for 10 seconds and 1 point was given per completion of each 1m increment marked by a cone. If the far end lines are not reached, those points were not awarded. Points were also not rewarded if the subject crossed his or her feet. Three trials of the ESST were performed, each of which was videotaped.

*Illinois Agility Test (IAT)*

The Illinois agility test course was a total of 10 meters and was marked by cones. **Figure 2.4** in Chapter 2 is an illustration of the IAT. The subject started by standing behind the starting line. This starting position was a modification from the original starting position where each person would start in a prone position. The test was modified in this way for this population of patients because of the wide age range. It was
anticipated that subjects who were older might have difficulty getting up from a prone position due to age related changes rather than impairments or activity limitation related to their recent meniscectomy. Therefore, in order to standardize this assessment, it was modified to include a standing start position. On the command “Go”, the subject would start and move as quickly through the course as possible. The time to complete each trial was recorded in seconds. Disqualification was determined if the participant failed to run the course as instructed. Three trials of the IAT were performed with a 30 second rest break in between and each trial was video recorded. The time it took to complete the course was recorded in seconds.

Stair Measure Test (SMT)

Each participant started at the bottom of a set of 9 steps (average size step, 20cm). They were instructed to ascend and descend the stairs in their usual manner and at a safe and comfortable pace. Since instructions were to climb the stairs in their usual manner, subjects were allowed to use the railing for safety and support if necessary. This was a timed test. A stopwatch was used to record the time in seconds that it took each subject to ascend and descend a flight of stairs. Figure 2.5 in Chapter 2 is an illustration of the SMT. Three trials were performed, all of which were videotaped.

Treatment

Subjects were treated by one of five physical therapists that agreed to participate in this study. These five physical therapists were chosen by the PI to assist with the treatment of these subjects, and the protocols were discussed with each physical therapist before the initiation of the study and during each subject’s episode of care.
The rehabilitation protocol consisted of 45 minutes to 1 hour of PT 2-3x/week for a total of 8 weeks. A general protocol was followed (Appendix C.1) for the first 4 weeks of rehabilitation. This protocol was developed by the PI, was based on UM’s Sports Medicine protocol for patients after meniscectomy, and included elements of manual therapy, ROM, strengthening, balance activities, gait training, and edema control. Each physical therapist was asked to follow the standardized protocol for the first 4 weeks of physical therapy. An individualized protocol was incorporated into the final 4 weeks of rehabilitation. This protocol was based on the quality of movement assessed by the PI during the 4-week functional assessment. The PI developed this protocol after watching the video recordings of all 5 performance-based measures. While watching these videos, the PI evaluated the subject’s movement and developed a list of impairments and functional limitations (Appendix C.2). An individualized protocol was developed from these findings and this protocol was given to the appropriate treating therapist to follow for the remaining 4-weeks of PT (Appendix C.3). Before initiation of the protocol, the PI discussed the objectives of the individualized protocol with the treating therapist in order to familiarize him/her with the treatment selected and goals established.

Statistical Analysis

All statistical analyses were conducted with SAS for Windows Version 9.2.

Specific Aim 1:

To determine the reliability, validity, and responsiveness of 5 performance-based measures (SLHT, CHT, ESST, IAT, and SMT) for patients after arthroscopic partial meniscectomy.
Responsiveness assesses an instrument’s ability to measure change over time or treatment. Responsiveness to change was assessed for all performance-based measures between week 4 and week 8. Effect size was calculated as follows: \( ES = \frac{\text{mean postoperative score at week 8} - \text{mean postoperative score at week 4}}{\text{standard deviation (SD) of postoperative score at week 4}} \). Small effects were considered to be greater than 0.20, moderate effects were considered to be greater than 0.50, and large effects were considered to be greater than 0.80. \(^{57}\) The standard error of measurement (SEM) was calculated as follows: \( \text{SEM} = \text{SD} \sqrt{1-R} \). The minimal detectable change (MDC) was also calculated using the following equation: \( \text{MDC} = (z\text{-score (95\% CI)} \times \text{SEM}) \sqrt{2} \).

Hypothesis 1A:

The 5 performance-based measures (SLHT, CHT, ESST, IAT, and SMT) will demonstrate an ICC greater than 0.70 representing acceptable test re-test reliability.

Patients completed 3 trials of each performance-based test. The first trial was considered a practice trial and therefore was not used to analyze reliability. Test-retest reliability was determined for each of the 5 performance-based measures based on the second and third trial. ICC was calculated and a value greater than 0.70 was considered acceptable. \(^{34}\)

Hypothesis 1B:

The five performance-based measures (SLHT, CHT, ESST, IAT, and SMT) will show a moderate to high correlation with the IKDC subjective knee
evaluation form and the Tegner Activity Scale thus demonstrating the construct validity of these performance-based tests. These five performance-based measures will also be correlated to the subscales of the IKDC subjective knee evaluation form (sports activities and function).

All five performance-based measures are meant to assess the ICF construct of activity limitation. More specifically, the SLHT and CHT measure the activity of hopping, the ESST assesses a patient’s ability to side step, the SMT evaluates climbing stairs, and the IAT measures agility or a patient’s ability to rapidly change direction. The Tegner Activity Scale and IKDC subjective knee evaluation form are both self-report outcome measures, but also measure the construct of activity limitation. The reliability and validity of these measures has already been established for patients with meniscus tears and therefore are appropriate to use in this analysis. The IKDC subjective knee evaluation form is composed of three subscales; symptoms, sports activities, and function. Additional analysis investigated the individual relationship between these subscales and the performance-based measures. Since the performance-based measures assess activities, it was hypothesized that they would be more highly correlated with IKDC function and sport activities than the full scale IKDC and/or the Tegner Activity Scale.

Construct validity for patients after arthroscopic partial meniscectomy was investigated by the correlation between the five performance-based measures with already established self-report measures that are known to assess the construct of
activity limitations, the IKDC subjective knee evaluation form and the Tegner Activity Scale.

Statistical analysis included both Pearson and Spearman correlation analysis and was first used to investigate the relationship between each functional measure and the two self-report measures used in their entirety. The Pearson correlation coefficient (r) was calculated when these performance-based measures were analyzed with respect to the IKDC due to the continuous nature of its score. The Spearman correlation coefficient was used in comparisons with the Tegner Activity Scale because it generates an ordinal score, and thus requires the use of non-parametric statistics. Additional statistical analysis included comparison of the same self-report measures with the individual components of the IKDC subjective knee evaluation form; sport activities and function. Final analysis compared the correlations for patients who had degenerative meniscus tears versus patients that had traumatic tears in order to determine if there was a stronger correlation in one group.

Specific Aim 2:

To identify demographic and pre-surgical differences between patients with non-degenerative versus degenerative meniscus tears.

Hypothesis 2A:

Patients with degenerative meniscus tears will be older and will have a higher BMI at week 0 when compared to patients with acute meniscus tears.
Statistical analysis was based on a 1-tailed hypothesis (alpha=0.05). Both parametric and non-parametric two group analyses (t-test and Wilcoxon rank sum test) were performed in order to compare the means of the degenerative group to the non-degenerative group based on age and BMI.

Hypothesis 2B:

Patients with degenerative meniscus tears will demonstrate lower scores (lower scores are worse) on both self-report measures (IKDC subjective knee evaluation form, Tegner Activity Scale) at week 0 when compared to those with acute meniscus tears.

Statistical analyses here were also based on a 1-tailed hypothesis (alpha=0.05). Parametric and non-parametric two group analyses (t-test and Wilcoxon rank sum test) were performed in order to compare the means of the degenerative group to the non-degenerative group based the IKDC subjective knee evaluation form and the Tegner Activity Scale.

Hypothesis 2C:

Patients with degenerative meniscus tears will demonstrate more pain and less AROM at week 0 when compared to patients with acute meniscus tears.

Parametric and non-parametric two group analyses (t-test and Wilcoxon rank sum test, (alpha=0.05)) were performed in order to compare the means of the degenerative group to the non-degenerative group based on pain and AROM.
Hypothesis 1D:

Patients with degenerative meniscus tears will demonstrate less isokinetic strength at week 4 when compared to patients with acute meniscus tears.

Parametric and non-parametric two group analyses (t-test and Wilcoxon rank sum test, (alpha=0.05) were performed in order to compare the means of the degenerative group to the non-degenerative group based on isokinetic strength measured by the Biodex.

Hypothesis 1E:

Patients with degenerative meniscus tears will demonstrate lower scores on the SLHT, CHT, and ESST and higher scores on the IAT and SMT at week 4 when compared to patients with acute meniscus tears.

Parametric and non-parametric two group analyses (t-test and Wilcoxon rank sum test, (alpha=0.05) were performed in order to compare the means of the degenerative group to the non-degenerative group based on the performance-based measures.

Specific Aim 3:

To identify differences in post-meniscectomy recovery in patients with degenerative and non-degenerative meniscus tears. Self-report, impairment, and performance-based outcome measures will be compared in patients with degenerative meniscus tears and patients with acute meniscus tears.
Hypothesis 3A:

Patients with degenerative meniscus tears will demonstrate lower scores on the IKDC and Tegner at week 8 and will demonstrate a smaller change in their IKDC and Tegner scores from week 0-week 8 when compared to patients with acute tears.

Statistical analysis was also based on a 1-tailed hypothesis (alpha=0.05). Parametric and non-parametric two group analyses (t-test and Wilcoxon rank sum test) were performed for this analysis. This was done to compare the mean change scores of the IKDC and Tegner in the degenerative group to the mean change scores in the non-degenerative group between week 0 and week 8.

Hypothesis 3B:

Patients with degenerative meniscus tears will demonstrate more impairment at week 8 and will also demonstrate a smaller change in impairments from week 0-week 8 when compared to patients with acute tears.

Parametric and non-parametric two group analyses (t-test and Wilcoxon rank sum test, (alpha=0.05) were also performed here to compare the mean change in pain, AROM, and strength in the degenerative group to the mean change in the non-degenerative group. Recovery was calculated for impairments based on these change scores. The change in pain and AROM were compared from week 0-week 8 and change in strength was calculated from week 4-week 8.
Hypothesis 3C:

Patients with degenerative meniscus tears will demonstrate scores on the performance-based measures with more activity limitations at week 8 and less of an improvement in these scores from week 0-week 8 when compared to patients with acute tears.

Parametric and non-parametric two group analyses (t-test and Wilcoxon rank sum test), based on a 1-tailed hypothesis, were performed in order to compare recovery in the degenerative group versus the non-degenerative group. The mean change in all five performance-based measures of the degenerative group was compared to the mean change in the non-degenerative group between week 4 and week 8.

Hypothesis 3D:

Patients with degenerative meniscus tears will have a larger difference between pre-morbid activity levels and activity levels after 8 weeks of physical therapy as measured by the Tegner and the IKDC compared to patients with non-degenerative tears.

A two group repeated measure ANOVA was used to compare the effect of time, the effect of group and the time group interaction for both the Tegner and the IKDC.
Chapter 2 – Reliability, Validity, and Responsiveness of Performance-Based Activity Level Outcome Measures

Background

In the current healthcare environment, there is an increasing emphasis on the accurate measurement of outcomes. Health outcomes are used to demonstrate the effectiveness of medical and therapeutic interventions, and these outcomes are increasingly being linked to reimbursement such that better outcomes may lead to higher levels of reimbursement. Outcomes can be used to demonstrate quality of care at an individual and population level, and can also be used to plan and manage treatment. Accurate measurement of outcomes in PT requires that the outcome measure selected is appropriate for the population and construct being investigated.

Self-report and performance-based measures are commonly used methods of measuring outcomes in PT, and these two methods have distinct advantages and disadvantages. Self-report measures are frequently used because of their practicality, low cost, low participant burden, and general acceptance. \(^{30}\) Self-report measures allow a clinician to efficiently gather information on symptoms, impairments, and activity limitations. Self-report measures are also valuable in assessing constructs with a subjective component such as quality of life or pain, both important determinants of quality of care. \(^{30}\) Common biases associated with self-report measures are recall and response bias. \(^{30}\) Recall and response bias are related to error derived from an imprecise recollection of past events that may cause a patient to over- or underestimate their current impairments and functional limitations.
Performance-based outcome measures are frequently used in the clinical setting, but are less frequently reported in the literature. In a recent meta-analysis examining the outcomes of meniscectomy, only 2 out of 6 articles reviewed actually used performance-based measures to assess outcome post-meniscectomy. The majority used only self-report measures. Performance-based measures objectively assess activity limitations through direct observation of an activity or task and therefore provide precise information about movement. Performance-based measures remove many of the issues of recall and response bias seen in self-report measures, but have disadvantages of their own. Performance-based measures can be affected by subject effort, and error can be easily introduced if there are multiple raters.

A selection of performance-based activity limitations and participation restriction measures that are recommended for patients with knee pathology have been described in the literature through the APTA’s clinical practice guidelines, but the psychometric properties have not been investigated for post-meniscectomy patients. The CPG for meniscal and articular cartilage lesions state that clinicians should use a validated patient-reported outcome measure, a general health questionnaire, and a validated activity scale for patients with knee pain and mobility impairments. Clinicians should utilize easily reproducible physical performance measures to assess activity limitation and participation restrictions associated with knee pain or mobility impairments and to assess changes in the patient’s level of function.

Hop testing has frequently been proposed as a practical, performance-based outcome measure that reflects the integrated effect of neuromuscular control, strength and confidence in the involved limb. The single-limb single hop for distance (SLHT),
single-limb triple crossover hop for distance (CHT), single-limb triple hop for distance, and the single-limb 6-meter timed hop are frequently used single-limb hop tests for individuals with knee injuries.

The CPG for meniscal lesions recommends that clinicians utilize these hop tests to assess activity limitation and participation restrictions associated with their patient’s knee pain or mobility impairments and to assess the changes in the patient’s level of function over the episode of care. The SLHT and CHT were chosen out of the 4 recommended single-limb hop tests to assess activity in this study. These hop tests have demonstrated high test-retest reliability in normal, young adults, and are often used in patients after ACL reconstruction. Data suggests that these tests are reliable for this population, but they have not been validated in patients after meniscectomy.

Other performance-based measures recommended by the CPG to assess activity limitations and participation restrictions are the 6-minute walk test, the timed up and go test, and the stair measure test (SMT). The SMT assesses how well a person can ascend and descend a flight of stairs and the reliability has been investigated in patients with total hip and knee arthroplasty. Like the hop tests, the SMT has been recommended for use in patients with meniscus tears, but no current literature has demonstrated its reliability or validity for patients after arthroscopic partial meniscectomy.

The CPG fails to include tests of multidirectional movement and therefore the Edgren Side Step Test (ESST) and Illinois Agility Test (IAT) were included in this study along with the measures that were specifically recommended by the CPG. The ESST was developed to assess an individual’s agility in the lateral direction. The reliability and validity of the ESST has been established for male non-disabled fit service members.
between the ages of 18 and 40 years old. The IAT is a test of motor ability, particularly running and dodging agility, in non-disabled individuals. Excellent reliability was established with a variation of the IAT in semiprofessional rugby players, using a shorter course, unknown performance surface, and with a modified starting position. Similar to the ESST, the IAT has also proven to be a reliable and valid measure for male non-disabled fit service members between the ages of 18 and 40 years old. Neither of these tests has been investigated for use in a population of patients after meniscectomy.

Validity of outcome measures must be established in order to determine whether a measure actually captures the construct of interest. Validity is not a characteristic of an instrument, as it can only be determined in relation to a particular question as it pertains to a defined population. Patients with degenerative versus non-degenerative meniscus tears are distinctly different and therefore may require the use of different outcome measures to accurately assess their activity limitations.

Responsiveness is the ability of the measure to detect real change. Determining the responsiveness of a measure allows the clinician to appropriately interpret whether a measurement reflects a true change in performance.

The purpose of this study is to determine the reliability, validity, and responsiveness of 5 performance-based measures (SLHT, CHT, ESST, IAT, and SMT) for patients after arthroscopic partial meniscectomy in order to show the utility of these tests in this population of patients. Due to the variability of patients with meniscus tears, a secondary purpose of this study was to compare the validity of these performance-based measures to already established self-report measures (IKDC, Tegner) in patients with degenerative meniscus tears versus patients with non-degenerative meniscus tears.
Test re-test reliability was examined for each of the 5 performance-based measures using the ICC. Validity was examined by testing the correlation of these measures with the full scale IKDC subjective knee evaluation form, the function and sport activities subsections of the IKDC, and the Tegner Activity Scale. Minimal detectable change (MDC), standard error of measurement (SEM), and effect sizes were calculated for each performance-based measure by examining these measures at two time points. Finally SEM and MDC were compared to change scores in this population and subpopulations with degenerative versus non-degenerative tears.

Methods

Sample and Recruitment

A convenience sample of patients was recruited from the UMH sports medicine clinic. Inclusion criteria were male and female patients who underwent a partial meniscectomy during the past year and were between the ages of 18-60 years old. Professional athletes, patients with a bilateral injury and/or a neurological impairment that limited their mobility and patients with other musculoskeletal pathology not related to a meniscal injury which limited their mobility (ex: ACL reconstruction) were excluded. Participants were recruited as part of a larger investigation.

Subjects were categorized into one of two groups based on whether their meniscus tear was degenerative or not, based on review of the arthroscopic images by the orthopedic surgeon. Complex degenerative tears and all other tears that could not be classified into the following categories; bucket handle tear, radial tear, oblique tear,
and/or longitudinal tear, were placed into the degenerative group. All other tears were placed into the non-degenerative group.

**Assessments**

The activity level assessments were completed at 4 and 8 weeks post-meniscectomy and included all 5 performance-based measures described earlier (SLHT, CHT, IAT, ESST, SMT). Before completing these assessments, subjects were required to warm-up. This warm-up consisted of 10 minutes on an upright or recumbent bicycle. The order of administration of the tests was SLHT, CHT, IAT, ESST, and SMT.

Both the involved lower extremity and the uninvolved lower extremity were assessed and 3 trials for each test were performed. The first trial was considered a practice trial and therefore was not included in calculation of reliability. All of the performance-based measures were completed at the University of Miami Medical Wellness Center.

**Self-Report Outcome Measures**

*The International Knee Documentation Committee (IKDC) Form*

The IKDC is a self-report outcome measure recommended for use by the CPG for meniscal lesions. It was created by a committee of international knee experts and includes multiple subsections: a demographic form, a health assessment form, subjective knee evaluation form, knee history form, surgical documentation form, and a knee examination form. These different forms can be used together or separately. The IKDC was initially designed to assess ligament injuries of the knee\textsuperscript{32,33} but has been validated for use in patients after meniscectomy.\textsuperscript{34} The subjective knee evaluation form is composed of three subcategories, symptoms, sports activities, and function, and is
considered a gold-standard for the measurement of activity limitations. As the name of the subcategories imply, the sport activities and function subcategories best represent activity limitations while the symptoms subcategory better represents impairments. The form is scored from 0-100 with 100 representing no limitations.\textsuperscript{32} A higher score on the IKDC is indicative of fewer symptoms and impairments related to the knee.

The sport activities sub-section of the IKDC lists 9 activities (going up stairs, going down stairs, kneeling on the front of your knee, squatting, sitting with knee bent, rising from a chair, running straight ahead, jumping and landing on involved leg, and starting and stopping quickly) and asks patients to subjectively report how difficult it is for them to perform these tasks from not difficult at all (score of 4) to unable to do (score of 0). The function portion of the IKDC includes 2 questions asking patients to rate the function of their knee prior to knee injury and currently. Rating is completed on a scale of 0 to 10 with 10 being normal and 0 being the inability to perform any of your usual daily activities.

*Tegner Activity Scale*

The Tegner Activity Scale has also been validated in a meniscus population with acceptable test-retest reliability, floor and ceiling effects, criterion and construct validity, and responsiveness to change.\textsuperscript{35,36} The Tegner quantifies a patient’s activity level by asking them to subjectively report their perceived level on a scale of 0-10 where a lower number represents lower activity. In a study of a group of 122 patients at least two years after undergoing surgery for a meniscal lesion, the Tegner had acceptable test-retest reliability (intraclass correlation coefficient, 0.817; 95% confidence interval, 0.75 to 0.87). The MDC was 1.0 for knees with an isolated meniscal lesion and the SEM was
0.4. The Tegner activity scale also showed a moderate effect size in the group with an isolated lesion (0.61) and a large effect size in the group with combined lesions (0.84), and had a moderate standardized response mean in the two groups (0.60 and 0.70, respectively). 

Activity Level (Performance-based) Outcome Measures

Single-Limb Single Hop Test for Distance (SLHT)

Figure 2.1 is a pictorial representation of the SLHT. Subjects were allowed one practice trial to test for pain associated with jumping. If a subject experienced significant pain during this practice, the test was terminated, and the subject continued on to the other performance-based tests. If they did not experience pain, they were allowed to complete the 2\textsuperscript{nd} and 3\textsuperscript{rd} trials of the SLHT. Each subject started by standing on the uninvolved limb with his or her heel in line with the starting line of a long jump tester mat, a non-slip mat with a soft landing surface. They were instructed to hop as far as they could and land safely on the same leg. Once the subject hopped, a piece of tape was placed at the heel of the uninvolved limb and this was used to measure the total distance hopped. This test was administered as a modification of the standardized version described in previous research, by allowing subjects to place their opposite limb for balance once they landed, increasing safety for older individuals.\textsuperscript{2} The distance hopped was measured from the heel to heel with a measuring wheel and was recorded in inches and converted to centimeters. Each subject then completed the same three trials on the involved limb; one practice trial and two test trials. Three trials were performed on both the uninvolved and involved limb. Trials were disqualified if subjects experienced significant pain or were unable to complete a single-limb hop.
Figure 2.1 – Single-limb Single Hop Test for Distance (SLHT)

Single-limb Crossover Hop Test for Distance (CHT)

Figure 2.2 is a pictorial representation of the CHT. Subjects started on the uninvolved limb and were required to jump for three consecutive hops for as far as they could jump. They were instructed to crossover from one side of the long jump tester mat alternating from one side to the other. Subjects were also required to perform a practice jump to assess for pain and ability to perform three trials on the involved limb. As with the SLHT, they were allowed to place their uninvolved limb for balance once they landed in between each hop. Trials were disqualified if the subjects experienced significant pain or were unable to complete a single-limb hop. The total distance was recorded in inches and converted to centimeters.

Figure 2.2 – Single-limb Crossover Hop Test for Distance (CHT)
**Edgren Side Step Test (ESST)**

Figure 2.3 is a pictorial representation of the ESST. The ESST was administered using a version standardized from previous literature. The units of measurement were changed from feet to meters, resulting in a slightly longer course of 4 m in length with four 1 m (3.28 ft.) increments. The starting position was modified from the original version where each subject started from the center cone to subjects starting with their right foot in line with the first cone. Each subject began in a standing position behind the far right cone. They were instructed not to cross their feet while sidestepping. On the command “Go”, the subject sidestepped to the left until their left foot touched or crossed the outside cone. The subject then sidesteps to the right until the right foot touched or crossed the right outside cone. The subject was timed for 10 seconds and 1 point was given per completion of each 1m increment marked by a cone. If the far end lines are not reached, those points are not awarded. Three trials of the ESST were performed, each of which was videotaped.

![Figure 2.3 – Edgren Side Step Test (ESST)](image)
Illinois Agility Test (IAT)

Figure 2.4 is a pictorial representation of the IAT. The IAT was also administered using a version standardized from previous literature and like the ESST was not included in the recommendation made for performance-based measures by the CPG. The Illinois agility test course is a total of 10 meters (32.8 ft.) and is marked by cones. The subject started by standing behind the starting line. This starting position was a modification from the original starting position where each subject would start in a prone position. The test was modified in this way for this population of subjects due to the general mobility required when transitioning from prone to standing. Since subjects ranged in age from 18-60 years old, transitioning from prone to standing may evaluate their individual mobility based on age related changes rather than just the function of their knee. On the command “Go”, the subject starts and moves as quickly as possible through the course. Subjects were asked to move forward and back to the start line where they then zigzag in and out of 4 cones on the way forward and back, and finally complete the course by moving in a straight line towards the finish line. The time to complete each trial was recorded in seconds. Subjects were disqualified if they failed to run the course as instructed. Three trials of the IAT were performed with a 30 second rest break in between.


Figure 2.4 – Illinois Agility Test (IAT) 

\[\text{Figure 2.4 – Illinois Agility Test (IAT)}\]

\[\text{Figure 2.4} - \text{Illinois Agility Test (IAT)}\]

\[\text{Figure 2.4} - \text{Illinois Agility Test (IAT)}\]

Stair Measure Test (SMT)

Figure 2.5 is a pictorial representation of the SMT. Each subject started at the bottom of a set of stairs that was 9 steps (average size step, 20cm). They were instructed to ascend and descend the stairs in their usual manner and at a safe and comfortable pace. Since instructions were to climb the stairs in their usual manner, subjects were allowed to use the railing for safety and support if necessary. A stopwatch was used to record the time in seconds that it took each subject to ascend and descend a flight of stairs. Three trials were performed and trials were disqualified if subjects could not complete this test as instructed.
Reliability, Validity, and Responsiveness

Reliability

Three trials of each performance-based outcome measure were recorded during each subject’s week 4 and week 8 assessments. Test re-test reliability was analyzed by comparing the 2\textsuperscript{nd} and 3\textsuperscript{rd} trial for each individual performance-based measure assessed at week 4. The first trial was eliminated from this analysis because it was the first time each subject completed the task and therefore it was considered his or her practice trial. The 2\textsuperscript{nd} and 3\textsuperscript{rd} trials were better representations of individual performance. Week 4 was chosen to assess test-retest reliability because this was the time period where the most variability in score was seen.
Validity

Hypothesis testing for construct validity involves testing the assumption that if a measure is a valid representation of a particular construct, then scores from that measure should be correlated to scores from measures of similar constructs. In this study, performance-based activity level measures were compared to the IKDC subjective knee evaluation form and the Tegner Activity Scale, both of which are gold standards and have been validated as outcomes measures that assess activity limitations and/or participation restrictions in patients after meniscectomy. Validity was assessed at week 8. The final 8-week assessment allowed for the most healing post-surgery and therefore was chosen as the most accurate representation of these performance-based measures.

Responsiveness

Responsiveness assesses an instrument’s ability to measure change over time or treatment. Responsiveness to change was assessed for all performance-based measures between week 4 and week 8. Three responsiveness measures were calculated; effect size, standard error of measurement (SEM), and minimally detectable change (MDC). Effect size provides information about the strength of a relationship between variables, in this case the week 4 and week 8 measurements for each performance-based measure. The SEM is a reliability measure that assesses response stability. The SEM estimates the standard error in a set of repeated scores, and it is the amount of error that is considered measurement error. These measures represent the change that is necessary for scores to exceed measurement error. The difference between the measures is that the MDC equation takes into account more variability and therefore is a more conservative measure of responsiveness than the SEM. In order for these performance-based measures to be
characterized as responsive to change, the change scores measured between week 4 and week 8 should be greater than at least the SEM and possibly the MDC as well.

**Statistical Analysis**

Statistical analyses were conducted with SAS for Windows Version 9.2. Test-retest reliability was determined at week 4 for each measure using the 2nd and 3rd trial for each subject. The intraclass correlation coefficient (ICC) was calculated and a value greater than 0.70 was considered acceptable.\

Construct validity for patients after arthroscopic partial meniscectomy was investigated using scores from each patient’s week 8 assessment. The five performance-based measures were compared to the IKDC subjective knee evaluation form and the Tegner Activity Scale. Statistical analysis included calculation of both Pearson correlation coefficients for the IKDC and Spearman correlation coefficient for the Tegner activity scale based on the parametric and non-parametric nature of the self-report measure respectively. Final analyses involved a comparison of the correlation of the performance-based measures to the gold standard self-report measures in the group of patients with degenerative meniscus tears versus those with non-degenerative tears.

Responsiveness to change was calculated for all five performance-based measures and included calculations of effect size, SEM, and MDC. Effect size was calculated as follows: \((\text{mean postoperative score at week 8} - \text{mean postoperative score at week 4})/\text{SD of postoperative score at week 4}\). Small effects were considered to be greater than 0.20, moderate effects were considered to be greater than 0.50, and large effects were
considered to be greater than 0.80. The SEM was calculated as follows: \( \text{SD} \times \sqrt{1 - R} \). The MDC was calculated using the following equation: \( z\text{-score (95\% CI)} \times \text{SEM} \times \sqrt{2} \).

**Results**

Table 2.1 describes the demographics of the sample. A total of 26 subjects were included in this study (22 men, 4 women; 39.7 ± 12(SD) years) with an average body mass index (BMI) of 27.2±4.3. Age ranged from 21 years old to 60 years old and BMI from 21.1 to 36.9 kg/m².

**Table 2.1 – Demographic Information for Patients after Meniscectomy**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sample Size (n)</td>
<td>26</td>
</tr>
<tr>
<td>Gender (n)</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>22</td>
</tr>
<tr>
<td>Female</td>
<td>4</td>
</tr>
<tr>
<td>Age (years, mean ± SD)</td>
<td>39.7±12</td>
</tr>
<tr>
<td>BMI (mean ± SD)</td>
<td>27.2±4.3</td>
</tr>
</tbody>
</table>

**Reliability**

Table 2.2 lists the ICC and 95% confidence intervals for each performance-based measure. Test-retest reliability was found to be excellent for all and ranged from 0.91 for the Edgren Side Step Test to 0.98 for the Stair Measure Test. This data suggests that all scores had good test-retest reliability when measured from one time to another by the same person.
Table 2.2 – Test-retest Reliability for the SLHT, CHT, ESST, IAT, and SMT Assessed at 4-Weeks Post-Menisectomy

<table>
<thead>
<tr>
<th>Functional Performance Based Test</th>
<th>ICC (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-Limb Single Hop Test for Distance (SHLT)</td>
<td>0.96 (0.91-0.98)</td>
</tr>
<tr>
<td>Single-Limb Crossover Hop Test for Distance (CHT)</td>
<td>0.97 (0.93-0.99)</td>
</tr>
<tr>
<td>Illinois Agility Test (IAT)</td>
<td>0.98 (0.96-0.99)</td>
</tr>
<tr>
<td>Edgren Side Step Test (ESST)</td>
<td>0.91 (0.81-0.96)</td>
</tr>
<tr>
<td>Stair Measure Test (SMT)</td>
<td>0.94 (0.87-0.97)</td>
</tr>
</tbody>
</table>

Validity

For the SLHT, CHT, and ESST a higher score is better and therefore indicative of better performance. The IAT and SMT are timed tests and therefore lower scores (less time in seconds) are indicative of better performance.

**Table 2.3** lists the Pearson or Spearman correlation coefficient (r) for each performance-based measure. Results indicate that at 8-weeks post-meniscectomy, the IAT and SMT were both significantly correlated with the full scale IKDC. The IAT demonstrated an inverse weak to moderate correlation \( r = -0.46, p = 0.03 \) and the SMT demonstrated an inverse moderate correlation \( r = -0.50, p = 0.01 \). Subjects with higher scores on the IKDC tended to have faster scores on the IAT and SMT, indicating better performance.

Results also indicate that at 8-weeks post-op, the CHT, IAT, and SMT were significantly correlated with the Tegner. The CHT demonstrated a weak correlation in the positive direction \( r = 0.44, p = 0.03 \) while the IAT \( r = -0.49, p = 0.02 \) and SMT
(r = -0.52, p = 0.009) demonstrated weak and moderate correlations in the negative direction. Subjects that reported a higher activity level on the Tegner hopped further and were able to complete agility activities and climb the stairs in less time.

Table 2.3 – Correlations between SLHT, CHT, ESST, IAT, and SMT and the Full Scale IKDC and the Tegner Activity Scale Assessed at 8-Weeks Post-Meniscectomy

<table>
<thead>
<tr>
<th>Self-report Measure</th>
<th>Functional Performance Measure (r, p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SLHT</td>
</tr>
<tr>
<td>IKDC Subjective Evaluation Form</td>
<td>0.08, 0.72</td>
</tr>
<tr>
<td>Tegner Activity Scale</td>
<td>0.37, 0.09</td>
</tr>
</tbody>
</table>

*Pearson r for IKDC and Spearman r for Tegner

Table 2.4 lists the Pearson correlation coefficient (r) and p-values for each of the functional performance tests and the IKDC sub-sections at week 8 post-meniscectomy. Results indicate that the IAT, ESST, and SMT are significantly correlated with the sport activities sub-section of the IKDC at 8 weeks post-op. The IAT demonstrated a moderate inverse correlation with the sport activities section of the IKDC (r = -0.54, p = 0.01). The SMT also demonstrated a moderate inverse correlation with the IKDC sport activities section (r = -0.61, p = 0.002). The ESST demonstrated a weak positive relationship (r = 0.49, p = 0.02). At week 8, IKDC function and the same performance-based measures (IAT, ESST, and SMT) were correlated. Once again the IAT (r = -0.45) and SMT
(r = -0.50) demonstrated inverse correlations as expected and the ESST (r = 0.46) demonstrated a positive correlation.

Table 2.4 shows the correlation coefficients (r) and p-values for all performance-based measures and the IKDC sub-sections and compares these values for patients with degenerative versus non-degenerate meniscus tears. Table 2.4 also shows the correlation with the Tegner Activity Scale. The group with non-degenerate tears demonstrated stronger correlations between the performance based measured and the IKDC than did the group with degenerative tears. The correlations were weaker for comparisons made with the Tegner.

Correlations between performance based measures and the subsections of the IKDC were present for subjects with non-degenerate tears but not for subjects with degenerative tears. At 8-weeks post-meniscectomy, the SLHT was moderately correlated with IKDC function (r = 0.64, p = 0.05) and the CHT was moderately correlated with IKDC sport activities (r = 0.72, p = 0.01). The IAT was highly correlated with IKDC sport activities (r = -0.85, p = 0.002) and moderately correlated with IKDC function (r = -0.73, p = 0.02). The ESST and SMT were also significantly correlated with both IKDC sport activities and function. The ESST was moderately correlated with IKDC sport activities (r = 0.70, p = 0.02) and IKDC function (r = 0.71, p = 0.01). The SMT was strongly correlated with IKDC sport activities (r = -0.87, p = 0.0006) and moderately correlated with IKDC function (r = -0.71, p = 0.01). There were no statistically significant correlations found for either group for the Tegner Activity Scale.
Table 2.4 – Correlations between SLHT, CHT, ESST, IAT, and SMT and the Self-Report Measures (Tegner Activity Scale, IKDC: Sport Activities and Function Sub-Sections) Assessed at 8-Weeks Post-Meniscectomy for Subjects with Degenerative Meniscus Tears and Non-Degenerative Meniscus Tears

<table>
<thead>
<tr>
<th>Functional Performance Measures</th>
<th>Correlation Coefficient (r), p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tegner Activity Scale</td>
</tr>
</tbody>
</table>
| **SLHT*  
Entire Group**          |                         |                       |                |
| Degenerative (11)            | 0.37, 0.09             | 0.28, 0.21            | 0.06, 0.79     |
| Non-Degenerative (10)        | 0.18, 0.60             | -0.13, 0.70           | -0.24, 0.49    |
| **CHT*  
Entire Group**         |                         |                       |                |
| Degenerative (11)            | 0.44, 0.03             | 0.34, 0.11            | 0.06, 0.77     |
| Non-Degenerative (11)        | 0.29, 0.39             | -0.08, 0.82           | -0.25, 0.46    |
| **IAT*  
Entire Group**         |                         |                       |                |
| Degenerative (11)            | -0.49, 0.02            | -0.54, 0.01           | -0.45, 0.04    |
| Non-Degenerative (10)        | -0.34, 0.30            | 0.09, 0.79            | -0.13, 0.69    |
| **ESST*  
Entire Group**        |                         |                       |                |
| Degenerative (10)            | 0.39, 0.07             | 0.49, 0.02            | 0.46, 0.03     |
| Non-Degenerative (11)        | 0.31, 0.39             | 0.32, 0.37            | 0.24, 0.51     |
| **SMT*  
Entire Group**         |                         |                       |                |
| Degenerative (12)            | -0.52, 0.009           | -0.61, 0.002          | -0.50, 0.01    |
| Non-Degenerative (11)        | -0.33, 0.29            | -0.38, 0.22           | -0.33, 0.29    |

*week 8 post-meniscectomy

**Responsiveness**

The effect size, SEM, and MDC for all performance-based measures are found in Table 2.5. Small effect sizes were calculated for the SLHT (0.27), the CHT (0.33), and the ESST (0.28) and a moderate effect size for the IAT (-0.59) and SMT (-0.51). The SEMs demonstrate that a change of 0.35 inches (0.889 cm) and 0.99 inches (2.51 cm) are required to exceed measurement error for the SLHT and CHT respectively. For the IAT and SMT, a change of 0.93 seconds and 0.44 seconds respectively are required to exceed measurement error. The ESST results show that a change of 1.49 m would be required to
exceed measurement error. The final responsiveness measure calculated was MDC, and as expected these values are higher than the SEM.

### Table 2.5 – Responsiveness Statistics for the SLHT, CHT, ESST, IAT, and SMT Calculated from 4-Weeks to 8-Weeks Post-Meniscectomy

<table>
<thead>
<tr>
<th>Performance-Based Outcome Measures</th>
<th>Effect Size</th>
<th>SEM</th>
<th>MDC</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLHT</td>
<td>0.27</td>
<td>0.89 cm</td>
<td>2.44 cm</td>
</tr>
<tr>
<td>CHT</td>
<td>0.33</td>
<td>2.51 cm</td>
<td>6.99 cm</td>
</tr>
<tr>
<td>IAT</td>
<td>-0.59</td>
<td>0.93 s</td>
<td>2.58 s</td>
</tr>
<tr>
<td>ESST</td>
<td>0.28</td>
<td>1.49 m</td>
<td>4.12 m</td>
</tr>
<tr>
<td>SMT</td>
<td>-0.51</td>
<td>0.44 s</td>
<td>1.22 s</td>
</tr>
</tbody>
</table>

### Discussion

**Reliability, Validity, and Responsiveness of the SLHT, CHT, IAT, ESST, and SMT**

Outcome measures are important tools for guiding clinical decision-making and reporting outcomes. In order to use these tools appropriately, clinicians must first understand the psychometric properties relevant to a particular patient population. Factors related to safety and feasibility should also be considered.

The benefit of performance-based measures in physical therapy is that they allow for more precise evaluation of movement. The APTA Orthopedic Section CPG recommends these measures to identify a patient’s baseline status relative to pain, function, and disability and for monitoring changes in the patient’s status throughout the course of physical therapy.

The SLHT, CHT, and SMT were recommended by the CPG for use with this population. The ESST and IAT are not included in the current practice guidelines and were added to assess multidirectional movement at 4 and 8-weeks after meniscectomy.
Current research has validated both the IKDC and the Tegner Activity Scale for patients with meniscus tears,\textsuperscript{8,32,34,36} but the activity limitation and participation restriction measures recommended by the CPG have not been validated in this population. The IKDC and Tegner are gold-standard patient-reported outcome measures that assess the construct of activity and therefore are appropriate measures with which to validate the SLHT, CHT, ESST, IAT, and SMT.

Evidence from this investigation on the psychometric properties of the performance-based measures suggests that the IAT, SMT, ESST, and CHT are reliable, valid, and responsive in patients after arthroscopic partial meniscectomy, but the safety and feasibility of these measures must also be considered when deciding if they are appropriate outcomes measures for this patient population. Evidence suggests that in the sub-group of patients with non-degenerative tears, the performance-based measures had stronger correlation with the IKDC than in the subgroup of patients with degenerative tears. These results indicate that these tests may be better suited for patients with more acute tears rather than older patients with chronic degenerative tears.

\textit{SLHT and CHT}

The SLHT (ICC=0.96) and CHT (ICC=0.97) both showed excellent test-retest reliability. Previous research exists on hop testing and reports that these tests are useful in measuring neuromuscular control, strength and confidence of the involved limb. Single-limb hop testing is often used in individuals with knee lesions to capture limb asymmetries, but has not been validated for use in patients after meniscectomy.\textsuperscript{8,40} Both the single limb single hop test for distance (ICC CI 0.92-0.96) and the single-limb crossover hop test for distance (ICC CI 0.93-0.96) have demonstrated high test-retest
reliability in normal, young adults. In addition, these tests have demonstrated reliability in patients with ACL reconstruction. These results were comparable to the results obtained in this study indicating that the SLHT and CHT are reliable and can be easily reproduced for patients after meniscectomy.

The SLHT and CHT were not correlated with the full scale IKDC at 8 weeks after meniscectomy nor were they correlated with the sport activities and function sub-sections of the IKDC, but there were some correlations found when examining the group of patients with non-degenerative tears. The CHT was however correlated with the Tegner Activity Scale. When the degenerative group and non-degenerative group were compared, results indicate that the SLHT and CHT may be valid tests for assessing activity limitations in patients with non-degenerative type tears after partial meniscectomy.

The SLHT and CHT can be used in the clinic to assess changes in patients between 4 and 8-weeks post-meniscectomy because they both demonstrate responsiveness to change. A small effect size (0.27), a SEM of 0.89 cm, and a MDC of 2.44 cm were calculated for the SLHT. A small effect size (0.33), a SEM of 2.51 cm, and a MDC of 6.99 cm were also calculated for the CHT. Responsiveness of the hop tests has previously been investigated. For healthy individuals, SEM was calculated for both the SLHT (4.61 cm) and the CHT (17.74 cm). The MDC for the SLHT was 12.78 cm and for the CHT was 49.17. It is difficult to compare these results to our results because our results are based on an injured population. MDC was reported for patients with ACL reconstruction for both hop tests, but was reported as a limb symmetry index and could not be compared to the value calculated in this study.
Figure 2.6 and 2.7 describe the change scores for the SLHT and CHT in subjects with degenerative tears and non-degenerative tears and compare these scores to the values calculated for SEM and MDC. Subjects with degenerative meniscus tears and subjects with non-degenerative tears both demonstrated SLHT change scores (week 8-week 4) greater than the SEM, but not greater than the MDC. With respect to the CHT, the change scores for subjects with degenerative tears were greater than the SEM, but not the MDC. The change scores for subjects with non-degenerative tears were greater than both the SEM and MDC.

Figure 2.6 - Comparison of the Change in SLHT from Week 4 to Week 8 in Subjects with Degenerative Tears vs. Non-Degenerative Tears and the Relationship of these Values to SEM and MDC
Figure 2.7 - Comparison of the Change in CHT from Week 4 to Week 8 in Subjects with Degenerative Tears vs. Non-Degenerative Tears and the Relationship of these Values to SEM and MDC

The SLHT and CHT were both recommended by the CPG to assess activity levels. The SLHT and CHT measure the activity of hopping. Hopping is a higher-level ballistic activity that requires good strength, stability, neuromuscular control, and proprioceptive ability of the knee, but the SLHT and CHT may not be appropriate and safe for all types of patients with meniscus tears. Hopping is a specialized activity that young patients returning to sport may need to accomplish after meniscus surgery. For patients with degenerative tears however, hopping may no longer be a functional task and therefore the SLHT and CHT may not be the most appropriate tests for use in this population.

IAT

Results from our study indicate that, for patients after partial meniscectomy, the IAT has better test re-test reliability that suggested by previous research. In a recent
study by Raya et al, the IAT was validated for use in healthy male service members and found an ICC of 0.68. In this study of patients after meniscectomy, the IAT showed excellent test-retest reliability with an ICC of 0.98.

The IAT was correlated with both the full scale IKDC and Tegner 8-weeks post-meniscectomy. For subjects with non-degenerative tears there was a strong correlation between performance on the IAT and either the function or sport activities sub-sections of the IKDC, but for subjects with degenerative tears these scores were not correlated. The IAT may be a valid instrument to assess activity in patients after meniscectomy, but should either be modified or used with caution in patients with degenerative tears.

The IAT is a useful clinical tool for assessing changes in patients between 4 and 8-weeks post-meniscectomy. The SEM and MDC calculated in this study for the IAT were 0.93 seconds and 2.58 seconds respectively. These results are comparable to the previous values established in the literature for healthy male service members, the SEM for the IAT was 0.65 seconds and the MDC was 1.80 seconds. Figure 2.8 describes the change scores for the IAT in subjects with degenerative tears and non-degenerative tears and compares these scores to the values calculated for SEM and MDC. Subjects with degenerative meniscus tears and subjects with non-degenerative meniscus tears demonstrated change scores greater than both SEM and MDC values for the IAT, further suggesting that the IAT is responsive to change.
The IAT was not included in the recommendations by the CPG, but this study suggests that it is a reliable, valid and responsive measure in assessing activity limitations in patients after partial meniscectomy. The IAT was developed as a test of motor ability, particularly running and dodging agility in healthy individuals.\textsuperscript{44,45} It is a measure of multi-directional (lateral, sagittal, and transverse) agility emphasizing the ability to accelerate and decelerate when performing a variety of maneuvers.\textsuperscript{47-52} The IAT is meant to have individuals jog or run through the course, but can be modified so that a patient can walk through the course. This adaptability makes this measure a more appropriate and safe test for patients with degenerative meniscus tears. People with degenerative meniscus tears are typically older and may not plan to return to jogging, but because the IAT is a timed test, it can measure initial activity and that can be compared to
another time period to assist with treatment planning or assess the outcome of intervention.

**ESST**

The ICC values for test-retest reliability were 0.91 for the ESST in this study of subjects with meniscus tears. The ESST has been validated for use in healthy male service members,\(^5\) and showed less than acceptable test-retest reliability (ICC=0.62) in this population. Results from our study demonstrate better test-retest reliability when compared to values calculated for healthy male service members but these results are difficult to compare.

The ESST was significantly correlated with both the sport activities and function sub-sections of the IKDC, but was not correlated with either the full IKDC or the Tegner activity scale. When comparing subjects with degenerative versus non-degenerative tears, performance on the ESST and the sections of the IKDC were not correlated for subjects with degenerative tears, but were correlated for subjects with non-degenerative tears. The ESST is a valid activity level measure, but may be more appropriate to use with patients who have a non-degenerative meniscus tear.

The ESST also appears to be responsive to change. In this sample of subjects after meniscectomy, the SEM was 1.49 m and the MDC was 4.12 m. In previous literature, the SEM was calculated as 1.41 m and the MDC 3.91 m for the ESST.\(^5\) Results of this study were comparable to values calculated in the study by Raya et al that investigated healthy male service members. **Figure 2.9** describes the change scores for the ESST in patients with degenerative tears and non-degenerative tears and compares these scores to the values calculated for SEM and MDC. Subjects with degenerative
meniscus tears and subjects with non-degenerative meniscus tears demonstrated change scores greater than both SEM and MDC values for the IAT, further suggesting that the IAT is responsive to change in this population.

Figure 2.9 - Comparison of the Change in ESST from Week 4 to Week 8 in Subjects with Degenerative Tears vs. Non-Degenerative Tears and the Relationship of these Values to SEM and MDC

The ESST was not recommended by the CPG, but appears to be a reliable, valid and responsive measure in assessing activity limitations in patients after partial meniscectomy. The Edgren Side Step Test assesses an individual’s agility in the lateral direction.\textsuperscript{58-62} The ESST has been found to be a valid measure of off-ice lateral agility in hockey players.\textsuperscript{59,60} Lateral mobility is an important activity to regain after meniscectomy surgery for all patients, but may be more difficult for patients with degenerative tears compared to non-degenerative tears. The ESST provides valuable
information to clinicians, is easily reproducible, and a patient can self-select a pace that reflects walking or running.

The SMT showed excellent test-retest reliability (ICC=0.94). Test-retest reliability has been established previously in patients with total hip and knee arthroplasty and in this population the ICC 0.90.33

The SMT has also been found to be a valid measure of activity limitation in this study and was correlated with both the sport activities and function sub-sections of the IKDC. When the sample was divided into 2 groups based on the type of tear, degenerative versus non-degenerative, SMT performance and the sections of the IKDC were not correlated in subjects with degenerative tears, however, the SMT was correlated with sections of the IKDC in subjects with non-degenerative tears.

The SMT is also responsive to change and therefore can detect a clinical difference in patients after partial meniscectomy. The SMT demonstrated a small effect size (-0.51), a SEM of 0.44 seconds, and a MDC of 1.22 seconds. In patients with total hip and knee arthroplasty,56 the SEM calculated was 2.35 seconds and the MDC was 5.49 seconds.56 Figure 2.10 describes the change scores for the SMT in subjects with degenerative tears and non-degenerative tears. Subjects with non-degenerative tears presented with change scores greater than the SEM, but not the MDC.
The SMT is a physical performance measure that assesses how well a patient can ascend and descend a flight of stairs. It was recommended by the CPG to assess activity limitation and participation restrictions associated with knee pain or mobility impairments and to assess the changes in the patient’s level of function over the episode of care. This test measures an activity that is necessary and appropriate for all individuals. The SMT is a timed test and therefore patients can complete it with whatever speed they feel comfortable. This test is also easily modifiable as demonstrated by the use of a handrail for safety in this study.

**Limitations**

The small sample size limited the power of this study to examine relationships. Another limitation was related to the standardization of assessment procedures due to the large variability in activity level of the subjects. There was one subject who could not
complete the strength assessment because of a knee problem unrelated to his meniscus tear. Three other subjects had difficulty or could not complete the single-limb hop tests; one subject could not hop because of pain in his low back and therefore this score was eliminated from analysis. The other two subjects could not complete the tests because of pain in their knee or fear of the activity and therefore these patients scored a zero on the tests they could not complete.

Conclusions and Clinical Relevance

The psychometrics of many performance-based measures have not been studied in populations of patients after partial meniscectomy surgery, and consideration of the mechanism of injury is important. The results of this study indicate that the SLHT, CHT, ESST, IAT, and SMT are reliable and valid performance-based outcome measures that can be used to assess activity limitations in patients after arthroscopic partial meniscectomy. The SLHT, CHT, ESST, IAT, and SMT are also all responsive to change in patients after arthroscopic partial meniscectomy making them appropriate to use in a clinical setting. The current clinical practice guidelines for meniscal lesions recommend the SLHT, CHT, and SMT, but exclude measures of multi-directional movement such as the ESST and IAT. Results from this study indicate that the SLHT and CHT are more appropriate for patients with non-degenerative tears than patients with degenerative tears, while the ESST, IAT, and SMT are appropriate for all patients after partial meniscectomy. Although more research is needed related to the selection of measures for patient with degenerative vs. non-degenerative meniscus tears, these 5 performance-based measures are appropriate to use in rehabilitation to assess changes in level of
function for people undergoing partial meniscectomy surgery, and can be used with confidence by clinicians working in clinical and research settings.
**Chapter 3 – Differences in Subjects with Degenerative Meniscus Tears and Non-Degenerative Meniscus Tears**

**Background**

Meniscus tears are the second most common orthopedic injury of the knee with an incidence of 12% to 14% and a prevalence of 61 cases per 100,000 persons.\(^{21,22}\) In the United States, 10% to 20% of all orthopedic surgeries consist of surgery to the meniscus on an estimated 850,000 patients each year.\(^1,2\)

Meniscus tears are commonly described based on mechanism of injury, and can be classified as either non-degenerative or degenerative. Non-degenerative tears result from excessive force applied to a normal knee and meniscus.\(^{23}\) These tears generally occur while cutting, decelerating, or landing from a jump when a mechanical non-contact force creates excessive rotation, hyper-flexion, and/or hyperextension of the knee.\(^{12}\) Non-degenerative meniscus tears may be radial, vertical-circumferential or horizontal-cleavage in orientation.\(^{16}\) Patients with non-degenerative tears are typically younger when compared to patients with degenerative tears.\(^{12}\) Degenerative tears occur most commonly in men in their fourth, fifth, and sixth decades of life.\(^{16}\) Degenerative meniscus tears result from repetitive normal forces acting on the meniscus over time.\(^{12}\) They usually have a complex tear pattern and are predominantly found in the posterior horn and mid-body of the meniscus.\(^{24}\)
Patients with degenerative tears tend to present with worse outcomes after arthroscopic partial meniscectomy compared to patients with non-degenerative tears.\textsuperscript{5,6} Englund et al reported that patients with degenerative tears had significantly worse knee function based on the Knee Injury and Osteoarthritis Outcome Score (KOOS) and poorer knee-related quality of life compared to those with traumatic or acute tears.\textsuperscript{7} Research also suggests that patients with degenerative tears have significantly lower scores on both knee-specific outcomes and the Short Form Health Survey (SF-36), except social functioning, when compared to those with traumatic tears.\textsuperscript{7}

The purpose of this study was to explore the differences in patients with degenerative versus non-degenerative tears after eight weeks of physical therapy (PT) intervention. Impairments and activity limitations were compared at three different time intervals; week 0 (within 1-week post-op), week 4 (4-weeks post-op), and week 8 (8-weeks post-op).

We hypothesized that subjects with degenerative meniscus tears would have more pain, less strength and knee range of motion (ROM), and more activity limitations when compared to subjects with non-degenerative tears, after 8 weeks of PT. We also hypothesized that subjects with degenerative meniscus tears would demonstrate less recovery in pain, strength, knee ROM, and activity limitations than subjects with non-degenerative tears after 8 weeks of PT. Finally, we hypothesized that subjects with degenerative tears would show a poorer recovery based on return to pre-morbid level of activity compared to patients with non-degenerative tears.
Methods

Sample

A convenience sample of was recruited from the University of Miami Hospital (UMH) sports medicine clinic. Male and female patients who underwent a partial meniscectomy and were between the ages of 18-60 years old were recruited for this study. Professional athletes, patients with a bilateral injury and/or a neurological impairment that limited their mobility and patients with other musculoskeletal pathology not related to a meniscal injury which limited their mobility (ex: ACL reconstruction) were excluded.

Subjects were categorized into one of two groups based on whether their meniscus tear was degenerative or not, based upon review of the arthroscopic images. The surgeon or the surgeon’s assistant categorized each subject’s tear based on the following categories; bucket handle tear, radial tear, oblique tear, longitudinal tear, undersurface tear, or complex degenerative tear. The categories of meniscus tear were then further collapsed into two groups. Complex degenerative tears and all other tears that could not be classified into one of the above-mentioned categories for meniscus tears were placed into the degenerative group, and all other tears were placed into the non-degenerative meniscus tear group.

Thirty subjects signed consent forms and were enrolled in this study. There were 4 subjects that were recruited for this study that were not compliant with physical therapy and these patients were eliminated from the study altogether. These subjects were unwilling or unable to complete the minimum of 4 weeks of physical therapy post-
meniscectomy. One additional subject was not categorized because the arthroscopic surgical images were not available. Therefore, was the final sample size was 25 subjects.

**Recruitment**

Participants were recruited on their initial PT visit, which was scheduled within 1-week post-arthroscopic partial meniscectomy. The principal investigator (PI) asked each patient if they were willing to participate in this study. The PI explained the purpose and the design of the study and an informed consent was signed. In addition, the following additional documentation was completed; the demographic form (**Appendix A.1**), current health assessment form (**Appendix A.2**), and the subjective knee evaluation form of the International Knee Documentation Committee Form (IKDC, **Appendix A.3**) as well as the Tegner Activity Scale (**Appendix A.4**). At this time a standard PT initial evaluation was also performed (**Appendix B**). **Figures A.1-A.4** are found in **Appendix A**, which includes all self-report measures utilized during the course of this study. **Appendix B** includes the documentation for the PT initial evaluation used for the knee at UMH.

**Outcome Measures**

**Demographic and Clinical Information**

**Initial Physical Therapy Evaluation**

A standard PT evaluation was performed within 1 week of surgery (week 0), and provided demographic and clinical information on each participant, which included the subject’s age, diagnosis, date of injury, and initial pain, range of motion, and strength (manual muscle test).
The IKDC has been studied in people with meniscus injury and has been found to be both reliable and valid. The IKDC was created by a committee of international knee experts and includes multiple sections including a demographic form, a health assessment form, subjective knee evaluation form, knee history form, surgical documentation form, and a knee examination form. These forms can be used together or separately. The demographic form of the IKDC is a self-report form that includes information on age, gender, height, weight and past medical history. The current health assessment form of the IKDC is also a self-report measure that provided information on current health status including a general measure of the subject’s activity level. Subjects completed the demographic and current health assessment forms of the IKDC once, at initial PT evaluation.

Symptoms

The subjective knee evaluation form is composed of three subcategories: symptoms, sports activities, and function. The entire form is scored from 0-100 with 100 representing no limitations, such that a higher score represents a better outcome. The symptoms subcategory consists of 7 questions, each of which requires the patient to grade their symptoms at the highest activity level at which they believe that they are able to function without significant symptoms, even if they are not actually performing activities at this level. Higher scores represent fewer symptoms. For purposes of this study, when just the symptoms section was scored, the highest possible score was 37 and this
represents no symptoms. The subjective knee evaluation form was completed at all 3 time intervals.

*Impairments*

**Pain**

A numerical rating scale ranged from 0-10 was used to assess pain. Subjects were asked to verbally rate their knee pain from 0-10 at week 0, week 4, and week 8 where 0 was representative of no pain and 10 was representative of extreme pain. In the full scale IKDC, pain was reverse scored such that 10 represented no pain and 0 represented extreme pain, therefore higher scores represented a more favorable condition.

**Range of Motion (ROM)**

Knee active range of motion (AROM) is the amount of active knee extension and flexion measured using a goniometer and therefore is measured on a continuous scale using degrees.\(^8,42\) Range of motion is traditionally a marker of good outcome and recovery, and is necessary for many functional tasks such as sitting, climbing stairs, and getting in and out of a car.\(^8,42\) The process of measuring knee AROM has been investigated and results indicate good validity as well as inter- and intrarater reliability.\(^42\)

Active and passive knee flexion and extension ROM were measured at initial PT evaluation, 4-weeks post-meniscectomy and 8-weeks post-meniscectomy. Measurements were taken as recommended by the clinical practice guidelines with a standard goniometer with the subject in a supine position.\(^8\)
Isokinetic Muscle Strength (IMS)

Strength is defined as the quadriceps torque, work, and/or quadriceps index and is therefore measured on a continuous scale. Strength was assessed at week 4 and week 8 using a dynamometer (Biodex).

Strength was first assessed on the uninvolved limb then the same procedure was completed for the involved limb. The procedure for each subject was as follows. The patient was seated on the Biodex with hips positioned in 90° of flexion. The distal tibia was secured to the dynamometer force arm just proximal to the lateral malleolus, and Velcro straps were used to stabilize the thigh and pelvis. The axis of rotation was adjusted so as to align with the lateral epicondyle of the femur. To ensure that the subject was exerting a maximal effort, she/he is familiarized with the procedure and receives verbal encouragement from the tester and visual feedback from the dynamometer’s real time force display. Instructions given to the subjects were to “kick out and pull back as fast and as hard as you can for the entire time period.” Subjects were instructed to stop only if they had significant pain that restricted them from performing the full range of motion. The test was performed with the knee flexed to 60, 180, and 300 degrees.

A quadriceps index was calculated as (involved side maximum force/uninvolved side maximum force) x 100. The score represents the amount of strength (work in ft./lbs.) of the involved quadriceps as it relates to the strength of the uninvolved quadriceps.
Activity Limitations

Self-Report

International Knee Documentation Committee (IKDC) Subjective Knee Evaluation Form

The sport activities sub-section of the IKDC lists 9 activities (going up stairs, going down stairs, kneeling on the front of your knee, squatting, sitting with knee bent, rising from a chair, running straight ahead, jumping and landing on involved leg, and starting and stopping quickly) and asks subjects to report how difficult it is for them to perform these tasks from not difficult at all (score of 4) to unable to do (score of 0). The function subscale of the IKDC includes 2 questions asking subjects to rate the function of their knee 1) prior to knee injury and 2) at the time of survey on a scale of 0 to 10 with 10 representing normal and 0 representing the inability to perform usual daily activities. This question was used to assess how subjects with degenerative meniscus tears and subjects with non-degenerative tears recovered after 8-weeks of rehabilitation by comparing it to their premorbid level of activity.

The IKDC subjective knee evaluation form was completed at three different time intervals; week 0 (initial PT evaluation, within 1-week post-op), week 4 (4 weeks s/p arthroscopic partial meniscectomy, from date of initial PT evaluation), and week 8 (8 weeks s/p arthroscopic partial meniscectomy.) Information on previous level of activity was collected from the IKDC, but was only collected at week 0.
**Tegner Activity Scale**

The Tegner is a single item outcome measure that uses a scale from 0-10 based on activities performed. It is frequently used to assess outcomes following treatment of knee injuries.\(^8\) The Tegner has been validated in a population of patients with meniscus injury with acceptable test-retest reliability, floor and ceiling effects, criterion and construct validity, and responsiveness to change.\(^{35,36}\)

The Tegner requires that each subject estimate their current activity level based on an ordinal scale from 0-10 where 0 represents sick leave or disability because of knee problems and 10 represents competitive sports. A higher score therefore represents a higher level of activity.

The Tegner Activity Scale was completed at the same intervals as the IKDC subjective knee evaluation form; week 0, week 4, and week 8 post-op. Like the IKDC, the Tegner was used to assess how subjects with degenerative meniscus tears and subjects with non-degenerative tears recovered with 8-weeks of rehabilitation. The self-reported previous (before surgery) activity level was compared to the current (week 4 and 8) level.

**Performance-Based**

**Single-limb Single Hop Test for Distance (SLHT)**

**Figure 2.1** is a pictorial representation of the SLHT and can be found in Chapter 2. The SLHT is a measurement of the distance a subject travels when a single hop on one limb is performed.\(^8\) The test re-test reliability has been investigated for this measure in both a healthy population and in a population of individuals with anterior cruciate ligament (ACL) reconstruction.\(^{39,40}\)
Subjects were allowed one practice trial to test for pain associated with jumping. If a subject experienced significant pain during this practice trial, the test was terminated, otherwise they were asked to complete two more trials of the hopping test. Each subject started by standing on the uninvolved limb with his or her heel in line with a starting line. They were instructed to hop as far as they could and land safely on the same leg. Once the subject hopped, a piece of tape was placed at the heel of the uninvolved limb and this was used to measure the total distance hopped. For each jump the distance was recorded in inches and was measured by a measuring wheel. Each subject was then asked to complete the same task on the involved limb. Three trials were performed on both the uninvolved and involved limb, and the average of these 3 trials was used for statistical analysis. Each trial was video recorded so that it could be viewed later.

**Single-limb Crossover Hop Test for Distance (CHT)**

This test measures the distance a subject travels when three maximal crossover hops forward are performed. The test-retest reliability was also investigated for this test in both a healthy population and population of individuals with ACL reconstruction.\(^{39,40}\)

The subject stood on the uninvolved limb, with the heel on the starting line. The subject performed three consecutive maximal hops as far as possible forward and landed on the same limb while alternately crossing over to the opposite side of a long jump hop mat. The distance hopped was measured from the starting line to the point where the heel landed after the third hop. The test was repeated on the involved limb.

**Figure 2.2** is a pictorial representation of the CHT and can be found in Chapter 2. For this test, subjects were also required to perform a practice jump to assess for pain and ability to perform three trials on the involved limb. As with the SLHT, subjects were
allowed to place their uninvolved limb for balance once they landed in between each hop. Trials were disqualified if subjects experienced significant pain or were unable to complete a single-limb hop. The total distance was recorded in inches. Three trials were performed on both the uninvolved and involved limb, and the average of these 3 trials was used for statistical analysis.

**Edgren Side Step Test (ESST)**

The ESST was first introduced in the literature to assess lateral mobility in basketball players; but psychometrics have not been established. The ESST has, however, been found to be a valid measure of off-ice lateral agility in hockey players.\(^{41,42}\)

**Figure 2.3** is a pictorial representation of the ESST and can be found in Chapter 2. The test involved a series of sidestepping maneuvers. The course was 4m in length with four 1 m (3.28 ft.) increments identified by cones. Each subject began in a standing position behind the far right cone. They were instructed not to cross their feet while sidestepping. On the command “Go”, the subject sidestepped to the left until their left foot touched or crossed the outside cone, then sidestepped to the right until the right foot touched or crossed the right outside cone. The subject was timed for 10 seconds and one point was given per completion of each 1m increment marked by a cone. If the far end lines are not reached, those points are not awarded. Points were also not rewarded if the subject crossed their legs. Three trials of the ESST were performed, each of which was videotaped.

**Illinois Agility Test (IAT)**

The IAT is a test of motor ability, particularly running and dodging agility in healthy individuals. Distinct characteristics of the IAT test include a prone start position
followed by a rapid transition to standing, followed by a combination of multi-directional maneuvers around obstacles. Excellent within-day reliability ($r = 0.98, p < 0.001$) was established with a variation of the IAT in semi-professional rugby players using a shorter course, unknown surface of performance, and without the prone to standing start and was found to be excellent. Numerous authors have described the IAT as a measure of multi-directional agility for a variety of sports without establishing the prerequisite performance metrics.

**Figure 2.4** is a pictorial representation of the IAT and can be found in Chapter 2. The Illinois agility test course is a total of 10 meters (32.8 ft.) and is marked by cones. The subject started by standing behind the starting line. This starting position was a modification from the original starting position where each person would start in a prone position. The test was modified in this way for safety in this population of patients. A certain degree of general mobility is required when transitioning from prone to standing and there was a wide range of ages (18-60 years old) included in this study.

Transitioning from prone to standing may evaluate their individual mobility based on age related changes rather than just the function of their knee. On the command “Go”, the subject started to move as quickly through the course as possible. Subjects first moved forward then backward to the start line, then they zigzagged in and out of 4 cones on the way forward and backward, and final completed the course by moving in a straight line towards the finish line. The time to complete each trial was recorded in seconds. Disqualification was determined if the subject failed to run the course as instructed. Three trials of the IAT were performed with a 30 second rest break in between.
**Stair Measure Test (SMT)**

The SMT assesses the speed at which a person can ascend and descend a flight of stairs. The test-retest reliability of this measure has been investigated in patients with total knee and hip arthroplasty and results indicate that it is a reliable measure in this population.

**Figure 2.5** is a pictorial representation of the SMT and can be found in Chapter 2. Each subject started at the bottom of a set of 9 steps (average size step, 20cm). They were instructed to ascend and descend the stairs in their usual manner and at a safe and comfortable pace. Since instructions are to climb the stairs in their usual manner, subjects were allowed to use the railing for safety and support, if necessary. A stopwatch was used to record the time in seconds that it took each subject to ascend and descend a flight of stairs. Three trials were performed, all of which were videotaped.

**Assessments**

**Table 1** in Chapter 1 provides a timeline for the assessment of the outcome measures. Three trials for each test were performed. Except for the performance-based assessments, each assessment was performed at the UMH outpatient PT clinic by the PI or the evaluating therapist. The performance-based measures were completed at the University of Miami’s (UM) Medical Wellness Center. The entire evaluation was video recorded for future analysis of impairments and functional limitations. The PI assessed the quality of movement to establish guidelines for each individual’s 4-8 week rehabilitation protocol by reviewing the videos recorded. The PI was the only person that performed the activity level assessments.
Treatment

Subjects were treated by one of five physical therapists that agreed to participate. These five physical therapists were chosen by the PI to assist with the treatment of subjects and the protocols were discussed with each physical therapist before the initiation of the study and during each subject’s 8-weeks of rehabilitation.

The rehabilitation protocol consisted of 45 minutes to 1 hour of PT 2-3x/week for a total of 8 weeks. Subjects were required to attend between 16 and 24 visits in 8 weeks. The total number of visits attended ranged from 6-26 with a mean attendance of 14.23±5.41 visits. The average number of visits for patients with non-degenerative tears during this time period was 15±5.75 visits and 13.15±5.19 for patients with degenerative tears (p = 0.21).

A general protocol was followed (Appendix C.1) for the first 4 weeks of rehabilitation. This protocol was developed by the PI and was based on UMH sports medicine protocol for patients after meniscectomy. It included elements of manual therapy, ROM, strengthening, balance activities, gait training, and edema control. This protocol was given to each treating physical therapist, and they were required to follow it for the first 4 weeks of PT.

An individualized protocol was incorporated into the final 4 weeks of rehabilitation (Appendix C.3). Objective and subjective results from the performance-based measures assessed at 4-weeks were used to develop a patient specific activity level treatment plan with the goal of returning subjects to their previous level of function after partial meniscectomy. Activity limitations were established from the five performance-based measures. These activity limitations were then further investigated in order to
determine the underlying impairments resulting in these activity limitations. Once the impairments were hypothesized, a treatment program was established to correct the impairments (Appendix C.2). For example, if a subject had difficulty pivoting/going around objects to right, the PI would consider the impairments that could affect this movement, such as ROM limitations, strength impairments, balance impairments, and pain. Since these impairments were measured as well, the PI was able to determine the possible impairments related to the activity limitations and develop an appropriate and individualized treatment plan. Using the same example, if measurement of impairments revealed left quadriceps weakness a component of the treatment plan would include left quadriceps strengthening. The protocol was given to the appropriate treating physical therapist to follow for the remaining 4-weeks of PT. Before initiation of the protocol, the PI discussed the objectives of the individualized protocol with the treating therapist in order to familiarize them with the treatment selected and the patient goals.

**Statistical Analysis**

Statistical analyses were conducted with SAS for Windows Version 9.2. Descriptive statistics were generated for all variables and data was further analyzed in order to determine the differences between subjects who presented with a degenerative meniscus tear and subjects who presented with another type of tear. In this study, recovery was conceptualized in three ways. First, it was defined by the final 8-week self-report, impairment, and performance-based outcomes. Second, recovery was defined as the magnitude of change in these same measures from either week 0 to week 8 or week 4 to week 8 and this was compared between subjects with degenerative meniscus tears and
subjects with non-degenerative meniscus tears. Finally, recovery was defined as return to premorbid level of activity as determined by pre-surgical Tegner and IKDC function scores.

For the above comparisons, statistical analysis was based on 1-tailed hypotheses and an alpha level of 0.05. Both parametric and non-parametric two group analyses, t-test and Wilcoxon rank sum test, were performed in order to compare the means of the degenerative group to the non-degenerative group based on age, BMI, previous level of activity, pain, AROM, strength, and the 5 performance-based measures.

T-test and Wilcoxon rank sum tests were used to compare differences between subjects with degenerative vs. non-degenerative tears at four time periods. These same tests were used to compare the magnitude of change from 0-8-weeks or 4-8-weeks post-meniscectomy.

To compare return to premorbid activity level in the group of subjects with degenerative vs. non-degenerative tears, a mixed model repeated measures ANOVA with two group comparison was calculated to determine an effect for time, group, and a time by group interaction.

Results

Sample Characteristics

Table 3.1 describes the characteristics of the subjects and compares the degenerative and non-degenerative groups. Thirty subjects were recruited for this study. Two of these subjects signed consent forms during their initial PT evaluation and only attended a few PT treatments. These two subjects did not continue PT through week 4 post-op. The PI contacted both of these patients via telephone and neither returned to PT.
These 2 subjects were therefore removed from the study. Another subject was removed from the study because he did not have his surgery at UMH. A fourth subject completed PT through week 4, but did not continue until his final 8-week post-op assessment. This was due to re-injuring his operated knee. This patient was also removed from the final sample. One subject was not categorized because the arthroscopic surgical images were not available making the final sample size 25 (21 men, 4 women). There were 13 subjects categorized as having degenerative meniscus tears and 12 with non-degenerative tears. The mean age of this sample was 39.6 ± 12.2 years old and the average body mass index (BMI) was 27.1 ± 4.3. Age ranged from 21 years old to 60 years old and BMI from 21.1 to 36.9 kg/m².

### Table 3.1 – Comparison of Demographic and Pre-Morbid Activity Levels for Subjects with Degenerative vs. Non-Degenerative Meniscus Tears

<table>
<thead>
<tr>
<th>Variable</th>
<th>Post-Meniscectomy Subjects</th>
<th>Degenerative Tears</th>
<th>Non-Degenerative Tears</th>
<th>P-value (t-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sample Size (n)</strong></td>
<td>25</td>
<td>13</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td><strong>Gender</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male (%)</td>
<td>21 (84.6)</td>
<td>12</td>
<td>9</td>
<td>0.24'</td>
</tr>
<tr>
<td>Female (%)</td>
<td>4 (15.4)</td>
<td>1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><strong>Age (years)</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.002</td>
</tr>
<tr>
<td>Mean±SD (min-max)</td>
<td>39.6±12.2 (21-60)</td>
<td>45.2±10.5</td>
<td>32.1±9.7</td>
<td></td>
</tr>
<tr>
<td><strong>BMI</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.05</td>
</tr>
<tr>
<td>Mean±SD (min-max)</td>
<td>27.1±4.3 (21.1-36.9)</td>
<td>28.3±4.8</td>
<td>25.4±3.2</td>
<td></td>
</tr>
<tr>
<td><strong>Previous Level of Activity</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IKDC Subjective Knee Eval Form (Question #10) Mean±SD (min-max)</td>
<td>9.31±1.26 (5-10)</td>
<td>9.33±1.07</td>
<td>9.23±1.48</td>
<td>0.42</td>
</tr>
<tr>
<td><strong>Tegner</strong></td>
<td></td>
<td></td>
<td></td>
<td>0.006</td>
</tr>
<tr>
<td>Mean±SD (range)</td>
<td>6.5±1.6 (2-10)</td>
<td>5.8±1.6</td>
<td>7.4±1.2</td>
<td></td>
</tr>
</tbody>
</table>

*t-test for chi-square
Patients with degenerative versus non-degenerative meniscus tears were older (45.2 ±10.5 vs. 39.6±12.2, p = 0.02) and more overweight (28.3±4.8 versus 25.4±3.2, p = 0.05).

Previous level of activity was quantified into two ways, based on 1) one question of the IKDC function sub-section of the subjective knee evaluation form and 2) one question from the Tegner Activity Scale. Subjects with degenerative meniscus tears reported on average a lower level of activity based on the Tegner than subjects with non-degenerative tears (5.8±1.6 vs. 6.5±1.6, p = 0.006). There was no difference in premorbid activity level based on the IKDC scores between the two groups.

**Table 3.2** describes the differences in previous level of activity based on the Tegner for subjects with degenerative tears vs. subjects with non-degenerative tears. None of the subjects with degenerative meniscus tears reported their previous level of activity within the highest three levels of activity represented by the Tegner whereas five subjects with non-degenerative tears considered themselves competitive before injury to their meniscus.

**Table 3.3** describes the differences in previous level of activity based on the IKDC demographic form for subjects with degenerative tears versus subjects with non-degenerative tears. There was an equal distribution of subjects in the degenerative group in each category of the IKDC. In the non-degenerative group there were no subjects who considered themselves non-sporting.
Table 3.2 – Comparison of Tegner Previous Level of Activity for Subjects with Degenerative Tears vs. Non-Degenerative Tears

<table>
<thead>
<tr>
<th>Tegner Categories (See Appendix IV)</th>
<th>Degenerative (n)</th>
<th>Non-Degenerative (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10 Competitive Sports</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>9 Competitive Sports</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>8 Competitive Sports</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>7 Competitive/Recreational Sports</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>6 Recreational Sports</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>5 Work, Competitive/Recreational Sports</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>4 Work</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>3 Work</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2 Work, Walking</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1 Work</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0 Sick Leave or Disability</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>n</td>
<td>13</td>
<td>12</td>
</tr>
</tbody>
</table>

Table 3.3 – Comparison of IKDC Previous Level of Activity for Subjects with Degenerative Tears vs. Non-Degenerative Tears

<table>
<thead>
<tr>
<th>IKDC Categories (Question #10 Demographic Form)</th>
<th>Degenerative (n)</th>
<th>Non-degenerative (n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High competitive sports</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>Well trained and frequently sporting</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Sporting sometimes</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Non-sporting</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>n</td>
<td>13</td>
<td>12</td>
</tr>
</tbody>
</table>

*p-value for chi-square = 0.32
Table 3.4 describes subjects based on the characteristics of a meniscus tear and compares them for the two groups. Statistically significant differences were found between the groups based on history of OA. The degenerative subgroup had a much higher percentage of OA in all compartments compared to the non-degenerative group with the largest difference being in OA of the femoral condyles and patella. Differences based on location of tear and zone of vascularity were not statistically significant.

Table 3.4 - Comparison of Characteristics Related to the Pathology of a Meniscus Tear for Subjects with Degenerative vs. Non-Degenerative Meniscus Tears

<table>
<thead>
<tr>
<th></th>
<th>Degenerative (%)</th>
<th>Non-Degenerative (%)</th>
<th>p-value ($X^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Location of Tear</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial meniscus tear</td>
<td>50%</td>
<td>84.62%</td>
<td>0.06</td>
</tr>
<tr>
<td>Lateral meniscus tear</td>
<td>50%</td>
<td>15.38%</td>
<td></td>
</tr>
<tr>
<td><strong>Zone of Vascularity</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red-red zone</td>
<td>0</td>
<td>16.67%</td>
<td>0.36</td>
</tr>
<tr>
<td>Red-white zone</td>
<td>63.64%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>White-white zone</td>
<td>36.36%</td>
<td>33.33%</td>
<td></td>
</tr>
<tr>
<td><strong>History of OA</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tibial OA</td>
<td>69.23%</td>
<td>25%</td>
<td>0.03</td>
</tr>
<tr>
<td>Femoral OA</td>
<td>69.23%</td>
<td>16.67%</td>
<td>0.008</td>
</tr>
<tr>
<td>Patella OA</td>
<td>58.33%</td>
<td>8.33%</td>
<td>0.009</td>
</tr>
</tbody>
</table>

Differences between Subjects with Degenerative Meniscus Tears and Subjects with Non-Degenerative Meniscus Tears at Week 0

Table 3.5 describes the differences in self-report (IKDC, Tegner) and impairment level measures (pain, AROM) at week 0. Initial scores on the patient-reported outcome measures (week 0) and initial measurements of impairments (week 0) were compared in
subjects with degenerative meniscus tears to subjects with non-degenerative meniscus tears. Statistically significant differences were found between the groups for the IKDC (p = 0.01) and active extension ROM (p = 0.007). The degenerative group subjectively reported more pain and knee related symptoms (35.4±9.1) compared to the non-degenerative group (46.2±13.8). The degenerative group lacked more active extension ROM (-5.2±3.2) compared to the non-degenerative group (-1.8±3.0).

Results of this study indicate that patients with degenerative meniscus tears and those with non-degenerative meniscus tears are distinctly different 1 week after surgery.

Table 3.5 - Comparison of Self-Report and Impairment Level Outcomes for Subjects with Degenerative vs. Non-Degenerative Meniscus Tears at Week 0

<table>
<thead>
<tr>
<th>Variable</th>
<th>Degenerative (mean +/- SD)</th>
<th>Non-Degenerative (mean +/- SD)</th>
<th>p-value (t-test, Wilcoxon)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Report Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IKDC Subjective Knee Evaluation Form</td>
<td>35.4±9.1</td>
<td>46.2±13.8</td>
<td>0.01</td>
</tr>
<tr>
<td>Tegner Activity Scale</td>
<td>1.9±1.3</td>
<td>1.8±1.3</td>
<td>0.41</td>
</tr>
<tr>
<td><strong>Impairment Level Outcomes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain (SPL)</td>
<td>3.3±1.5</td>
<td>4.2±2.7</td>
<td>0.22</td>
</tr>
<tr>
<td>Range of Motion (Degrees)</td>
<td>98.4±14.3</td>
<td>98.3±32.7</td>
<td>0.50</td>
</tr>
<tr>
<td>Active Flexion</td>
<td>-5.2±3.2</td>
<td>-1.8±3.0</td>
<td>0.007</td>
</tr>
</tbody>
</table>

Differences between Subjects with Degenerative Meniscus Tears and Subjects with Non-Degenerative Meniscus Tears at Week 4

Table 3.6 describes the differences in self-report (IKDC, Tegner), impairment (pain, AROM, strength) and activity level measures (SLHT, CHT, ESST, IAT, SMT) at week 4. Isokinetic strength and activity level measurements were initially taken at week 4. The impairment level and self-report measures were re-assessed at week 4. There
were no statistically significant difference between subjects with degenerative meniscus tears and non-degenerative meniscus tears at any of the speeds assessed for strength or any of the performance-based measures. Subjects with non-degenerative tears reported significantly more pain (1.83±1.64) four weeks after surgery than subjects with degenerative meniscus tears (0.58±1.08).

Table 3.6 - Comparison of Self-Report, Impairment, and Activity Level Outcomes for Subjects with Degenerative vs. Non-Degenerative Meniscus Tears at Week 4

<table>
<thead>
<tr>
<th>Variable</th>
<th>Degenerative (mean +/- SD)</th>
<th>Non-Degenerative (mean +/- SD)</th>
<th>p-value (t-test, Wilcoxon)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Report Outcomes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IKDC</td>
<td>66.40±15.49</td>
<td>70.21±14.91</td>
<td>0.27</td>
</tr>
<tr>
<td>Tegner</td>
<td>4.46±1.13</td>
<td>4.75±1.86</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Impairment Level Outcomes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain (SPL)</td>
<td>0.58±1.08</td>
<td>1.83±1.64</td>
<td>0.019</td>
</tr>
<tr>
<td>AROM (Degrees)</td>
<td>131.8±9.09</td>
<td>135±10.5</td>
<td>0.22</td>
</tr>
<tr>
<td>Flexion</td>
<td>-1±1.13</td>
<td>-0.67±0.89</td>
<td>0.21</td>
</tr>
<tr>
<td>Extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isokinetic Muscle Strength (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 degrees/sec</td>
<td>0.77±0.32</td>
<td>0.87±0.27</td>
<td>0.2</td>
</tr>
<tr>
<td>180 degrees/sec</td>
<td>0.79±0.27</td>
<td>0.9±0.22</td>
<td>0.15</td>
</tr>
<tr>
<td>300 degrees/sec</td>
<td>0.8±0.22</td>
<td>0.94±0.21</td>
<td>0.073</td>
</tr>
<tr>
<td><strong>Activity Level Outcomes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Limb Hop Test for Distance (in)</td>
<td>3.37±1.66</td>
<td>4.04±1.87</td>
<td>0.18</td>
</tr>
<tr>
<td>Crossover Hop Test for Distance (in)</td>
<td>9.32±4.70</td>
<td>9.98±6.49</td>
<td>0.39</td>
</tr>
<tr>
<td>Stair Measure Test (sec)</td>
<td>6.99±1.94</td>
<td>5.82±1.57</td>
<td>0.062</td>
</tr>
<tr>
<td>Illinois Agility Test (sec)</td>
<td>26.35±6.28</td>
<td>22.81±6.76</td>
<td>0.094</td>
</tr>
<tr>
<td>Edgren Side Step Test (m)</td>
<td>19.75±5.67</td>
<td>19.86±4.85</td>
<td>0.48</td>
</tr>
</tbody>
</table>

Differences between Subjects with Degenerative Meniscus Tears and Subjects with Non-Degenerative Meniscus Tears at Week 8

Table 3.7 describes the self-report, impairment, and activity level impairments for patients with degenerative tears vs. non-degenerative tears at 8-weeks post-op. Pain was the only outcome measured at week 8 where a statistically significant differences was found between the groups (p = 0.04). Subjects with non-degenerative meniscus tears
still reported more pain (0.67±1.23) at 8-weeks post-op compared to subjects with degenerative meniscus tears (0±0). There was a small difference in SLHT and CHT scores between the two groups at 8 weeks such that subjects with degenerative tears hopped a slightly shorter distance than those with non-degenerative tears, but this difference was not statistically significant.

Table 3.7 - Comparison of Self-Report, Impairment, and Activity Level Outcomes for Subjects with Degenerative vs. Non-Degenerative Meniscus Tears at Week 8

<table>
<thead>
<tr>
<th>Variable</th>
<th>Degenerative (mean +/- SD)</th>
<th>Non-Degenerative (mean +/- SD)</th>
<th>p-value (t-test, Wilcoxon)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Report Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IKDC Subjective Knee Evaluation Form</td>
<td>79.85±15.69</td>
<td>77.63±15.56</td>
<td>0.36</td>
</tr>
<tr>
<td>Tegner Activity Scale</td>
<td>5.5±1.94</td>
<td>6.17±2.25</td>
<td>0.17</td>
</tr>
<tr>
<td><strong>Impairment Level Outcomes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain (SPL)</td>
<td>0±0</td>
<td>0.67±1.23</td>
<td>0.044</td>
</tr>
<tr>
<td>Range of Motion (Degrees)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active Flexion</td>
<td>134.1±10.13</td>
<td>136.5±6.86</td>
<td>0.25</td>
</tr>
<tr>
<td>Active Extension</td>
<td>-0.15±1.57</td>
<td>0.27±1.10</td>
<td>0.23</td>
</tr>
<tr>
<td><strong>Isokinetic Muscle Strength (%)</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 degrees/sec</td>
<td>0.81±0.27</td>
<td>0.85±0.20</td>
<td>0.37</td>
</tr>
<tr>
<td>180 degrees/sec</td>
<td>0.90±0.23</td>
<td>0.84±0.16</td>
<td>0.26</td>
</tr>
<tr>
<td>300 degrees/sec</td>
<td>0.85±0.19</td>
<td>0.91±0.094</td>
<td>0.20</td>
</tr>
<tr>
<td><strong>Activity Level Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Single Limb Hop Test for Distance (in)</td>
<td>4.16±1.29</td>
<td>5.06±1.13</td>
<td>0.054</td>
</tr>
<tr>
<td>Crossover Hop Test for Distance (in)</td>
<td>11.05±4.15</td>
<td>13.38±3.79</td>
<td>0.092</td>
</tr>
<tr>
<td>Stair Measure Test (sec)</td>
<td>5.46±1.34</td>
<td>5.05±1.42</td>
<td>0.24</td>
</tr>
<tr>
<td>Illinois Agility Test (sec)</td>
<td>21.25±2.49</td>
<td>20.54±3.85</td>
<td>0.31</td>
</tr>
<tr>
<td>Edgren Side Step Test (m)</td>
<td>21.07±4.04</td>
<td>22.97±4.71</td>
<td>0.17</td>
</tr>
</tbody>
</table>

Differences between the Magnitude of Change for Subjects with Degenerative Meniscus Tears and Subjects with Non-Degenerative Meniscus Tears from Week 0 – Week 8 and Week 4-Week 8

Table 3.8 describes the change in self-report, impairment, and activity level impairments for patients with degenerative tears versus non-degenerative tears from week
0-week 8 and week 4-week 8 when appropriate. **Figures 3.1, 3.2, and 3.3** provide a representation of the magnitude of change for the self-report, impairment, and activity level measures for patients with degenerative tears vs. non-degenerative tears. The magnitude of change was analyzed between initial self-report (week 0), impairment (week 0), and performance-based measures (week 4) and final measurements (week 8).

Patients with degenerative tears demonstrated a greater magnitude of change from week 0 to week 8 on the IKDC than did patients with non-degenerative tears (44.48±13.43 vs. 34.11±20.98, p=0.42). Patients with degenerative meniscus tears showed a greater magnitude of change from week 0 to week 8 in active extension ROM than did patients with non-degenerative meniscus tears (5±3.21 vs 2±3.26, p=0.17). Finally, patients with degenerative tears demonstrated a greater change in their speed climbing stairs from week 4 to week 8) compared to patients with non-degenerative tears (1.55±1.47 vs. -0.70±0.42, p= 0.24).

**Table 3.8 - Comparison of the Change in Self-Report, Impairment, and Activity Level Outcomes for Subjects with Degenerative vs. Non-Degenerative Meniscus Tears from Week 0-Week 8 or Week 4-Week 8**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Degenerative (mean +/- SD)</th>
<th>Non-Degenerative (mean +/- SD)</th>
<th>p-value (t-test, Wilcoxon)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Self-Report Measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IKDC Subjective Knee Evaluation Form</td>
<td>44.48±13.43</td>
<td>34.11±20.98</td>
<td>0.042</td>
</tr>
<tr>
<td>Tegner Activity Scale</td>
<td>3.62± 1.89, 4</td>
<td>4.33±2.31, 5</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>Impairment Level Outcomes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pain (SPL)</td>
<td>-3.31±1.55</td>
<td>-3.33±2.64</td>
<td>0.49</td>
</tr>
<tr>
<td>Range of Motion (Degrees)</td>
<td>35.69±19.05</td>
<td>41.64±33.60</td>
<td>0.30</td>
</tr>
<tr>
<td>Active Flexion</td>
<td>5.0±3.21</td>
<td>2.0±3.26</td>
<td>0.017</td>
</tr>
<tr>
<td>Active Extension</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Isokinetic Muscle Strength (%)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60 degrees/sec</td>
<td>0.05±0.28</td>
<td>-0.02±0.24</td>
<td>0.26</td>
</tr>
<tr>
<td>180 degrees/sec</td>
<td>0.11±0.28</td>
<td>-0.04±0.16</td>
<td>0.074</td>
</tr>
<tr>
<td>300 degrees/sec</td>
<td>0.05±0.16</td>
<td>-0.03±0.24</td>
<td>0.19</td>
</tr>
<tr>
<td>Activity Level Measures</td>
<td>0.78±0.94</td>
<td>0.59±0.77</td>
<td>0.31</td>
</tr>
<tr>
<td>-------------------------</td>
<td>------------</td>
<td>------------</td>
<td>------</td>
</tr>
<tr>
<td>Single Limb Hop Test for Distance (in)</td>
<td>1.63±3.27</td>
<td>3.02±3.89</td>
<td>0.19</td>
</tr>
<tr>
<td>Crossover Hop Test for Distance (in)</td>
<td>-1.55±1.47</td>
<td>-0.70±0.42</td>
<td>0.04</td>
</tr>
<tr>
<td>Stair Measure Test (sec)</td>
<td>-4.38±4.98</td>
<td>-3.14±3.30</td>
<td>0.26</td>
</tr>
<tr>
<td>Illinois Agility Test (sec)</td>
<td>1.78±5.92</td>
<td>2.97±3.93</td>
<td>0.30</td>
</tr>
<tr>
<td>Edgren Side Step Test (m)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 3.1 – Recovery in Subjects with Degenerative Tears vs. Non-Degenerative Tears Based on the Self-Report Measures (IKDC and Tegner)
Figure 3.2 – Recovery in Subjects with Degenerative Tears vs. Non-Degenerative Tears Based on Impairments (Pain, AROM, Strength)
Figure 3.3 – Recovery in Subjects with Degenerative Tears vs. Non-Degenerative Tears Based on the Performance-Based Measures (SLHT, CHT, ESST, IAT, SMT)
Results indicate that patients with degenerative meniscus tears recover well in the 8-weeks following meniscectomy. This is evidenced by the fact that, except for pain, there are no significant differences between these subjects and subjects with non-degenerative tears at week 8 and subjects with degenerative meniscus tears demonstrate a greater magnitude of change in some of the measures evaluated (IKDC, AROM, and the SMT). In addition, subjects with degenerative meniscus tears nearly recover to their previous level of activity reported on the IKDC and Tegner.

**Figure 3.4** provides a graphical representation of the previous level of activity for both the Tegner and IKDC and how this level changed over 8-weeks of physical therapy. Subjects with degenerative tears were compared to subjects with non-degenerative tears. No differences were found between the pre-morbid and 8-week scores on the Tegner and this was true for subjects with degenerative meniscus tears and subjects with non-degenerative tears.

Subjects with degenerative tears had a mean lower previous level of activity based on the Tegner (5.8±1.6) compared to patients with non-degenerative tears (7.4±1.2) and this difference was statistically significant (p = 0.006). Patients with degenerative tears also had a mean higher activity level based on question #10 on the IKDC subjective knee evaluation form (9.33±1.07) compared to patients with non-degenerative tears (9.23±1.48) on the IKDC, but this difference was not statistical significant (p = 0.42).

After 8-weeks of PT, patients with degenerative tears still reported a lower Tegner activity level (5.54±1.94) compared to patients with non-degenerative tears (6.17±2.25), but this difference was not statistically significant (p = 0.17). Based on question #10 of the IKDC, patients with degenerative tears reported an 8.15 compared to
an 8 reported by patients with non-degenerative tears, which was also not statistically significant (p=0.42).

Similar trends in recovery to previous level of activity were seen with respect to patients with degenerative meniscus tears and patients with non-degenerative meniscus tears. Neither group returned to pre-morbid levels of IKDC function, nor there was no difference in recovery between the two groups. Patients with degenerative meniscus tears had the same activity related to baseline activity as patients with non-degenerative tears (p = 0.91). There was also no interaction of group and time (p = 0.61). Although neither group returned to premorbid function, there was no difference in recovery. For the Tegner, there was no effect for time, no differences were found in premorbid and 8 week score in either group (p = 0.17). There also was no interaction effect meaning the 2 groups were the same over time and therefore there was no difference in recovery (p = 0.15). Finally, there was no effect found for group and therefore no difference between the groups, although differences approached significance 5.33 vs. 7.45, p = 0.06), and perhaps a larger sample might have had significant findings. Patients with degenerative meniscus tears were closer to returning to their previous level of activity.
Figure 3.4 – Recovery Based on Previous Level of Activity Subjectively Reported on the Tegner and IKDC

Previous Activity Level: IKDC

Previous Activity Level: Tegner
Discussion

Patients with degenerative meniscus tears are a distinctly different population of patients than patients with non-degenerative tears. These patients are significantly older, more overweight, and have a lower level of activity before injury than patients with non-degenerative meniscus tears. These differences can be mostly explained by the mechanism of injury. Younger patients are more likely to have an acute traumatic event as the cause of their meniscal pathology while degenerative tears result from repetitive normal forces acting upon the meniscus over time.\textsuperscript{12}

Within 1 week of surgery (week 0), subjects with degenerative meniscus tears subjectively felt worse (IKDC) and were lacking more active knee extension than subjects with non-degenerative tears. An explanation for this may be related to the chronicity of degenerative meniscus tears. The chronic wear and tear of this injury leads to a greater potential for pain, impairments, and activity limitations and these factors all have an effect on recovery after arthroscopic partial meniscectomy.

Despite differences seen early in the rehabilitation process, 4-weeks post-meniscectomy, the only significant difference found between subjects with degenerative meniscus tears and subjects with non-degenerative tears was pain. Subjects with degenerative tears reported less knee pain at 4-weeks than subjects with non-degenerative tears. This is the opposite of what was hypothesized and conflicts with research that reports an increase in pain sensitivity with age.\textsuperscript{69,70} More recent research on the mechanisms of pain state that under circumstances where pain is likely to persist, older people are especially vulnerable to the negative impacts of pain.\textsuperscript{71} This may offer a better explanation related to the chronicity of pain in patients with degenerative meniscus
tears. Perhaps these patients are so accustomed to pain that once the pain is reduced, they feel and subjectively report a larger reduction in pain.

Subjects with degenerative meniscus tears still reported significantly less pain at 8-weeks post-op compared to subjects with non-degenerative tears. In fact, at 8-weeks none of the subjects with degenerative tears reported pain, but there was very little pain in either group. It was hypothesized that subjects with degenerative tears would present with lower scores on the IKDC and Tegner, more pain, less ROM and strength, and lower activity levels based on the performance-based measures used in this study. Results suggest that subjects with degenerative meniscus tears actually recovered just as well as subjects with non-degenerative tears, as there were no statistically significant differences found between the groups for any of the outcomes measured except for pain. These results are not consistent with literature stating that patients with degenerative tears present with worse outcomes. As previously stated, Englund et al reported that patients with degenerative tears had significantly worse knee function based on the KOOS and poorer quality of life because of their knee compared to those with traumatic/acute tears. Patients with degenerative tears had significantly lower scores on both knee-specific outcomes and the SF-36 when compared with those with traumatic tears.

In this study, data was analyzed and subjects were compared based on their final outcomes, but also based on the magnitude of change. When compared in this way, subjects with degenerative tears demonstrated greater improvement with respect to the IKDC, AROM, and the SMT.

The rationale behind this greater magnitude of change is that subjects with degenerative meniscus tears reported they were subjectively worse on the IKDC and had
more deficits in AROM at week 0 compared to subjects with non-degenerative tears. Subjects with degenerative tears also did not climb the stairs as well as subjects with non-degenerative tears four weeks after surgery. The initial self-report, impairment and activity level measurements taken were worse and therefore there was a greater potential for change with eight weeks of physical therapy. This is not to say, however, that patients with degenerative tears do not recover as well as those with non-degenerative tears. In fact, results of this study indicate that they do.

An additional indicator that subjects with degenerative meniscus tears recovered well was comparison to their previous level of activity. Subjects with degenerative tears had a mean lower previous level of activity based on the Tegner (5.8±1.6) compared to those with non-degenerative tears (7.4±1.2) and this difference was statistically different (p = 0.0057). Subjects with degenerative tears also had a mean higher activity level based on question #10 on the IKDC subjective knee evaluation form (9.33±1.07) compared to those with non-degenerative tears (9.23±1.48) on the IKDC, but this difference was not statistically significant (p = 0.42).

After 8 weeks of PT, subjects with degenerative tears still reported a lower Tegner activity level (5.54±1.94) compared to those with non-degenerative tears (6.17±2.25), but this difference was not statistically significant (p = 0.17). Based on question #10 of the IKDC, patients with degenerative tears reported an 8.15 compared to an 8 reported by patients with non-degenerative tears, which was also not statistically significant (p = 0.42).

Similar trends in recovery to previous level of activity were seen with respect to subjects with degenerative meniscus tears and subjects with non-degenerative meniscus
tears. Neither group returned to pre-morbid levels of IKDC function nor there was no difference in recovery between the two groups. Subjects with degenerative meniscus tears had the same change related to baseline activity as those with non-degenerative tears (p = 0.91). There was also no interaction of group and time (p = 0.61). Although neither group returned to premorbid function, there was no difference in recovery. For the Tegner, there was no effect for time, no differences were found in premorbid and 8 week score in either group (p = 0.17). There also was no interaction effect meaning the 2 groups were the same over time and therefore there was no difference in recovery (p = 0.15). Finally, there was no effect found for group and therefore no difference between the groups, although differences approached significance (5.33 vs. 7.45, p = 0.06), and perhaps a larger sample might have had significant findings. Subjects with degenerative meniscus tears were closer to returning to their previous level of activity when compared to those with non-degenerative tears, and this point may have clinical relevance. A goal of PT after meniscectomy is to return patients to their previous level of function and patients with degenerative tears could potentially exceed their previously reported level of activity and are therefore good candidates for surgery and rehabilitation following surgery.

Clinicians expect that patients with degenerative tears will recover differently when compared to patients with more traumatic/acute tears. This prognosis is typically based on more easily identifiable characteristics such as the patient’s age and BMI. Patients with degenerative tears are often older (>40 years old), have a higher BMI, are associated with a more chronic history of knee pain, and more knee related impairments and functional limitations when compared to patient with more acute traumatic meniscus
tears. Previous research suggests that patients with degenerative tears have worse outcomes when compared to patients with traumatic meniscus tears. Results of this study are contrary to these results. Recovery is similar eight weeks after meniscectomy for subjects with degenerative tears and subjects with non-degenerative tears, and subjects with degenerative meniscus tears actually show a greater change in recovery with eight weeks of rehabilitation for the IKDC, pain, active extension, strength at 180 and 300deg/sec, and the IAT and SMT. Additional research is needed in this area to investigate the effectiveness of physical therapy in a subgroup of patients with degenerative meniscus tears.

**Limitations**

A limitation of this study was that we did not control for age, because age is linked to the mechanism of meniscus injury. While older subjects can have non-degenerative tears, degenerative meniscus injuries do not typically occur in young subjects. Non-degenerative tears in older subjects are likely to have some degenerative elements. It is difficult to separate the effect of age on patients with degenerative tears.

Lack of standardization of treatment frequency was another limitation of this study and this was mainly due to patient non-compliance. Most patients were compliant for the first four weeks of rehab, but from four to eight weeks there was a significant drop-off of attendance. For the last four weeks of rehab, the average attendance was 4.96±4.35 visits. Patients should have attended at least eight sessions during their final four weeks of PT. Despite non-compliance in some patients, there was no relationship found between number of PT sessions and any of the outcome measures.
Another limitation of this study was the sample size. The sample size was small and therefore there may not have been enough power to demonstrate all the potential differences between these groups. Sample size analysis for a power of 80% to be achieved in this study recommended a sample size of 100. Power analysis for a t-test with an alpha level of 0.05 and a one-tailed hypothesis revealed that the differences in the means found for the performance-based measures in this study only had 33% power. A much smaller sample size of 26 was actually recruited, but even with the low number of subjects, differences were found between patients with degenerative tears and patients with non-degenerative tears.

Additional limitations related to the sample are specific to data collection and ability of patients to perform each of the performance-based measures accurately and safely. One subject did not complete isokinetic strength testing at either time interval because of patellofemoral pain that the subject had before surgery. Two subjects were unable to complete the SLHT. One patient was unable to because of low back pain and the other because of fear related to injuring his knee. The SLHT measurements were therefore not recorded for the first subject and recorded as zero for the second subject. There were twice as many subjects who were unable to complete the CHT and the same rationale was used for whether data was eliminated or recorded as zero. The same subject who did not complete the SLHT at week 4 also opted out of the ESST at week 4 due to fear. However, he completed all testing at week 8. There was also one subject that chose not to complete the 3rd trial of the ESST and the IAT at week 8 because he did not want his knee to flare up as he felt it did after the week 4 assessment. This is an area that requires further investigation in order to determine which performance-based
measures are most important for this population of patients especially 4 weeks after meniscectomy.

In order to more accurately assess recovery in this population of patients, performance-based measures should be compared using the uninvolved lower extremity or baseline testing scores and this was not done in this study. In addition, pre-operative impairments and self-report measures would have been useful.

**Conclusions**

The results of this study did not support our original hypothesis that subjects with degenerative meniscus tears would demonstrate worse recovery after an arthroscopic partial meniscectomy when compared to subjects with non-degenerative tears after eight weeks of rehabilitation. In fact, subjects with non-degenerative meniscus tears showed very similar recovery to those with non-degenerative tears. These groups were different prior to surgery, but were able to show very similar gains in their impairments and functional limitations over the course of 8-weeks of structured rehab. Further research is needed in this area to provide evidence for the effectiveness of physical therapy in patients with degenerative meniscus tears and to investigate how self-report measures correlate with impairment and functional limitations in this population of patients.
Chapter 4 - Conclusions

Meniscus tears are the second most common orthopedic injury of the knee with an incidence of 12% to 14% and a prevalence of 61 cases per 100,000 persons.\textsuperscript{2,3} In the United States, 10% to 20% of all orthopedic surgeries consist of surgery to the meniscus on an estimated 850,000 patients each year.\textsuperscript{4,5} PT is a standard of care for these patients, but research is conflicting on the benefits of PT in returning patients to their previous level of function. Two possible explanations for conflicts in this literature are the variability in the use of outcome measures to describe recovery after partial medial meniscectomy and the variability of patients undergoing this procedure.

The Variability in the Use of Outcome Measures

In the current healthcare environment, there is an increasing emphasis on the accurate measurement of outcomes to demonstrate the effectiveness of all types of medical and therapeutic interventions. These outcomes are increasingly being linked to reimbursement such that better outcomes lead to higher levels of reimbursement. Outcomes can be used to demonstrate quality of care at an individual and population level, and can also be used to plan and manage treatment. Accurate measurement of outcomes in PT requires that the outcome measure selected is appropriate for the population and construct being investigated.

The Orthopedic Section of the APTA has a continuing effort to create evidence-based documents for orthopedic physical therapy management of patients with musculoskeletal impairments described in the World Health Organization’s International Classification of Functioning, Disability, and Health (ICF) through its introduction of clinical practice guidelines (CPG).\textsuperscript{31}
The purposes of these clinical guidelines are to describe evidence-based PT practice including diagnosis, prognosis, intervention, and assessment of outcomes for musculoskeletal disorders commonly managed by orthopedic physical therapists, identify appropriate outcome measures to assess changes resulting from PT interventions, and create a reference publication for orthopedic PT clinicians, academic instructors, clinical instructors, students, interns, residents, and fellows regarding the best current practice of orthopedic PT.  

The CPG for meniscal lesions are combined with those for articular cartilage lesions and state that clinicians should use a validated patient-reported outcome measure, a general health questionnaire, and a validated activity scale for patients with knee pain and mobility impairments. Clinicians should also utilize easily reproducible physical therapy performance measures to assess activity limitation and participation restrictions associated with their patient’s knee pain or mobility impairments and to assess changes in the patient’s level of function.

The outcome measures recommended by the CPG for meniscal lesions include; the Medical Outcomes Study 36-item Short Form (SF-36), the Knee Outcome Survey – Activities of Daily Living Scale (KOS – ADL), the Knee Injury and Osteoarthritis Outcome Score (KOOS), the International Knee Documentation Committee Subjective Knee Evaluation Form (IKDC), Lysholm Knee Scale, Cincinnati Knee Rating Scale, Tegner Activity Scale, and the Marx Activity Scale. Physical impairment measures recommended by the clinical practice guidelines are; the modified stroke test, bulge sign, knee passive ROM, knee active ROM, maximum voluntary isometric quadriceps strength, isokinetic muscle strength, and knee joint line tenderness. The activity
limitation and participation restriction measures recommended are; the single-limb hop tests, 6-minute walk test, timed up-and-go test, and stair measure test. These outcomes measures are recommended by the CPG based on current research and best practice, but they need to be specifically examined in populations of patients with meniscal tears. One purpose of this study was to examine the psychometric properties of these outcomes measures, and to determine differences in populations of patients with degenerative vs. non-degenerative meniscal tears in order to better guide the use of outcome measures in these subpopulations.

From the list above, several impairment level measures, self-report activity measures, and participation measures were chosen for examination in this study. The IKDC was selected because it includes multiple sections and is therefore comprehensive and includes a general health questionnaire that has been validated in patients with meniscal tears. The Tegner Activity Scale was also recommended by the CPG for patients with knee pain and mobility impairments. The Tegner Activity Scale is an activity level and participation restriction outcome measure that is widely used in the literature and is reliable and valid for knee injuries.

The primary impairment level outcome measures examined in this study were pain, active ROM of the knee, and isokinetic muscle strength. The IKDC subjective knee evaluation form also contains a sub-section, symptoms, which assesses at the impairment level. Table 1.1 lists the outcome measures used in this study based on ICF category. The activity level outcome measures selected for this study were the single-limb single hop test for distance (SLHT), single-limb crossover hop test for distance (CHT), stair measure test (SMT), Illinois agility test (IAT), and Edgren side step test (ESST). The
SLHT, CHT, and SMT were recommended in the CPGs. The IAT and ESST were included because they assess components of activity, lateral and multi-directional movements, which are not addressed in the hop tests or the SMT. They are also safe to use in an injured population with patients of all ages. The IKDC subjective knee evaluation form sport activities and function sub-sections and the Tegner Activity Scale also measure activity limitations.

**Recommendations Based on Reliability, Validity, and Responsiveness Data**

Outcome measures are important tools for guiding clinical decision making, but these tools must be used with skill and understanding. The effective use of outcome measures is an important aspect of clinical care. Clinicians must first consider and understand the psychometric properties of an outcome measure, and must understand the clinical situation when choosing which measures to use. Clinicians must also consider the relevance of the outcome measure to a particular type of patient or population of patients. The anticipated impairments and activity limitations must be considered, but these must be related to each individual patient and the type of activities to which the patient may be returning. Finally, safety, feasibility and ease of performing the measure must also be considered as not all outcome measures are clinically friendly. Evidence from this investigation on the psychometric properties of the performance-based measures suggests that the IAT, SMT, ESST, and CHT are reliable, valid, and responsive in patients after arthroscopic partial meniscectomy,

The IAT was developed as a test of motor ability, particularly running and dodging agility in healthy individuals. It is a measure of multi-directional (lateral, sagittal, and transverse) agility emphasizing the ability to accelerate and decelerate when
performing a variety of maneuvers. These activities are functional for younger patients who are trying to return to sporting activities after meniscectomy, but may not be as appropriate for older patients with degenerative tears. On the other hand, the adaptability of the IAT may make this measure an appropriate and safe test for patients with degenerative meniscus tears. The IAT is meant to have individuals jog or run through the course, but can be modified so that a patient can walk through the course. This would make it more relevant for an older, less active population of people who do not plan to return to jogging, and still allow for comparison of initial activity limitation and activity limitations at the end of an episode care. The IAT measures a wide range of movements at the same time, with minimal equipment and set-up, in a short period of time and is therefore a valuable and clinically friendly outcome measure.

The ESST was developed to assess an individual’s agility in the lateral direction. Lateral mobility is an important activity to regain after meniscectomy surgery for all patients, especially patients who are returning to sport. Lateral movements are more difficult for patients with degenerative tears because they are likely to have some form of OA in their knee associated with their meniscus tear. However, patients can move through this test as slowly as possible, which makes it a safe and feasible test for all patients after meniscectomy. The ESST provides valuable information to clinicians and is also easily reproducible.

The SMT is an outcome measure that assesses the activity limitation of climbing stairs. Although this test does not include measurement of multiple movements at the same time, it does measure an activity that is necessary and appropriate for all individuals. The SMT is a timed test and therefore patients can complete it at whatever
speed they feel comfortable. This test is also easily modifiable as demonstrated by the use of a handrail for safety in this study. The reliability and validity of the SMT has been tested in patients after hip and knee replacement surgery, and as evidenced by this research, the SMT is a valid performance based activity limitation measure for use in patients after meniscectomy.

The CHT measures the activity of hopping. Hopping is a higher-level ballistic activity that requires good strength, stability, neuromuscular control, and proprioceptive function of the knee.\(^\text{12}\) However, the CHT may not be appropriate and safe for all types of patients with meniscus tears. Patients with acute or traumatic meniscus tears may be accustomed to hopping and may need to return to hopping after surgery. Hopping is a specialized activity that may be more important for younger patients or patients returning to higher level sports than for the older non-sporting patient. For patients with degenerative tears, hopping may no longer be a functional task, and may not be appropriate for patients with OA. This should be considered when choosing it in the clinic as an assessment tool for patients after meniscectomy.

The CPG for meniscal lesions recommends three (SLHT, CHT, and SMT) out of the five performance-based measures explored in this study.\(^\text{1}\) Two additional measures (IAT and ESST) were chosen for evaluation in this study based on previous positive findings from Comprehensive High-Level Activity Mobility Predictor-Sport (CHAMP-S) research.\(^\text{14,26}\)

Out of the five performance-based tests investigated, the findings of this study provide support for three for use in the clinic with patients after arthroscopic partial meniscectomy. The use of the IAT, ESST, and SMT are supported by this study because
they are reliable and valid measures of activity level in patients after arthroscopic partial meniscectomy. They are also safe for the wide variation in ages and activity levels seen in this population of patients. Although the IAT and ESST were not recommended by the CPGs, they were endorsed by the results of this study as valid measures of activity limitation in this population.

**Health Care Implications**

With the growing emphasis on outcomes-based reimbursement, research on the effectiveness of rehabilitation interventions is crucial, and currently the research on the effectiveness of rehabilitation after partial meniscectomy is lacking. Outcome measures should be used to measure the impact of PT on health outcomes relevant to the patient, and should be specific and appropriate to the population being investigated.\(^8\) This work adds to the body of knowledge related to appropriate outcome measures for use in this population.

**Clinical Implications**

The Orthopedic Section of the APTA’s CPG recommend that clinicians use a validated patient-reported outcome measure, a general health questionnaire, and a validated activity scale for patients with knee pain and mobility impairments.\(^1\) The CPG establishes that these tools are useful for identifying a patient’s baseline status relative to pain, function, and disability and for monitoring changes in the patient’s status throughout the course of physical therapy. A variety of these measures have been described in the literature and the CPG recommends some of these, but none are specific to patients after meniscectomy. The measures that have been validated for these patients are self-report measures, not performance-based measures.
Self-report measures are commonly used to quantify activity and function in physical therapy. Self-reported outcome measures are frequently used due to their practicality, low cost, low participant burden, and general acceptance. Self-report measures are also useful in assessing quality of life. They allow for the quick retrieval of information on impairments, activity limitations, and participation restrictions, but they have potential for recall and response bias. However, there is a need for assessing lower extremity function through a more direct method such as performance-based tests of activity limitation. Performance-based outcomes measures are more direct measures of activity limitations that provide precise information about movement and remove many of the issues of recall and response bias seen in self-report measures. Performance-based measures allow clinicians an opportunity to observe movement and therefore paint a clear picture of existing impairments and functional limitations. This helps guide rehabilitation after meniscectomy in order to achieve optimal results.

In addition to treatment planning, performance-based measures can also be used to describe and quantify outcomes. Outcomes after meniscectomy are typically described in relation to surgical outcomes and, less frequently, functional outcomes. Surgical outcomes are commonly described by radiograph based on the presence of osteoarthritis (OA). Radiographic evidence of OA progression is important in this population, but it may not be the best outcome to determine how well a patient can function after surgery because it is a better representation of initial surgical outcomes. Postoperative radiographic changes are only of interest when they are associated with clinical signs and symptoms, and minimal research exists examining the relationship between clinical signs and symptoms and radiographic changes. Some studies have
found radiographic and subjective outcomes to be correlated, while others have found no significant correlation. More research is needed in this area to promote the use of performance-based measures rather than radiographic evidence when describing outcomes after meniscectomy.

Performance-based measures can be used to evaluate patient activity, assess changes in activity limitations or levels, and describe outcomes of an episode of care. The CPG recommends the use of performance-based measures as they provide a valuable means for clinicians to capture essential impairments and functional limitations important to a patient’s individualized recovery. Both self-report and performance-based activity level measures provide clinicians with valuable information related to a patient’s ability and capacity, but one should not replace the other. Performance-based measures provide an advantage over self-report measures because they evaluate movement and components of movement. Self-report measures are important because a patient’s perception of their recovery is just as important as their actual recovery. Self-report and performance-based measures should be used together to assess outcomes in patients after meniscectomy and to guide clinical practice.

While this is the recommendation, a current meta-analysis demonstrates the majority of outcome measures used to assess outcomes after arthroscopic partial meniscectomy are self-report measures. Out of 6 articles analyzed, only 2 actually used performance-based measures. The performance-based measures used in these 2 studies were a timed walk test, the SMT, single-leg stance, and squatting.
The Variability of Patients with Meniscus Tears

Patients with meniscus tears vary widely. One basis for this variability is the mechanism of injury, which can usually be categorized as either non-degenerative or degenerative. Individuals with non-degenerative tears have usually experienced an acute traumatic event that resulted from excessive rotation and hyperflexion and/or extension of the knee. These patients are normally younger and more active. In contrast, people with degenerative tears have typically been experiencing knee pain and related activity limitations for a period of years due to constant wear and tear on the meniscus. They are usually older, tend to have higher BMIs and are less active when compared to patients with non-degenerative tears. Patients with degenerative meniscus tears and patients with non-degenerative tears are populations of people with distinct characteristics and may present differently to the clinical setting both pre-operatively and post-operatively.

Previous evidence suggests that when outcomes after arthroscopic partial meniscectomy are compared for patients with acute and degenerative meniscus tears, patients with degenerative tears tend to present with worse outcomes. Englund et al reported that patients with degenerative tears had significantly worse knee function after surgery based on the Knee Injury and Osteoarthritis Outcome Score (KOOS) and poorer knee-related quality of life compared to those with traumatic/acute tears. Patients with degenerative tears had significantly lower scores on both knee-specific outcomes and the Short Form Health Survey (SF-36), when compared with those with traumatic tears after arthroscopic partial meniscectomy.
The SLHT, CHT, ESST, IAT, and SMT are more Valid Activity Level Outcome Measures for Patients with Non-degenerative Meniscus Tears than for Patients with Degenerative Meniscus Tears

As described earlier, data from this study was collected to investigate the validity of the SLHT, CHT, ESST, IAT, and SMT. The correlations between these performance-based measures to already established activity level outcomes measures, the IKDC and Tegner, were established for subjects with meniscus tears. These relationships were also examined in subjects with degenerative meniscus tears versus subjects with non-degenerative tears.

Scores from all five of the performance-based measures in subjects with non-degenerative tears were more highly correlated with the IKDC and Tegner than the scores of patients with degenerative meniscus tears. These results indicate that these measures may be more appropriate for patients with non-degenerative meniscus tears.

Performance-based measures are important tools for guiding clinical decision making, but the effective use of such measures is based on a number of factors. Clinicians must first consider and understand the psychometric properties when deciding which outcomes to use. Clinicians must also consider the previous level of activity of their patients as well as their patient’s goals for return to these previous activities. These outcome measures should utilize movements that are more clinically relevant for patients after meniscectomy and that are safe and functional for older, more overweight, less physically fit and less active individuals.

For example, the results of this study suggest that SLHT and CHT were more valid measures for use in patients with non-degenerative tears than patients with
degenerative tears because hopping was an activity that was more appropriate for patients with non-degenerative tears. Many older patients with degenerative tears have not hopped in years and therefore there is no functional need for them to hop in the future. Therefore, it might be more appropriate to eliminate hop testing from a performance-based assessment in this population of patients. Other performance-based measures need to be investigated for use with patients with degenerative tears and this is a potential area for future research. Perhaps measures that incorporate activities such as squatting, kneeling, and getting on and off the floor may be more relevant for patients with degenerative meniscus tears.

*After Arthroscopic Partial Meniscectomy Patients with Degenerative Meniscus Tears and Patients with Non-degenerative Meniscus Tears Recover in a Similar Manner after 8-Weeks of Physical Therapy*

In this study, recovery was conceptualized in three ways. First, it was defined by the final 8-week self-report, impairment, and performance-based activity level outcomes. Second, recovery was defined as the magnitude of change in these outcomes. The changes in the self-report and impairment measures were analyzed from week 0 to week 8 and the changes in the performance-based measures were analyzed from week 4 to week 8. Finally, recovery was conceptualized as return to baseline function.

*Recovery after 8-Weeks of Physical Therapy*

The IKDC subjective knee evaluation form and the Tegner Activity Scale were the self-report measures used during this study to assess change in patients with meniscus tears over 8-weeks of rehabilitation. Higher scores on the IKDC represent improvement, indicating fewer and less severe symptoms and improved activity. A higher number on
the Tegner represents a higher activity level or better function. Both groups of patients, those with degenerative meniscus tears and without non-degenerative tears demonstrated improvements from week 0 to week 8 on both measures. The majority of this improvement is seen from week 0 to 4. The rate of recovery decreases from week 4 to week 8.

On the IKDC, subjects with degenerative meniscus tears (77.63±15.56) and patients with non-degenerative tears (79.85±15.69) subjectively report similar symptoms, impairments, and activity limitations eight weeks after meniscectomy. The two groups also report similar levels of activity based on the Tegner Activity Scale after eight weeks of physical therapy. The mean activity level for subjects with degenerative tears was 5.54±1.94 compared to 6.17±2.25 for patients with non-degenerative tears. Recovery based on the magnitude of change from week 0 to week 8 for both self-report measures showed a statistically significant difference between groups based on the IKDC, but not the Tegner. Patients with degenerative tears demonstrated a larger change on their mean IKDC scores (44.48±13.43) compared to patients with non-degenerative tears (34.11±20.98). An explanation for why a difference was found with respect to the IKDC, but not the Tegner may be explained by the baseline (week 0) differences between patients with degenerative and non-degenerative tears. A statistically significant difference existed between the groups at week 0 based on the IKDC and not for the Tegner. Immediately after surgery, subjects with degenerative meniscus tears reported lower IKDC scores (35.4±9.1) than did subjects with non-degenerative tears (46.2±13.8).

Pain, AROM, and strength measured by the Biodex were the impairment level outcomes used to assess change in patients with meniscus tears over eight weeks of
rehabilitation. Patients with degenerative meniscus tears and those with non-degenerative tears both showed improvements in pain (decreased pain), AROM (increased flexion and extension), and strength (increased % on strength involved/uninvolved limb) from week 0 to week 8. Pain and AROM show more of an improvement from week 0 to week 4 than from week 4 to week 8.

Patients with degenerative tears subjectively reported less pain (0±0) than patients with non-degenerative tears (0.67±1.23) at 8-weeks post-meniscectomy, but neither group reported a lot of pain after eight weeks of PT. Perception of pain changes with age and therefore this may be a possible explanation for the difference found. In addition, the chronic nature of pain in patients with degenerative meniscus tears has more of a potential for reducing this symptom after surgery.28-30

Recovery of active flexion ROM was similar in both groups over the 8-weeks of rehabilitation. Patients with degenerative meniscus tears demonstrated 134.1±10.13 degrees of active flexion at week 8 compared to patients with non-degenerative tears who demonstrated 136.5±6.86 degrees of flexion. The change in flexion ROM was also very similar between the groups. Patients with non-degenerative meniscus tears demonstrate a change of 41.64±33.60 degrees from week 0 to week 8 compared to patients with degenerative tears who demonstrated a change of 35.69±19.05 degrees. Recovery of active extension ROM behaved a little differently. No differences were found between the groups after eight weeks of PT, but a statistically significant difference was found in the magnitude of change from week 0 to week 8. This can once again be explained by the initial difference present at week 0 for patients with degenerative meniscus tears and patients with non-degenerative tears. Regaining extension ROM is imperative after
meniscectomy, and both groups had similar improvements over the course of 8 weeks. However, these groups appear to regain this ROM at different time intervals, which is possibly due to the chronicity of a degenerative tear vs. a non-degenerative tear and therefore the chronicity of ROM deficits. At week 0, subjects with degenerative tears lacked more extension than subjects with non-degenerative tears. These subjects demonstrated greater improvements from week 0 to week 4, whereas those with non-degenerative tears demonstrate more of a steady slow improvement throughout the entire 8-weeks. Subjects with degenerative tears (5±3.21) showed a greater magnitude of change compared to subjects with non-degenerative tears (2±3.26) in their active extension ROM over 8-week of rehabilitation.

Strength was measured on the Biodex at 60 degrees/sec, 180 degrees/sec, and 300 degrees/sec and isokinetic quadriceps strength was compared between the involved and uninvolved limb so that a percent was calculated. Quadriceps strength measured at 60 degrees/sec is a measure of pure strength because of the slower speed. Strength of the involved quadriceps was 81% that of the uninvolved quadriceps eight weeks after meniscectomy in subjects with degenerative meniscus tears. Strength of the involved quadriceps was 85% that of the uninvolved quadriceps eight weeks after meniscectomy in patients with non-degenerative meniscus tears. Although subjects with degenerative meniscus tears presented with a larger percent deficit in strength at week 8 compared to those with non-degenerative tears, there was not a statistically significant difference between strength measured at 60deg/sec. Subjects with degenerative tears, however, were able to gain 4% strength in their involved quadriceps strength from week 4 to week
whereas subjects with non-degenerative tears actually lost 2% of their involved quadriceps strength during this time.

It appears that, in this population, strength peaked in patients with non-degenerative tears at 4-weeks post-op, whereas patients with degenerative meniscus tears continued to get stronger. One explanation for this finding might have been related to compliance with physical therapy, but preliminary data analysis did not show any statistically significant differences between the numbers of visits that patients with degenerative meniscus tears attended versus patients with non-degenerative tears. The average number of visits for patients with non-degenerative tears during this time period was 15±5.75 visits vs. 13.15±5.19 for patients with degenerative tears (p = 0.21).

Another explanation for this finding is that these results may be related to the chronic nature of degenerative meniscus tears. Because these patients might have had meniscus tears for a longer period of time compared to patients with non-degenerative tears, they also might have had more strength impairments leading up to surgery. Pre-surgical strength was not measured in this study. A third explanation for this finding related to strength gains might be differences in home exercise activity, but this also was not captured in this study. It is possible that people with degenerative tears might have been more compliant with their home programs.

Finally, analysis of strength in this study was calculated as a percent of the involved limb compared to the uninvolved limb and patients with degenerative meniscus tears may also have a weaker uninvolved limb due to increased age, BMI, decreased baseline activity level, and the possibility of additional OA. The home exercise program
might have increased the strength of both limbs for the people with degenerative tears, making strength increases in the involved limb more difficult to interpret.

Isokinetic quadriceps strength measured at 300 degrees/sec is a better measure of muscular endurance because of the faster speed. At this speed, strength of the involved quadriceps was 85% that of the uninvolved quadriceps at eight weeks after meniscectomy in subjects with degenerative meniscus tears. Strength of the involved quadriceps was 91% that of the uninvolved quadriceps at eight weeks after meniscectomy in subjects with non-degenerative meniscus tears, but once again this difference was not statistically significant. Subjects with degenerative meniscus tears demonstrated better improvement at 300 deg/sec (5%) over 4-weeks than they did when their strength was assessed at 60 degrees/sec (3%). Therefore these subjects regained muscular endurance better than strength over 4-weeks of rehab and showed a larger percentage change of their quadriceps endurance (5%) when compared to subjects with non-degenerative meniscus tears (-3%). As discussed earlier, subjects with degenerative tears improved the strength of their involved quadriceps from 4 to 8-weeks post-op, but those with non-degenerative tears actually lost 4% strength.

Isokinetic quadriceps strength measured at 180 degrees/sec represents strength and endurance because a moderate speed is used during assessment. Strength of the involved quadriceps was 90% that of the uninvolved quadriceps at eight weeks after meniscectomy in subjects with degenerative meniscus tears. Strength of the involved quadriceps was 84% that of the uninvolved quadriceps at eight weeks after meniscectomy in subjects with non-degenerative meniscus tears, but this difference was not statistically different. At this intermediate speed, subjects with degenerative meniscus tears actually
regained more of their involved quadriceps strength than those with non-degenerative
 tears. Subjects with degenerative meniscus tears demonstrated better improvement at
300deg/sec (11%) over 4-weeks than they did when their strength was assessed at 60
degrees/sec (4%). In other words, there seems to be better recovery of power rather than
strength of the quadriceps muscle in patients with degenerative meniscus tears.

The SLHT, CHT, ESST, IAT, and SMT were the performance-based outcome
measures used during this study to assess activity limitation and change in activity
limitations in subjects with meniscus tears after eight weeks of rehabilitation. After eight
weeks of PT, no statistically significant differences were found between subjects with
degenerative meniscus tears and those with non-degenerative meniscus tears. When
recovery was compared based on the magnitude of change from week 0 to week 8, there
was still no statistically significant difference between the groups of patients found for
any of the activity level performance-based measures.

Patients with degenerative meniscus tears and patients with non-degenerative
tears recover in a similar manner after surgery after eight weeks of PT. Differences may
exist in the patterns of recovery, but this is inevitable as patients with degenerative
meniscus tears are older, more overweight, and have lower levels of premorbid activity
levels when compared to patients with non-degenerative tears.

Recovery Based on Return to Baseline Function

Recovery defined by the change from week 0 to week 8 is largely affected by
initial symptoms, impairments and activity limitations. In order to accurately report
recovery it is necessary to know the pre-morbid status of a patient. Subjects were not
treated before surgery, but data on pre-morbid activity level was collected at week 0
through the IKDC and Tegner. There were 2 questions that originated from the IKDC that addressed previous level of activity. The first was a question on the subjective knee evaluation form (question #10) that asked subjects to rate the function of their knee prior to knee injury 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 sports. The second question was a component of the demographic form and asked that patients rate their activity as one of the following: high competitive sports person, well trained and frequently sporting, sporting sometimes, or non-sporting. Question #10 of the IKDC was used for purposes of statistical analysis during this study. The Tegner Activity Scale required each subject to select a current activity level and an activity level before injury. **Figure 3.4** provides a graphical representation of the previous level of activity for both the Tegner and IKDC and how this level changed over eight weeks of PT.

When analyzing this data, the subject’s previous level of activity was compared to their level of activity reported after eight weeks of PT in order to determine whether subjects were able to recover to their pre-morbid activity level. Subjects with degenerative tears were compared to patients with non-degenerative tears. No differences were found between the pre-morbid and week 8 scores on the Tegner and this was true for subjects with degenerative meniscus tears and subjects with non-degenerative tears.

Subjects with degenerative tears had a mean lower previous level of activity based on the Tegner (5.8±1.6) compared to those with non-degenerative tears (7.4±1.2) and this difference was statistically different ($p = 0.006$). Subjects with degenerative tears also had a mean higher activity level based on question #10 on the IKDC subjective knee
evaluation form (9.33±1.07) compared to those with non-degenerative tears (9.23±1.48) on the IKDC, but this difference was not statistically significant (p = 0.42).

After eight weeks of PT, subjects with degenerative tears still reported a lower Tegner activity level (5.54±1.94) compared to subjects with non-degenerative tears (6.17±2.25), but this difference was not statistically significant (p = 0.17). Based on question #10 of the IKDC, subjects with degenerative tears reported an 8.15 compared to an 8 reported by patients with non-degenerative tears, which was also not statistically significant (p = 0.42).

Similar trends in recovery to previous level of activity were seen with respect to subjects with degenerative meniscus tears and subjects with non-degenerative meniscus tears. Neither group returned to pre-morbid levels of IKDC function nor there was no difference in recovery between the two groups. Subjects with degenerative meniscus tears had the same activity as change as related to baseline activity as subjects with non-degenerative tears (p = 0.9088). There was also no interaction of group and time (p = 0.6098). Although neither group returned to premorbid function, there was no difference in recovery. For the Tegner, there was no effect for time, no differences were found in premorbid and 8 week score in either group (p = 0.1717). There also was no interaction effect meaning the 2 groups were the same over time and therefore there was no difference in recovery (p = 0.1490). Finally, there was no effect found for group and therefore no difference between the groups, although differences approached significance (5.33 vs. 7.45, p = 0.06), and perhaps a larger sample might have had significant findings. Subjects with degenerative meniscus tears were closer to returning to their previous level of activity when compared to subjects with non-degenerative tears, and this point may
have clinical relevance. A goal of PT after meniscectomy is to return patients to their previous level of function and patients with degenerative tears as these patients could potentially exceed their previously reported level of activity and are therefore good candidates for surgery and rehabilitation following surgery.

Clinical Relevance

Evidence suggests that patients recover well after arthroscopic partial meniscectomy with eight weeks of physical therapy. As recommended by the CPG for meniscal lesions, self-report measures (IKDC and Tegner), impairments (pain, AROM, and strength), and activity level measures (SLHT, CHT, ESST, IAT, SMT) were chosen to assess post-meniscectomy patients. It was hypothesized that subjects with degenerative meniscus tears would not recover as well as subjects with non-degenerative tears, but evidence from this study resulted in a rejection of the original hypotheses. Subjects with degenerative meniscus tears presented with a lower baseline level of activity, but recover to a similar activity level after eight weeks of rehab when compared to those with non-degenerative tears. These patients do not quite reach the same level of activity as patients with non-degenerative tears, but recover to the same previous self-reported activity level before they had torn this meniscus. The ultimate goal of rehab is to return patients to their previous level of activity and this outcome was achieved in both patients with non-degenerative tears and those with degenerative tears. Although differences in groups were seen with respect to pain, patients were able to perform multi-directional functional activities in a similar manner after only 8-weeks of physical therapy. Patients also subjectively reported a similar reduction of symptoms and improvement of activity over this same time period.
Performance-based measures can be used to evaluate patients, assess changes, and describe outcomes after physical therapy. The CPG recommends the use of performance-based measures and they provide a valuable means for clinicians to capture essential impairments and functional limitations important to a patient’s individualized recovery. Both self-report and performance based activity level measures can provide clinicians with valuable information about a patient’s activity level, but one should not replace the other. Performance-based measures provide an advantage over self-report measures because they evaluate movement in a direct and specific way. Self-report measures are important because they reflect a patient’s perception of their recovery, which is an important construct. Self-report and performance-based measures should be used together to assess outcomes and to guide clinical practice in patients after meniscectomy.

Out of the five performance-based tests investigated, three are supported by this research for their use in the clinic with patients after arthroscopic partial meniscectomy. The IAT, ESST, and SMT are reliable and valid measures of activity level in patients after arthroscopic partial meniscectomy. They are also safe for the wide variation in ages and activity levels seen in this population of patients.

Limitations

Sample Size and Recruitment

Sample size analysis for a power of 80% to be achieved in this study indicated a necessary sample size of 100. Power analysis for a t-test with an alpha level of 0.05 and a one-tailed hypothesis revealed that the differences in the means found for the performance-based measures in this study had only 33% power. A much smaller sample
size of 26 was actually recruited, but even with the low number of subjects, differences were found between patients with degenerative tears and patients with non-degenerative tears.

Difficulty with recruitment was the major limiting factor to a small sample size and different strategies for recruitment will be implemented in future research. The most challenging aspect of the recruitment process was referral of subjects from the sports medicine department at the University of Miami (UM). Because some patients were referred for physical therapy treatment at clinics other than the study clinic, the sample collected was not reflective of the number of meniscectomies performed by the sports medicine department at UM during this same time period. In the future, it would be beneficial to recruit patients from all facilities to which the sports medicine department refers.

Retention and Recruitment

Thirty subjects signed consent forms and were therefore enrolled in this study. Twenty-seven was the final sample size. There were 4 subjects that were recruited for this study that were not compliant with physical therapy and these patients were eliminated from the study. The majority of subjects who agreed to participate completed the 8-weeks of physical therapy, but compliance was variable. This is typical of most physical therapy clinics.

Original methodology stated that subjects would receive PT 3x/week for 8-weeks, but modifications were necessary. Some patients were unable to commit to this schedule for 8-weeks. Frequency of treatment was modified to 2-3x/week. Patients therefore were required to attend between 16 and 24 visits in 8-weeks. The total number of visits
attended ranged from 6-26 with a mean attendance of 14.23± 5.41 visits. The average number of visits during this time period was 15±5.75 visits for patients with non-degenerative meniscus tears and 13.15±5.19 for patients with degenerative tears. Most patients were compliant for the first four weeks of rehab, but from weeks 4-8, attendance declined. For the last four weeks of rehab, the average attendance was 4.96±4.35 visits. The average number of visits for patients with non-degenerative tears during this time period was 5±4.84 visits and 4.62±4.05 for patients with degenerative tears. There were no statistically significant differences in compliance between patients with degenerative tears and non-degenerative tears so the results reported in this study were not affected by a difference in compliance. In the future, to improve compliance, it would be beneficial to provide subjects with an incentive to participate in this study.

Treatment

Two treatment protocols were developed during the course of this study, a standardized 0-4-week protocol for all patients and an individualized 4-8-week protocol. The principal investigator was unable to treat all patients and therefore treatment variability was introduced when five other physical therapists were recruited to be involved in this study. This was minimized through the use of a standardized protocol from 0-4-weeks. This protocol was developed by the principal investigator and was a modification of UM sports medicine protocol for meniscectomies. Each treating physical therapist was required to follow this protocol, but patients were progressed as tolerate and therefore reached different milestones at different time periods.

The 4-8-week protocol was individualized for each subject based on assessment of his or her performance at 4-weeks post-op. The principal investigator developed an
individualized protocol for each subject based on visual observations of activity limitations made from the recordings of each patient’s 4-week functional assessment.

An area of future research stems from the development of this protocol. As discussed earlier, performance-based measures can be used to assess outcomes, but can also guide clinical care and treatment planning. An area for future research is the use of performance-based measures in developing a treatment plan for individuals after knee surgery.

Assessments

Initial research methodology proposed that patients would have their initial physical therapy evaluation within 48 hours of surgery. Due to scheduling conflicts, it was impossible to schedule every patient for their initial evaluation within 48 hours of surgery. The time frame for the initial evaluation was therefore changed to be within one week of surgery. Additional assessments were planned for four week post-op and eight weeks post-op. These assessments had to be performed at the UM medical wellness center and therefore scheduling these was sometimes a challenge. It was difficult to schedule patients for each of these assessments at exactly four and eight weeks post-meniscectomy. Subjects were never scheduled earlier, but they were sometimes scheduled later than originally planned for each of these assessments. In future research endeavors, these assessment periods should be more standardized. In additional, more pre-operative data would be collected so that comparisons could be made to baseline characteristics.
Confounding Variables

Comparisons were made between subjects with degenerative tears and patients with non-degenerative tears. The average age of subjects in the degenerative group was 45 years old compared to 32 years old in the non-degenerative group. Because age was not correlated with any of the self-report, impairment, or activity level performance based measures, it was never statistically controlled for. To determine the impact of age on outcomes in degenerative vs. non-degenerative subject, the sample would have to include younger patients who had degenerative tears and older patients who had traumatic tears.

Future Research

Factors that Predict Recovery in Patients after Partial Meniscectomy

Factors related to recovery have been considered in current literature, but there is significant controversy regarding these factors. Research on surgical outcomes reveals that preoperative and intra-operative predictors of poor clinical or radiographic outcomes included total meniscectomy or removal of the peripheral meniscal rim, lateral meniscectomy, degenerative meniscal tears, presence of chondral damage, presence of hand OA suggestive of genetic predisposition, and increased body mass index. Greater articular cartilage degeneration assessed at surgery, greater size of meniscal resection, greater laxity of the anterior cruciate ligament, and prior surgery on the index knee are the strongest predictors of poor functional outcomes. Variables that were not predictive of outcome were inconclusive, or had mixed results included meniscal tear pattern, age, mechanical alignment, sex of patient, activity level, and meniscal tears associated with ACL reconstruction. Radiographic evidence of OA is the most widely used outcome in
these studies. The majority of studies also use at least one self-report measure that is either disease specific or joint specific and may include some questions related to function, but there is minimal use of functional outcome measures in the current literature. This is an important and necessary addition to the evidence on outcomes following arthroscopic partial meniscectomy. In addition, the characteristics of a meniscus tear influence recovery and it is imperative that we understand this relationship in order to direct proper rehabilitation.

**Correlation between Isokinetic Strength and Activity Limitations**

Strength is often considered a marker for rehab success and return to sport and isokinetic strength testing is the gold-standard. However, isokinetic strength may not be correlated to function. Preliminary statistical analysis from this study has demonstrated that strength as measured by the Biodex is not correlated with performance.

The relationship between functional testing and leg strength has been investigated by several authors, who found a wide range of correlations from $r = 0.38$ to $r = 0.78$. The majority of this research investigates the relationship between strength and hop testing. In one study by Lephart et al, results revealed that conventional physical characteristics (hamstring and quadriceps peak torque, anterior joint laxity, thigh circumference, and ROM) correlated poorly ($r = .01$ to $r = .42$) with the functional tests. Conclusions of this study reported that use of such traditional physical impairment measures for predicting function in the ACL-insufficient athlete may be inappropriate, and the physical performance tests designed for this study appear to be a more valuable assessment of the athlete's functional capacity. When attempting to assess strength and ability to return to full participation, functional testing such as squatting and stair
climbing may be more appropriate than the more traditional and preferred method using
an isokinetic strength measurement.

Research on this topic would add to the current body of knowledge on the
relationship between isokinetic strength and function in patients with ACL injuries.
Research in this topic area would parallel the suggestions made in the ACL research for
patients with meniscus tears and therefore also emphasize the importance of using
performance-based measures in physical therapy.

**Correlation between Impairments, Activity Limitations, and Radiographic Evidence of Osteoarthritis**

Radiographic evidence of osteoarthritis (OA) is the gold-standard for discussing
outcomes in post-meniscectomy research; however, radiographic changes are not
consistently correlated with impairments and functional limitations.

Radiographic evidence of OA progression is important in this population, but it
may not be the most relevant indicator of how well a patient returns to their previous
level of activity after surgery. Postoperative radiographic changes are only of interest
when they are associated with clinical signs and symptoms. Some studies have found
radiographic and subjective signs to be correlated, while others have found no significant
correlation. In a study of 107 partial lateral meniscectomies, results indicate that there is
usually progressive degenerative and radiographic changes after an arthroscopic partial
lateral meniscectomy, but without significant negative influence on knee function. Additional research is necessary to determine recovery in patients and more specifically
describe differences in patients with degenerative and acute meniscus tears. Clinical
impairment level outcome measures and activity level performance based measures
should also be utilized to objectively quantify recovery status-post arthroscopic partial meniscectomy.

Research has proven the importance of the meniscus. Loss of meniscal tissue is associated with instability and both biomechanical and clinical studies have shown increased stress and degeneration of the articular cartilage after a meniscectomy.\textsuperscript{35-37} The prevalence and severity of OA has been compared in patients who have undergone arthroscopic partial meniscectomy to non-operative patients with meniscus tears and results indicate an earlier development of OA in patients after meniscectomy.\textsuperscript{38,39}

In a systematic review by Fabricant and Jokl in 2007,\textsuperscript{40} four studies used radiographic outcomes as the primary mechanism of describing recovery after arthroscopic partial meniscectomy.\textsuperscript{9,37,41,42} In all of these studies radiographic change was the primary outcome measure used, but radiographic outcomes were never correlated with functional outcomes. Another review of 75 patients who had undergone an arthroscopic partial lateral meniscectomy,\textsuperscript{37} demonstrated no significant correlation between radiographic changes and subjective symptoms or functional outcomes was found.\textsuperscript{9}

The majority of literature that describes outcomes following arthroscopic partial meniscectomy is based on radiographic findings. There is a recognized relationship between injury to the meniscus and osteoarthritis, but this relationship needs further investigation. There is disagreement in the literature regarding the degree to which radiographic OA correlates to impairments and functional limitations of the knee. It is imperative that we conduct longitudinal studies to better understand this relationship
Effectiveness of Physical Therapy in Patients Post-meniscectomy

Currently there is a lack of level I research that demonstrates the benefits of PT after meniscectomy.\textsuperscript{14} Physical therapy is frequently integrated after partial meniscectomy to return patients to their pre-injury level of activity. Rehabilitation after partial meniscectomy can generally progress as tolerated with no substantial contraindications or limitations. The main goals are to control the pain and inflammation associated with surgery, maintain ROM and general conditioning, restore or maintain isolated muscle function, and optimize integrated lower extremity neuromuscular coordination in order to accelerate recovery following surgery and return patients to pre-injury levels of activity following partial meniscectomy. Existing research related to the topic of meniscus injury and physical therapy is not extensive and it is weak.\textsuperscript{45-47}

One prospective, randomized study, found that a well-planned, unsupervised rehabilitation program enables patients undergoing arthroscopic knee surgery to return to sports within the same time frame as patients who receive supervised PT.\textsuperscript{31} In contrast, another study concluded that early and intensive rehabilitation was imperative to successful functional outcomes after partial meniscectomy.\textsuperscript{32} Unfortunately, neither of these were high quality randomized controlled trials.

A variety of interventions have been described for the treatment of knee pain and mobility impairments associated with meniscal lesions, but there is a limited amount of evidence from high-quality randomized, controlled trials. Currently the clinical practice guidelines suggest progressive knee motion, weight bearing and return to activity, but these are all based on weak and theoretical evidence. The guidelines also recommend supervised rehab, therapeutic exercise and neuromuscular electrical stimulation. Higher-
level research is needed in this area to prove that rehabilitation is effective after arthroscopic partial meniscectomy.

**Final Conclusions**

This work provides information on the reliability and validity of five activity level performance-based outcome measures for patients after arthroscopic partial meniscectomy, the SLHT, CHT, ESST, IAT and SMT. Additionally, outcome measures should be appropriate to the population of patients being examined. Because there are two different subpopulations of patients with meniscus tears, patients with degenerative meniscus tear and patients with non-degenerative meniscus tears, different activity level outcome measures should be considered when studying and treating these different types of patients with meniscus tears. Finally, this work demonstrates similar patterns of recovery in patients with degenerative and non-degenerative meniscus tears. Both groups nearly recover to their pre-morbid level of activity after eight weeks of physical therapy. This work adds to the knowledge about both outcome measures to be used with patients after partial meniscectomy, and differences in the recovery of patients with degenerative versus non-degenerative meniscus tears.
Literature Cited


Appendices

Appendix A – Self-Report Outcome Measures

A.1 - IKDC Demographic Form

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</tbody>
</table>

The following is a list of common health problems. Please indicate “Yes” or “No” in the first column, and then skip to the next item. If you do have the problem, please indicate in the second column if you receive medications or some other type of treatment for the problem. In the last column, indicate if the problem limits any of your activities.

<table>
<thead>
<tr>
<th>Health Problem</th>
<th>Do you have the problem?</th>
<th>Do you receive treatment for it?</th>
<th>Does it limit your activities?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heart disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>High blood pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asthma or pulmonary disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Diabetes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ulcer or stomach disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bowel disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kidney disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Liver disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anemia or other blood disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overweight</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cancer</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Depression</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Osteoarthritis, degenerative arthritis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Back pain</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lyme disease</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other medical problem</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alcoholism</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. Do you smoke cigarettes?
   - Yes
   - No, I quit in the last six months.
   - No, I quit more than six months ago.
   - No, I have never smoked.

2. Your height __________ centimeters inches

3. Your weight __________ kilograms pounds

4. Your race (indicate all that apply)
   - White
   - Black or African-American
   - Hispanic
   - Asian or Pacific Islander
   - Native American Indian
   - Other

5. How much school have you completed?
   - Less than high school
   - Graduated from high school
   - Some college
   - Graduated from college
   - Postgraduate school or degree

6. Activity level
   - Are you a high competitive sports person?
   - Are you well-trained and frequently sporting?
   - Sporting sometimes
   - Non-sporting
A.2 – IKDC Current Health Assessment Form

IKDC CURRENT HEALTH ASSESSMENT FORM *

Your Full Name ____________________________________________

Your Date of Birth __________________________________________
    Day / Month / Year

Today’s Date _______________________________________________
    Day / Month / Year

1. In general, would you say your health is: □ Excellent □ Very Good □ Good □ Fair □ Poor

2. Compared to one year ago, how would you rate your health in general now?
    □ Much better now than 1 year ago □ Somewhat better now than 1 year ago □ About the same as 1 year ago
    □ Somewhat worse now than 1 year ago □ Much worse now than 1 year ago

3. The following items are about activities you might do during a typical day. Does your health now limit you in these activities? If so, how much?

   a. Vigorous activities, such as running, lifting heavy objects, participating in strenuous sports
      Yes, Limited
      Yes, Limited
      No, Not
      A Lot
      A Little
      Limited
      At All

   b. Moderate activities, such as moving a table, pushing a vacuum cleaner, bowling, or playing golf
      □ □ □

   c. Lifting or carrying groceries
      □ □ □

   d. Climbing several flights of stairs
      □ □ □

   e. Climbing one flight of stairs
      □ □ □

   f. Bending, kneeling or stooping
      □ □ □

   g. Walking more than a mile
      □ □ □

   h. Walking several blocks
      □ □ □

   i. Walking one block
      □ □ □

   j. Bathing or dressing yourself
      □ □ □

4. During the past 4 weeks, have you had any of the following problems with your work or other regular daily activities as a result of your physical health?

   a. Cut down on the amount of time you spent on work or other activities
      □ □

   b. Accomplished less than you would like
      □ □

   c. Were limited in the kind of work or other activities
      □ □

   d. Had difficulty performing the work or other activities (for example, it took extra effort)
      □ □
5. During the **past 4 weeks**, have you had any of the following problems with your work or other regular daily activities as a result of any emotional problems (such as feeling depressed or anxious)?

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
</table>
   a. Cut down on the amount of time you spent on work or other activities | ☐ | ☐ |
   b. Accomplished less than you would like | ☐ | ☐ |
   c. Didn't do work or other activities as carefully as usual | ☐ | ☐ |

---

**Page 2 – IKDC CURRENT HEALTH ASSESSMENT FORM**

6. During the **past 4 weeks**, to what extent has your physical health or emotional problems interfered with your normal social activities with family, friends, neighbors, or groups?

   ☐ Not At All    ☐ Slightly    ☐ Moderately   ☐ Quite a Bit    ☐ Extremely

7. How much bodily pain have you had during the **past 4 weeks**?

   ☐ None    ☐ Very Mild    ☐ Mild    ☐ Moderate     ☐ Severe    ☐ Very Severe

8. During the **past 4 weeks**, how much did pain interfere with your normal work (including both work outside the home and housework)?

   ☐ Not At All    ☐ A Little Bit    ☐ Moderately    ☐ Quite a Bit    ☐ Extremely

9. These questions are about how you feel and how things have been with you during the past 4 weeks. For each question, please give the one answer that comes closest to the way you have been feeling. **How much of the time during the past 4 weeks:**

<table>
<thead>
<tr>
<th>All of the time</th>
<th>Most of the time</th>
<th>A good bit of the time</th>
<th>Some of the time</th>
<th>A little of the time</th>
<th>None of the time</th>
</tr>
</thead>
</table>
   a. Did you feel full of pep? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
   b. Have you been very nervous? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
   c. Have you felt calm and peaceful? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
   d. Did you have a lot of energy? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
   e. Have you felt down-hearted and blue? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
   f. Did you feel worn out? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
   g. Have you been a happy person | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
   h. Did you feel tired? | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

10. During the **past 4 weeks**, how much of the time has your physical health or emotional problems interfered with your social activities (like visiting with friends, relatives, etc.)?

   ☐ All of the time    ☐ Most of the time    ☐ Some of the time    ☐ A little of the time    ☐ None of the time

11. How **TRUE** or **FALSE** is each of the following statements for you?

<table>
<thead>
<tr>
<th>Definitely True</th>
<th>Mostly True</th>
<th>Don't Know</th>
<th>Mostly False</th>
<th>Definitely False</th>
</tr>
</thead>
</table>
   a. I seem to get sick a little easier than other people | ☐ | ☐ | ☐ | ☐ | ☐ |
   b. I am as healthy as anybody I know | ☐ | ☐ | ☐ | ☐ | ☐ |
   c. I expect my health to get worse | ☐ | ☐ | ☐ | ☐ | ☐ |
   d. My health is excellent | ☐ | ☐ | ☐ | ☐ | ☐ |
A.3 – IKDC Subjective Knee Evaluation Form

2000 IKDC SUBJECTIVE KNEE EVALUATION FORM

Your Full Name ____________________________________________

Today’s Date: __/__/____ Date of Injury: __/__/____

Day Month Year Day Month Year

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?
   - Very strenuous activities like jumping or pivoting as in basketball or soccer
   - Strenuous activities like heavy physical work, skiing or tennis
   - Moderate activities like moderate physical work, running or jogging
   - Light activities like walking, housework or yard work
   - 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?
   - Never
   - 0
   - 1
   - 2
   - 3
   - 4
   - 5
   - 6
   - 7
   - 8
   - 9
   - 10
   - Constant

3. If you have pain, how severe is it?
   - No pain
   - 0
   - 1
   - 2
   - 3
   - 4
   - 5
   - 6
   - 7
   - 8
   - 9
   - 10
   - Worst pain imaginable

4. During the past 4 weeks, or since your injury, how stiff or swollen was your knee?
   - Not at all
   - Mildly
   - Moderately
   - Very
   - Extremely

5. What is the highest level of activity you can perform without significant swelling in your knee?
   - Very strenuous activities like jumping or pivoting as in basketball or soccer
   - Strenuous activities like heavy physical work, skiing or tennis
   - Moderate activities like moderate physical work, running or jogging
   - Light activities like walking, housework, or yard work
   - Unable to perform any of the above activities due to knee swelling

6. During the past 4 weeks, or since your injury, did your knee lock or catch?
   - Yes
   - No

7. What is the highest level of activity you can perform without significant giving way in your knee?
SPORTS ACTIVITIES:

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

- Very strenuous activities like jumping or pivoting as in basketball or soccer
- Strenuous activities like heavy physical work, skiing or tennis
- Moderate activities like moderate physical work, running or jogging
- Light activities like walking, housework or yard work
- Unable to perform any of the above activities due to giving way of the knee

CURRENT FUNCTION OF YOUR KNEE:

<table>
<thead>
<tr>
<th>Cannot perform daily activities</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>No limitation in daily activities</th>
</tr>
</thead>
</table>

9. How does your knee affect your ability to:

<table>
<thead>
<tr>
<th></th>
<th>Not difficult at all</th>
<th>Minimally difficult</th>
<th>Moderately difficult</th>
<th>Extremely difficult</th>
<th>Unable to do</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Go up stairs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Go down stairs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. Kneel on the front of your knee</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. Squat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. Sit with your knee bent</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. Rise from a chair</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>g. Run straight ahead</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>h. Jump and land on your involved leg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>i. Stop and start quickly</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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 sports?

FUNCTION PRIOR TO YOUR KNEE INJURY:

<table>
<thead>
<tr>
<th>Cannot perform daily activities</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>No limitation in daily activities</th>
</tr>
</thead>
</table>
A.4 – Tegner Activity Scale

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_________

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

## Appendix B – Initial PT Evaluation

<table>
<thead>
<tr>
<th>Date of Eval / Start of Care</th>
<th>Date of Injury</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupation</td>
<td>Referring Physician</td>
</tr>
<tr>
<td>Medical Diagnosis</td>
<td>Precautions</td>
</tr>
<tr>
<td>Treatment/Diagnosis</td>
<td>Surgery Type / Date</td>
</tr>
</tbody>
</table>

### History/Mechanism of Injury/Chief Complaint:


### PMI/PSH:


### Diagnostic tests:


### Medications:


### Pain Site & Pattern:

<table>
<thead>
<tr>
<th>Pain Level (0-10): Current:____ At Best:_____ At Worst:_____</th>
<th>Prior PT: Y / N</th>
<th>With Improvement: Y / N</th>
</tr>
</thead>
</table>

### Objective Assessment:

#### Observation/Inspection & Posture:

<table>
<thead>
<tr>
<th>Girth</th>
<th>R</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Joint Line</td>
<td>cm</td>
<td>cm</td>
</tr>
<tr>
<td>Above patella</td>
<td>cm</td>
<td>cm</td>
</tr>
<tr>
<td>Below patella</td>
<td>cm</td>
<td>cm</td>
</tr>
</tbody>
</table>

### Sensation:

<table>
<thead>
<tr>
<th>Mediolateral</th>
<th>R</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip flexion (L2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip flexion (L5)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Reflexes:

<table>
<thead>
<tr>
<th>Patellar</th>
<th>L3/4</th>
<th>S1/2</th>
</tr>
</thead>
<tbody>
<tr>
<td>R</td>
<td>L</td>
<td></td>
</tr>
<tr>
<td>Knee ext (L3)</td>
<td></td>
<td>Ankle PF (S1)</td>
</tr>
<tr>
<td>Ankle DF (L4)</td>
<td></td>
<td>Knee flex (S2)</td>
</tr>
</tbody>
</table>

### Motion

<table>
<thead>
<tr>
<th>Knee Flexion</th>
<th>R</th>
<th>L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knee Extension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip Flexion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip Extension</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip Adduction</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip Internal Rotation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hip External Rotation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Special Tests

<table>
<thead>
<tr>
<th>Lower Extremity Functional Scale &amp; Value:</th>
<th>Pain Catastrophizing Scale Score:</th>
</tr>
</thead>
</table>

### Flexibility / Joint Mobility / Palpatation:

<table>
<thead>
<tr>
<th>Balance</th>
<th>Patient Identification Sticker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Limb Hop:</td>
<td></td>
</tr>
<tr>
<td>Timed Up and Go:</td>
<td></td>
</tr>
<tr>
<td>6 minute Walk:</td>
<td></td>
</tr>
</tbody>
</table>

---

### Assessment of Current Level of Function & Reason for Referral:

Patient will be seen ___ times per week for ___ weeks.

Clinician Signature: [signature]

Date: ____________

I certify that the need for these services is pursuant to this plan of treatment while under my care.

Physician Signature: [signature]

Date: ____________

---

[Type text]
| Patient states prior level of function | Independent with all ADL's, functional transfers, work duties, household and community ambulation, stair negotiation, and safety concerns. Explain if "was not": |
| Patient would benefit from Therapy to address: | Reaching, bending, crawling, carrying, overhead activities, stooping, squattting, kneeling, standing, walking, ceiling, sit to stand, stair climbing, home care ADL's, other. |
| Rehab Potential: | Excellent = Good = Fair = Poor | Patient Barriers to achieving goals: | Yes = No |
| Patient/Family oriented to Rehab: | Program and Goals: | Yes = No |
| Potential oriented to condition and precautions: | Yes = No |
| Level of family support: | |

<table>
<thead>
<tr>
<th>STG (steps to LTG's)</th>
<th>BY:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LTG (functional, measurable and do not exceed PLOF or justify)</th>
<th>BY:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
</tr>
</tbody>
</table>

**PLAN OF CARE:**
- Hot pack for muscle relaxation, increased circulation
- Cold-pack to reduce inflammation, spasm, pain
- Ultrasound to promote tissue mobility, decreases scar formation
- TENS/NSAIDs to reduce inflammation
- Traction to relieve compression-related symptoms
- Other (ie. splinting, bracing, orthotics)
- Electrical stimulation for strengthening, pain and spasm reduction, muscle re-education
- Therapeutic exercises for strengthening, endurance, stabilization, and flexibility
- Neuromuscular re-education to improve balance, posture, coordination, proprioception, kinesthetic awareness
- Manual therapy to promote tissue, joint mobility, ROM, and joint nutrition via mobilization/myofascial release
- Gait Training for safe ambulation and stair negotiation
- Home Management Training: home exercise program, body mechanics, energy conservation, safety, dressing, transfers
Appendix C – Physical Therapy Protocols

C.1 – Example of Week 0 – Week 4 General PT Protocol

Manual Therapy

• Patella mobilization – all directions, 5 minutes
• Once incision sites are well healed initiate scar mobilization – 5 minutes

ROM

• Restore normal ROM (flexion and extension
• Flexion
  o Heel slides – 30x
  o When patient is able to achieve 90-95° progress to recumbent bike for
    ROM – 10 minutes
  o Prone knee flexion
  o AAROM – 5 x 30 seconds
  o PROM/Contract relax – 10 x 10 seconds
• Extension
  o Hamstring stretch – 5x30 seconds
  o Calf stretch – 5x30 seconds
  o Supine extension with ankle weights – 5 minutes
  o Prone extension with ankle weights – 5 minutes
  o When patient achieves extension ROM equal to opposite/non-injured leg
    progress to WB extension – TKEs
**Strength**

**Hip**

- 4 way SLR
- Once patient is able to perform SLR independently without extensor lag in all directions discharged from crutches and progress patient to standing hip exercises with t-band

**Knee**

- Quad sets
  - With Russian NMES
  - Start with 10:20 for 10 minutes
  - When patient can perform quad set independently and hold for 10 seconds progress to 10:10 without
  - Quad set with adduction – 30x holding for 10 seconds
- Squats – 3x10
- Lunges – vmo re-education with airex pad – 2x10
- TKE – 3x10, holding for 5 seconds
- Shuttle
- Leg press (double) with adduction – 3 x10
  - Single leg press – 3x10
  - Sidelying press – 3x10
- Hamstring curls – seated with resistance, 3 x10
- Knee extension – seated with resistance, 3x10
- Eccentric dips – 2x10
Ankle

- Teach patient ankle DF, PF, inversion and eversion to perform as part of HEP
- Balance
  - Weight shifting in standing – side to side and forward back, 20x each direction progressing to balancing on injured leg (non-compliant surface) for 10 seconds
  - Once patient can balance on non-compliant surface, progress to compliant surface (foam airex pad) until patient can balance for 30 seconds

Gait training

- Once patient can perform a SLR independently without extensor lag and can balance on injured leg for 10 seconds discharge crutches
- Hurdles – leading with injured leg and then non-injured leg focusing on heel strike and knee flexion, 5x

Edema

- Ice anterior and posterior knee elevated and extended on bolster – 10-15 minutes
C.2 – Decisions Making Scheme for Individualized Protocol
C.3 - Example of Week 4 – Week 8 Individualized PT Protocol

Activity Limitations/Impairments:

• Hopping; impaired distance and height
• Pivotting going around objects to right
• ER of foot with side stepping

Warm-up

• Elliptical x 10 minutes
• Jogging at an interval of 2 minutes walking:
  o 1 minute jogging progressing to 1 min walk: 2 min jog → 10 minutes jogging

ROM

• End range of motion
  o Prone knee flexion with stretch out – 5 x30sec
  o If lacking, PROM
• Stretches
  o Hamstring stretch – 5x30sec
  o Calf stretch – 5x30sec
  o ER stretching – 3x30sec

Strength

• Seated hamstring curls and quad extensions – 3x10
• Single leg squats – 2x10
• Calf raises – 3x15 for gastroc and 3x10 soleus
• Eccentric calf – 2x10
• Clamshell for right hip abduction – GTB 3x10
• S/l right hip abduction – 3x15
• S/l shuttle press for right hip abduction – 3x10
• T-band strengthening right hip IR – 3x10

Proprioception
• Side stepping with t-band – BTB 6x25 feet
• SLS foam/trampoline with UE rotation – 3x15
• SLS on airex pad/bosu – 5 x 30sec

Power
• Slide board – lateral slides with emphasis on push-off – 3x30 seconds

Endurance
• Quick step – off green plyo box, alternating taps quickly – 3x30 seconds
• Ladder drills
• Quick step fwd/side – 5x each
• Double hop – 3x
• Single hop – 1x
• Skier – side lunge back and forth to the outside of the ladder – 5x
• Double hop crossover – 2x
• Single hop crossover – 1x