Evaluation of Outcomes in Assessment of Iliotibial Band Syndrome Rehabilitation Programs

by

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Abstract

One of the most common running related injuries and leading cause of lateral knee pain in recreational runners is iliotibial band syndrome (ITBS). The popularity of recreational running and rate of running related injuries are increasing. This study's goals were to evaluate the effects of three different exercises programs in reducing ITBS symptoms and determine if the experimental exercise group program provides a new progressive rehab intervention for ITBS management. This study consisted of volunteer female distance runners age 19-45 with ITBS—with a 10-mile per week average running distance during a three-month period. After recording age, gender, injured leg, pain, body weight, and height the participants were split into three treatment groups: i) an experimental exercise group, ii) a conventional exercise group, and iii) a stretching group. Outcomes measured were the Y Balance test (YBT), single leg mini squats (SLMS), dynamometer readings (DN), lower extremity functional scale (LEFS), and numeric pain rating scale (NPRS). The YBT, SLMS and LEFS were taken at weeks 0 and 8, hip strength DN measurements were taken biweekly and the NPRS was taken weekly for 8-weeks. Hypothetically the experimental exercise group should exhibit similar or greater improvements in ITBS symptoms compared to current researched programs for hip strength and stretching. A two-way factorial, repeated measures, analysis of variance (ANOVA) model examined the effects each exercise program had on the outcome measures for between and within group's differences. Statistical significance within the experimental group was determined for the composite YBT and DN measurements for injured and non-injured leg, injured leg for the posterior medial reach for the YBT, LEFS questionnaire, NPRS during running activity and the SLMS. Statistical significance was determined between the stretching and experimental exercise groups. The stretching group exhibited statistically significant YBT anterior reach for the injured/non-injured leg and the LEFS

questionnaire. Although there were no statistical differences found for the experimental exercises group, it consistently showed improvements in outcome measures and never scored less than the other two groups.

Preface

SieuNarine-McKay, **Janine**, DC, RCCSS(C), BHK, developed the research design, completed the application for ethics approval, oversaw and assisted in data collection, oversaw and assisted in subject recruitment, interpreted results and wrote this thesis.

Taunton, Jack, BSc, MSc, MD, CASEM, Celebrini Rick, PhD, MPT and Hunt Michael, BHK, MSc, MPT, PhD, contributed to the research design, and document preparation of this thesis.

Gustafsson, Emelie, BSc, MSc**,** ran data analysis and generated statistical tables.

Lau, Ken, BSc, MSc Statistics, completed subject randomization and provided unique identification codes.

Cukic, Kristina, fourth year Kinesiology student at UBC, research assistant for data collection, data input and assisted in recruitment.

Taunton, Jack, BSc, MSc, MD, CASEM assisted in ethics approval process and assisted in subject recruitment.

Gannon, Ryan, B. Chiro.Sc, M.Chiro., assisted in subject recruitment, and completed the subject inclusion.

Biegler, Jenny, BSc, MPT and **Lajoie Evelyne** BSc. Kin, MPT, assisted in data collection.

Anand, Richa, PhD, helped in the editing of this document.

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No manuscripts resulting from the work presented in this thesis have been published to date.

This study involved human subjects and was granted full board approval from the University of British Columbia Clinical Research Ethics Board (certificate # H13-01816).

Table of Contents

List of Tables

List of Figures

List of Abbreviations

Abbreviation	Full form
ANOVA	Analysis of Variance
DN	Dynamometer
FL	Fascia lata
FPS-R	Faces Pain Scale-Revised
HHD	Hand-held dynamometer
GM	Gluteus medius
ICC	Intra-class correlation coefficient
ITB	Iliotibial band
ITBS	Iliotibial band syndrome
ITT	Iliotibial tract
LFC	Lateral femoral condyle
LEFS	Lower extremity functional scale
MVC	Maximum voluntary contraction
NSAIDs	Non-steroidal anti-inflammatory drugs
NSCA	National Strength and Condition Association
NPRS	Numeric Pain Rating Scale
PFP	Patellofemoral pain
RE	Runner economy
REB	Research Ethics Board
ROM	Range of motion

SLMS	Single leg mini squat
SD	Standard deviation
TFL	Tensor fascia lata
UBC	University of British Columbia
VAS	Visual analogue scale
Vo_2	Oxygen consumption
VRS	Verbal Rating Scale
YBT	Y balance test

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CHAPTER 1: INTRODUCTION AND REVIEW OF THE LITERATURE

1.1 ILIOTIBIAL BAND SYNDROME

Iliotibial band syndrome (ITBS) is one of the most commonly occurring injuries and a leading source of pain in runners, alongside plantar fasciitis, meniscal injuries, patellar tendinopathy, and patelleofemoral pain (PFP) (Taunton et al., 2002). ITBS is defined by pain around the lateral femoral condyle (LFC) which occurs after repetitive motion of the knee, which creates friction as the iliotibial band (ITB) slides over the lateral femoral epicondyle (Fredericson et al., 2000). Traditionally, it has been attributed to repetitive flexing and extending of the knee during long-distance running, creating excessive friction within the distal ITB and the adjacent lateral femoral condyle (Grau et al., 2011). In two separate studies conducted on the impact of ITBS, 2.1% and 4.7% of all running injuries were traced to problems with the ITB per every 1,000 runners. Examinations of the motion of the leg as the foot strikes the ground detected impingement of the ITB just after foot strike (Fredericson et al., 2000, Hamill et al., 2008). Seventy percent of all runners report overuse injuries, but ITBS continues to be difficult to treat. This is a cause for concern given that ITBS is the second most common running injury behind PFP syndrome (Fredericson et al., 2000).

1.2 ANATOMY OF THE ILIOTIBIAL BAND (ITB)

The ITB is a lateral thickening, and reinforcement, of the fascia lata (FL) in the thigh. Proximally, it splits into superficial and deep layers, enclosing tensor fascia lata (TFL) and anchoring this muscle to the iliac crest and receives most of the tendons of the gluteus maximus. (Fairclough et al., 2006). The ITB is simply understood as a dense band of fibrous connective tissue that passes over the lateral femoral epicondyle and attaches to Gerdy's tubercle on the anterolateral aspect of the tibia (Fairclough et al., 2006). Two distinct regions of ITB are identifiable: a ‘tendinous’ part proximal to the lateral femoral epicondyle and a ‘ligamentous’ part between the epicondyle and Gerdy's tubercle (Fairclough et al., 2006). The ITB's function, along with its associated muscles, is the extension, abduction and lateral rotation of the hip as well as contributing to lateral knee stabilization (Fairclough et al., 2006). When the limb is loaded—either neutrally or when the tibia rotates internally or externally—the ITB tenses (Fairclough et al., 2006). Parts of the ITB also tense during the various positions of knee joint flexion. As the knee progressively flexes, tension shifts from anterior to posterior fiber bundles and the bands of FL attached to the patella (which are contiguous with the ITB) come under tension as the patella moves around the femoral condyle, while the ligamentous part of the ITB is tensioned in turn as the tibia moves posteriorly (Fairclough et al., 2006). Dissections have revealed that the ITB is consistently anchored to the femur in the region of the lateral epicondyle by strong fibrous strands which are often obliquely orientated (Fairclough et al., 2006).

1.3 ANATOMY AND BIOMECHANICS OF THE HIP COMPLEX

Anatomically, the hip joint is comprised of two parts, the femoral head and acetabulum, the so-called “ball and socket”. The hemispherical femoral head is attached to the femoral neck. It angles anteriorly, superiorly and medially (this is known as the angle of inclination) in order to fit into the acetabulum. The acetabulum itself consists of three bones of the innominate complex (the pubic, the ilium, and the ischium), and orients itself facing laterally, angling slightly towards the inferior and anterior direction in relation to the body axis. The hip, therefore, is a multi-axial ball-and-socket joint, which has three degrees of freedom for rotation: the sagittal plane, the frontal plane, and the transverse plane. Each plane is associated with different movements; the sagittal plane is associated with flexion and extension, the frontal plane with abduction and adduction, and the transverse plane with external and internal rotation. This joint's stability is essential to keeping the upper body balanced and to provide the necessary resistance to withstand the forces produced during motion. All motions between the acetabulum and the femoral head are rotational due to the congruency between articulating surfaces, (Harding et al., 2003; Whitesides 2001). This articular congruency of the joint is maintained by the joint capsule, acetabular labrum, articular cartilage, and the surrounding musculature. Ligaments, which restrict excessive motion and prevent dislocation, are also integral to the stability of the hip joint. The ligaments responsible for stabilizing the hip joint are the ischiofemoral, pubofemoral, and iliofemoral. The joint capsule is constructed in such a way as to provide mechanical strength; the capsule encircles the femoral neck and the joint, and is reinforced by the iliofemoral and ischiofemoral ligaments (Norkin and Levangie, 1992). Due to the tautness of this structure and the connecting ligaments, the hip joint is most stable at quadruped position and during hip extension. Therefore, the joint is most vulnerable, and injury is most likely to occur, during adduction and flexion.

Motion involving the hip joint is produced by the surrounding, associated muscles. Different groups of muscles are responsible for different movements such as extension, flexion, abduction, adduction, and internal and external rotations. Extensions are the responsibility of a group of extensor muscles, including the gluteus maximus, biceps femoris, semitendinosus, and the semimembranosus. Flexion meanwhile is produced by the iliacus, iliopsoas, rectus femoris, TFL, and the sartorius. The gluteus medius (GM), gluteus minimus, and TFL are responsible for abduction while adduction is produced by pectineus, adductor brevis, adductor longus, gracilis, and adductor magnus. Rotational movements occur both externally and internally; external rotation is produced by the obturatorius internus, obturatorius externus, gemellus superior, gemmelus inferior, quadratus femoris, and piriformis, while internal rotation is only possible through the cooperative action of GM and TFL (Moore et al., 1992).

1.4 Iliotibial Tract Functionality

Running motions take place in: frontal, transverse and sagittal planes. The repetitive motion of running has been shown to result in lateral sub-system weakness, specifically dysfunctions in the GM and TFL muscle (Myers et al., 2009). Whenever either the TFL or the gluteus maximus contract, the ITB tenses and tightens, causing contracture and external rotation of the hip and valgus of the tibia and hip flexion (although distal segments of the ITB aid other ligaments in the knee joint and remain in tension in both flexion and extension) (Yount, 1926).

Due to the anterior-lateral position of the ITB relative to the hip axis of motion, contracture of the band causes flexion and abduction of the hip (Beals, 2009). The contracture of the ITB to abduct the hip creates pressure on the sciatic nerve, which underlies the gluteus maximus and further under the piriformis muscle, and exerts further pressure on the pelvic bones (Ober, 1936). This process is more pronounced during running: the TFL and gluteus maximus act together to pull on the ITB during the initial stance phase when the knee is flexed, and also as the gluteus maximus fires as a part of the posterior oblique myofascial sling from terminal stance through toe-off (Myers et al., 2009). Upon this basis, testing was developed to test for the contracture of the ITB (Ober, 1936). Ober’s test requires the patient to lie on the non-pathological side of the body with the knee flexed until lumbar lordosis is eliminated. The injured leg is then extended and abducted so as to keep it in line with the body. A comparison of each leg's adduction range can provide a clinical estimate as to the state of the ITB; a pathological leg with a tight ITB will display restricted motion (Ober, 1936). Treatment can then follow, including surgically releasing the tight

ITB and thus alleviating pressure on the underlying sciatic nerve by reducing tension in the gluteus maximus (Kaplan et al., 1958; Ober, 1936). The ITB is functionally integral to the maintenance of upright posture as well as being an essential shock absorber and lateral stabilizer for the knees and hips (especially during the stance phase) and fortunately, the removal of small segments of the ITT does not negatively affect normal functioning during these operations (Kaplan et al., 1958; Ober, 1936). The posterior sub-system, which functions to stabilize the transverse plane, employs a range of muscles including the latissimus dorsi, thoracolumbar fascia and the gluteus maximus (Myers et al., 2005). The lateral sub-system consists of the GM, TFL, abductor complex and quadratus lumborum muscle (Myers et al., 2009) and functions to provide frontal plane stability. The ITB has little control over its positioning or tone; tension within it increases when the origin and/or insertion are moved further apart.

Although related species have tensor fascia femoris muscles, only *Homo sapiens* has an ITB associated with the hip complex (Kaplan et al., 1958). Biomechanical research indicates that the ITB functions as a connecting ligament between the ilium and the knee, and the tensor fascia lata muscle acts to flex and medially rotate the thigh (Kaplan et al., 1958). In order for the hip joint to remain stable, the ITT supplies a “tension-band” effect, reducing the mechanical load on the medial cortex of the femur (Birnbaum et al., 2004). The band also increases pressure on the trochanter during adducting contracture and decreases the pressure during abducting contracture; in effect, the ITT acts to centralize the hip by reducing pressure on the acetabulum when the proximal femur is in varus and increasing pressure when it is in valgus (Birnbaum et al., 2004). In essence, the ITT functions as a counterbalance to the weight on the lower limbs and acts as a tension band for the hip (Beals, 2009).

1.5 PREVALENCE OF ILIOTIBIAL BAND SYNDROME

Although humans, bipedal by nature, have always run, running as an activity, recreational or otherwise, is a recent phenomenon. The first Boston Marathon was staged in 1897 with a field of 15 runners. The sport grew astronomically through the latter half of the 20th century and a century later, the 100th Boston Marathon drew over 35, 000 participants from around the word. Literally thousands of races now exist for every distance and type of runner; the running industry, from shoes to coaching generates millions of dollars. Nearly 34 million people in the United States alone perform some form of regular running.

Not surprisingly, as running has increased—with more people than ever running longer distances—there has been a subsequent increase in running-related injuries. While injuries are a constant challenge for many athletes, they are especially common amongst populations of recreational runners, specifically those engaged in extended training programs (longer than 12 weeks) (Boyens et al., 1989). Injuries incurred as a result of running were observed to occur most heavily in training and less often during racing (Foster et al., 1992). This phenomenon has become increasingly observable over the course of the 20th century (Niemuth, 2005). Forty percent of female racers reported injury. Of those, 60.2% reported being unable to run for 2-4 weeks, while 39.8% of female racers reported that they were unable to run for at least 0-2 weeks.

Running injuries, defined as localized pain that dictates a change or frequency in training, often lead runners to seek an outside health professional or use medication to continue running. The overall yearly incidence rate for running injuries varies between 37% and 56% (van Mechelen, 1992). Most running injuries are lower extremity injuries, with predominance for the knee, about 50 to 75% of running related injuries (van Mechelen, 1992). Injuries to the hips are also significant, with a range of reported injury from 3.3% to 11.5%, across multiple reports (van Gent et al., 2007).

The overall prevalence of these two types of incidents is also significant given the suggestion in the literature that injuries to the ITB are related to weaknesses and injury in the hips (Finnoff et al., 2011). ITBS is a common occurrence in individuals that are physically active in running, and while optimal treatment is still under study, health practitioners report a strong level of confidence in diagnosing ITBS based on the case history of the individual (Lavine, 2010). These same practitioners also report confidence in expected health outcomes based on their prescribed treatment regimen.

1.6 PREDICTORS OF ILIOTIBIAL BAND SYNDROME

Human legs bear a significant amount of weight, and repetitive use may expose joints to overuse (Niemuth, 2005). However, the ability of these joints and other key structures to withstand injury is related to adjacent muscle formations that provide added support throughout the leg. The human musculoskeletal system is intertwined, and distal weakness can have repercussions in other parts of the system (Niemuth, 2005). The numerous contributors to injury along the ITB include training methods, muscle strength and flexibility, the quality of footwear, and poor biomechanics during running (Macintyre et al., 1991). Although many factors may contribute to the development of ITBS, the condition is most often aggravated by repetitive strain and multifactorial errors, improper footwear, lower extremity mal-alignments and muscle imbalances.

Biomechanically, a running gait involves two stages of gait, stance and swing phase and include: initial contact, mid stance, toe off, mid swing, initial contact (Novacheck, 1998). Most chronic injuries from running are related to the mid and late stages of a running stance, when impact forces are at their highest. This leads to a number of lower extremity injuries, and can also include injuries to the Achilles tendon.

The pain caused by these injuries is reproducible when a runner replicates the amount of time they have previously run before detecting pain, usually in the form of burning, along the lateral sides of the knee. In the earliest phase of ITBS, pain quickly subsides once running has ceased. However, it typically reoccurs at the next run. If the inflammation becomes severe due to continuous running, the pain can begin to present in daily walking activities, and is most acutely noticeable when ascending and descending stairs.

1.6.1 Hip Strength

The strength of the hips is predicted to determine the degree and frequency of injury using the closed kinetic chain model (Plastaras et al., 2006). Observation of biomechanical motion in symptomatic women indicated that those with lower hip strength were subject to internal rotation movements that, over time, led to pain within the knee (Ireland et al., 2003). Biomechanical factors leading to ITBS are consistently seen in the literature. Weakness in the hip abductors leads to greater knee internal rotation and hip adduction, which are both associated with ITBS and can be seen as a dynamic valgus. Runners with ITBS demonstrate weaker hip abductors on the affected side of their body versus the unaffected side and compared against unaffected control groups (Strauss, 2011).

Hip abductor weakness played a role, but its predictive power was weaker than external rotation muscle groups (Niemuth, 2007). An examination of 139 inter-collegiate basketball and track athletes was conducted to examine hip abduction and external rotation strength (Niemuth, 2007). In 14 injured athletes, injuries were related to the lower extremities in the following categories: (1) 65% experienced an injury to the foot and ankle; (2) 23% experienced injury to the knee; and (3) 13% experienced an injury to the hip. These injuries were then correlated with weakness in the abductor and external rotator muscle groups. While hip abductor weakness did play a role, weakness in the external rotation muscle groups acted as the best predictor of injury. The roles that both play in ITBS demonstrate that injury at the location of the knee can find its source higher in the leg.

Hip abduction strength differences in ITBS patients were found in both males and females (Ramskov et al., 2014). Age was associated with maximal eccentric hip abduction strength: per one-year increase in age a -0.0045 ± 0.0013 Nm/kg (SD) decrease in strength was found, $p < 0.001$ (Ramskov et al., 2014). For each additional year of age there was an observed decrease in hip abduction strength. This study also determined baseline strength differences between sexes. Among 832 participants of this study, there were observable differences in eccentric abduction strength between males and females (1.62 ± 0.38 Nm/kg (SD) and 1.41 ± 0.33 Nm/kg (SD) respectively). The development of ITBS could be predicted on the basis of deviation from normative values established for each sex during a corresponding period of age. Hip-abduction of the dominant leg was also found to be significantly larger than that in the non-dominant leg for patients presenting with lower extremity injuries (Jacobs et al., 2005).

1.6.2 Fatigue

Running economy (RE) is typically defined as the energy demand for a given velocity of submaximal running, and is determined by measuring the steady-state consumption of oxygen (VO_2) and the respiratory exchange ratio (Saunders et al., 2004). According to an article by Hayes et al. (2011), running can be considered as a series of repeated bounds that uses the stretch-shortening cycle. During a stretch shortening cycle, the muscle lengthens, acting eccentrically, before a concentric, shortening action (Hayes et al., 2011). A number of studies have shown the energetic cost of running at a fixed speed to increase with fatigue, that is, toward the end of a prolonged run (Saunders et al., 2004; Hayes et al., 2011). Endurance running can be considered a series of repeated submaximal stretch shortening cycles (Hayes et al., 2011). Fatigue has been shown to contribute to weakness in muscles and subsequent injury to the lower extremities (Hayes et al., 2011). In studies of distance runners, RE deteriorated after a session of high speed running (Hayes et al., 2011). When measured running at VO_2 maximum or maximal oxygen uptake for four minutes, runners became fatigued (Hayes et al., 2011). It was hypothesized that stride mechanics experienced a breakdown as fatigue increased (Hayes et al., 2011). The results of the study indicated that eccentric strength expression may have a potential regulatory role in determining running performance (Hayes et al., 2011).

A similar study was conducted on an all-female group consisting of 20 healthy female runners and 12 females diagnosed positively with ITBS (Brown, 2011). Participant age range was between 18 and 50 years old, all were rear foot strikers, and all ran a minimum of 15 miles per week with the capacity to run at least a single 9-minute mile (Brown, 2011). Deformities across the forefoot could account for faulty biomechanics while running leading to excessive rear foot striking which was in-turn linked to ITB injury (Brown, 2011). Interestingly, previous, research estimated that the foot took somewhere in the area of 1,000 strikes per mile, and that injury due to faulty biomechanics was cumulative over that period (Taunton and Clement, 1981). Further research is needed in determining if there is a relation between muscular fatigue in middle and long distance runners and the onset of ITBS symptoms.

In the study by Hayes et al. (2011), subjects presenting with ITBS demonstrated a lower ability to resist fatigue in the GM and hip abductors as compared to healthy subjects. This study suggested that hip abductors in subjects with ITBS were not weaker, thus leading to ITBS, but that the muscles were more prone to fatigue. This is consistent with the presentation of ITBS, which occurs or worsens after 20-30 minutes of running. Fatigue also exerts an impact on running stance. Runners that ran to fatigue demonstrated a 9.1% decrease in hip adduction angles, suggesting that gait significantly alters over the course of a run. Increased hip adduction angles are associated with ITBS (Noehren et al., 2014). This study suggests that a runner's condition pre-run is healthy, with muscles and gait that are at-par with healthy runners. However, given the lack of resistance to fatigue, muscles weaken more quickly, leading to a change in gait.

1.6.3 Biomechanical Factors

One study demonstrated that while hip adduction plays a role in knee injury, it is not always entirely clear how strong the relationship is (van der Worp et al., 2012). Researchers examined the strength of hip abductors in relationship with the kinetic motion of runners. This provided evidence that observable differences in runners with and without ITBS was not clearly linked to hip abductors, and the resulting observation of internal knee rotation and ankle/foot inversion/eversion did not provide a clear link to ITBS. This study of motion drew no clear links either from hip abductor weakness or from biomechanical motion, but was one of a few studies that began to examine the movement of the leg as a factor in promoting ITBS. The lack of weakness in the muscles was reinforced by Louw and Deary (2014), who found no role for a lack of strength in the development of ITBS.

Further previous findings were studies by Grau et al. (2011), who found decreased hip abduction in ITBS runners when compared against controls. Patients presenting with ITBS demonstrate kinematic differentiation at the hip in the frontal and sagittal planes, at the knee in the sagittal plane, and at the ankle in the sagittal plane. The difference in results was attributed to sex specific differences. Previous studies detecting increased hip abduction consisted of higher female populations, while Grau's and co-authors' study included 72% male participants. The study by Grau et al. was also cross-sectional as opposed to longitudinal, and could not determine whether variation in hip abduction contributed to ITBS, or whether variation occurred in response to injury. However, Grau et al. (2011) continued to emphasize the biomechanical role as a contributor to the development of ITBS.

The emphasis on biomechanical factors was reinforced by a study of the female gait while running (Ferber et al., 2010). Runners that were both symptomatic and asymptomatic for ITBS were observed and the range of their leg motion documented during a run. Thirty five females who had previously suffered from ITBS were compared against 35 females that exhibited no symptoms of inflammation of the ITB (Ferber et al., 2010). After being age-matched and distance matched, a comparison of the leg motion, including the motion of the hip, knee, and ankle, was conducted (Ferber et al., 2010). Females presenting with ITBS demonstrated a greater peak in their rear foot inversion movement, peak knee internal rotation angle, and peak hip adduction angle when compared against asymptomatic controls (Ferber et al., 2010). This suggests that females demonstrating symptoms of ITBS possess a significantly different kinematic profile that places them at higher risk of increased stress on the ITB (Ferber et al., 2010). Checking female runners for similar motion profiles may help to predict or prevent ITBS type injuries. Researchers particularly identified the increased peak knee internal rotation angle as a predictor of ITBS development (Ferber et al., 2010; Fredericson et al., 2000). It is hypothesized that increased knee rotation increases stress on the tissues of the knee joint, which includes the ITB, however, weakness in other distal parts of a person's physiology may also lead to pain in the ITB (Ferber et al., 2010).

Partly contradicting a body of literature that suggests biomechanics may be responsible for ITBS, Louw and Deary (2014) asserted that ITBS is unlikely to be caused by biomechanics in the foot or tibia, instead, implicating the frontal and sagittal plane of motion for the hip joint as the primary cause of ITBS.

1.6.4 Potential Structural Cause

ITB is limited in its degree of motion it can conduct due to fibrous connections. However, medial-lateral excursion is possible as the FL becomes tense. This in turn presents a risk for greater pressure on surrounding tissue (Fairclough et al., 2006). The tissue underlying the ITB tract is densely packed with vascularized tissue with potentially high, pressure-sensitive nerve endings. Compression along this region can cause a systemic issue in which the hip abductors react to neural feedback from beneath the ITB tract, creating abnormal motion and resulting in greater friction on the ITB, resulting in inflammation. The TFL functions by pulling the ITT superiorly and anteriorly (Tucker, 2007). It assists with muscle flexing, medial rotation, hip abduction and extension of the knee joint. Injuries may arise due to a number of structural abnormalities that arise. The TFL can become long and weak, which impacts flexors. The TFL can also become short, which impacts hip abductors. Lengthening of the posterior GM is associated with weakening of that muscle and impact on the hip abductors.

1.6.5 Other predictors

Other predictors of ITB include training errors, which may include a rapid change in exercise routine (Strauss et al., 2011). This can involve a change from hill running to excessive stride, or taking on greater mileage during a run than the runner is adjusted to. ITB is also associated with the type of running surface; running surfaces with excessive arch generate increased tension in the lateral components of the knee, which are then associated with ITBS. In separate studies, surface was found to be linked to injury (Taunton and Clement, 1981; Taunton, 2002). Excessive exposure to training surfaces such as concrete and asphalt, which have very poor ability to absorb shock, were associated with injury (Taunton and Clement, 1981; Taunton, 2002). However, surfaces that were very soft, such as those with sand, were also linked with injury (Taunton and Clement, 1981; Taunton, 2002). Injury was also linked with transition between surfaces injury (Taunton and Clement, 1981; Taunton, 2002). Runners transitioning from trail running to running on pavement should do so gradually, and the researchers proposed that runners use a variety of surfaces to minimize the chance of injury (Taunton and Clement, 1981).

Previous predictors in the literature indicated that surface and speed were both related to knee injuries. However, these two seem to be factors independent from distance, which was not observed as a variable that could predict knee injury. Indeed, increased running distance seemed to act as a protective factor in a complicated review of literature compiled by van Gent et al. (2007), and was not itself associated with injury to the knee, although the prevalence of other forms of lower extremity injury occurred in males with increased distance.

This was not observed in females, which suggests a complicated relationship between distance, time, muscle strength and biomechanical motions, as predictors of ITB and other lower extremity injuries that arise due to running. The observation that running injury in females was not associated with training distance was reinforced in findings by Foster et al. (1992), who reported only a weak correlation between distance and the prevalence of injury. The role of distance in generating injury was complicated by gender and length of runs (Macintyre et al., 1991). Female middle distance runners had lower rates of injuries to their knees than did male middle distance runners. Middle distance runners who ran between 800 and 5000 meters, suffered injury around the knee, not observed in short and long distance runners. Elite middle distance male runners were especially prone to injury at the knee, which the research suggested was a result of training intensity.

Terrain was also found to be associated with running injuries, in separate studies by Foster et al. (1992) reported 38.7% of all injuries were the result of terrain conditions. Terrain does not encompass weather, but describes the relative smoothness or angle of a running surface. Slanted surfaces tend to require a greater stride from the leg leaning toward the slant, and this causes a deviation in running motion from one leg to the other. This can lead to inflammation of the ITB (Glodzik, 2009). Downhill running was also associated with generating greater amounts of friction in the ITB and resulted in quadriceps fatigue. The quadriceps muscle is responsible for helping to stabilize the knee, and the fatigue produced in a downhill run puts runners at risk of inflammation in the ITB. Downhill running is regularly reported as the most common source of pain for runners (Louw and Deary, 2014), and it should be particularly investigated to determine the biomechanics involved.

A history of previous injuries was also a risk factor for both male and female runners (van Gent et al., 2007). Ongoing complications due to the injury were hypothesized to be a result of decreased flexibility, leading to disuse and atrophy of the region around the ITB, and were linked to the development of tibial stress syndrome (Taunton and Clement, 1981). This reduction in flexibility was one reason that stretching has been an ongoing response to injuries around the ITB.

Age also plays a role in the occurrence of ITBS, and being less than 34 years old is associated with higher risk of ITBS among men. Other factors that lead to the development of ITBS include exercise activity for less than 8.5 years which was linked to injuries among both sexes along the ITB. Additionally, weight played a role in increasing the chance of injury in women (Taunton et al., 2002).

1.7 DIAGNOSIS.

The presence of ITBS in an individual is assessed through a clinical examination and review of the patient's history (Strauss et al., 2011). The emphasis in diagnosis is to look at a patient's history and current presentation (van der Worp et al., 2012). Patients that present with ITBS generally report pain along the lateral component of the knee, which is localized at the region of the distal ITB. This places the pain between the lateral femoral condyle and its point of entry into the Gerdy's tubercule. Onset of pain is typically observed by the patient following a repetitive flexion-extension behavior, which often includes running. Over time, the condition worsens and pain begins earlier in the exercise activity. At its worst, progressive symptoms of ITBS become observed by the patient even while at rest. Symptoms presented at a visit with a physician usually consist of burning pain occurring superior to the lateral joint line of the knee (Fredericson and Weir, 2006). Before the condition has progressed, symptoms may occur only after a reproducible time, with feelings of pain subsiding after a cessation of activities. Patients report increasing regularity in symptoms over time.

Evaluation of ITBS should include a complete knee examination to rule out other causes and to isolate and identify ITBS as the cause (Strauss et al., 2011). A patient should be evaluated while standing to determine the alignment of their lower extremities, and the knee itself should be examined to determine if there is any soft-tissue swelling. A range of motion test should also be performed to examine any restrictions on the knee's motion. Physicians typically detect tenderness upon palpitation of the ITB superior to the lateral joint line (Fredericson and Weir, 2006). In milder cases this may not be reproducible, but as the injury progresses and grows in severity, there may not only be pain, but local edema and crepitation.

Three forms of provocative tests are also used when assessing a patient for ITBS (Strauss et al., 2011). The Noble test requires a patient to lie supine while the knee is flexed at 90° with direct pressure applied to the lateral femoral epicondyle. Pain should be reproducible near 30° of knee flexion. The Noble test is typically used in studies to confirm a diagnosis of ITBS (van der Worp et al., 2012). Ongoing questions as to the validity of the Noble linger, though the test is often positive (Fredericson and Weir, 2006). The Ober's test requires the practitioner to try and attempt to adduct the affected leg from this position. The patient is considered positive for ITBS if the leg cannot be adducted from this point (Strauss et al., 2011). The Ober test is considered complimentary to the Noble Test (van der Worp et al., 2012). As a means of determining ITBS, it is commonly applied during clinical examination to determine the length of the ITB. It was used in studies when determining the length of the ITB in symptomatic males (Noehren et al., 2014).

Minimal tightness is determined if the leg can be passively stretch to a position that is horizontal, but not completely adducted to the table (Fredericson and Weir, 2006). Moderate tightness is determined if the leg can only be passively adducted to horizontal. Maximum tightness is determined when the leg cannot be passively adducted to horizontal. These three degrees of determination constitute the means by which the Ober test is administered. The Thomas test determines rigidity and tightness in the iliopsoas muscle, rectus femoris muscle, and ITB. The patient is required to lie supine with both knees held to their chest. The affected leg is extended and lowered, and the patient is considered positive for ITBS if the patient cannot completely extended the leg to horizontal (Straus et al., 2011). In athletic populations, the femur should hang to 12° below horizontal off the table, with 15° abduction, while the knee hangs with 52° of flexion (Fredericson and Weir, 2006).

Another test that is employed during examination is the Renne test, in which patients are asked to stand on the affected leg while the knee is flexed 30-40°. If presentation of pains is reported, the subject is considered positive for ITBS (van der Worp et al., 2012). A final test requires a patient to stand just apart from a wall with feet together. If the client cannot contract their abdomen and gluteal muscles in order to flatten the lumbar spine onto the wall, then the TFL and ITB could be weak or shortened (Tucker, 2007). In all cases of diagnosis, pain is initially reported to physicians in one of four ways: (1) onset of pain comes after running, without causing restriction to distance or speed, (2) pain comes during running, without causing restriction to distance or speed, (3) pain onset occurs during running and restricts distance or speed, and (4) pain severity is extreme enough to prevent running. These four reports are the 'injury grade' developed in the Lindenberg system (Tucker, 2007).

Unilateral balance and dynamic neuromuscular control are required for running and thus the single-limb mini squat and the Y-balance test™ (YBT™) (Functional Movement Systems Inc., VA, USA) are two useful means of assessing muscle function and balance (Plisky et al., 2006; Westrick et al., 2012; Ageberg et al., 2010). Y-Balance evaluations can be separated into upper and lower quarter. For the purpose of this study, we used the Y-balance lower quarter (YBT™-

LQ). The single limb mini-squat resembles daily function and is easy to perform, and is thus a meaningful indicator of lower extremity movement quality. It can also indicate misalignments. The single limb mini squat has been shown to be the single most useful and validated dynamic standing test (Zeller et al., 2003). This test is a visual assessment in all three planes of motion, frontal, transverse and sagittal. Motion at the hip, knee and ankle can be observed in all three planes and may reveal dynamic hip drop (Trendelenberg test), knee valgus and/or foot pronation. Weak hip abduction can lead to hip adduction, pelvic drop and lack of knee control (Zeller et al., 2003; Lavine, 2010). Likewise, the Y-balance test is a reliable measure and a valid dynamic test to predict risk of lower extremity injury and to identify dynamic balance deficits (Gribble et al., 2013; Plisky et al., 2009; Plisky et al., 2006). It is recommended that the YTB™-LQ test should be used for return to sport testing, pre-participation physicals, and annual musculoskeletal exams (Gribble et al., 2013). Poor performance on the YBT™-LQ has been associated with elevated risk for non-contact lower extremity injury (Plisky et al., 2006).

Pain and function in the lower extremity can be measured by physicians using a Lower Extremity Functional Scale (LEFS), which is both easy to score and that can be used to determine the range of disability across a number of different conditions (Binkley et al., 1999). This scale uses 20 items, each with a maximum score of 4 and a total possible score of 80. The questions consist of an introductory statement: “Today, do you or would you have any difficulty at all with:” This is followed by a list of items describing various physical functions. The LEFS can be used to determine a patient’s initial function, assess their ongoing progress, outcomes, and to set goals. Initial assessments can be followed up by weekly outpatient proceedings, with short and long-term goals established as measured using the scale. Binkley suggested that the LEFS be compared against other surveys and testing to continue to measure its validity in determining patient performance (Binkley et al., 1999).

The necessity for standardized, subjective modes of determining whether pain is clinically important was determined in studies of patients reporting pain and the responses of physicians to the report (Krebs et al., 2007). In an examination of 548 patients reporting pain, 40% reported pain as the main reason and 22% as the secondary reason for a visit to their physician. When screened for pain, there was only a modest level of accuracy in determining whether a patient had clinically significant pain using a standard numeric pain rating scale (NPRS) that is widely utilized in primary care. A number of factors can determine how a patient reports pain, including questionnaire wording, the focus on currently existing pain over intermittent symptoms, and the use of the word "pain" as the means for describing a patient's condition. This suggested the need for more objectively worded, broader scales that could properly lead to a determination of whether a patient's pain was clinically significant. Despite weakness, the four point rating scale remains the most valid widely accepted tool for self-reporting current stages of pain (Ferreira-Valente et al., 2011). Of the Visual Analogue Scale (VAS), Numerical Pain Rating Scale (NPRS), Verbal Rating Scale (VRS), and Faces Pain Scale-Revised (FPS-R), the four most common pain intensity-rating scales, NPRS remains the strongest predictor of clinically important pain. While all four are similarly accurate, NPRS consistently predicts clinically important pain at a slightly more accurate rate than its contemporaries (Ferreira-Valente et al., 2011). The literature suggests that ongoing data collection is necessary to determine the comparative accuracy of LEFS against the NPRS, VAS, VRS and FPS-R.

The current difficulty in dealing with ITBS and predicting it stems from a lack of known pathology (van der Worp et al., 2012). The literature suggests that initially, ITBS was thought to be caused by excessive friction between the ITB and the lateral femoral condyle. Other investigations determined that muscle strength, particularly in the gluteus maximus (Falvey et al., 2010) and hip abductors (Ireland et al., 2003) play a role in the presentation of ITBS.

There is some variability in hip abductor weakness as a predictor (van der Worp et al., 2012), although was attributed to variations in samples, measurement devices, age, sex, and performance level. Men did not demonstrate a weakness in hip abductor muscles upon examination, which may illustrate a difference between the sexes in the development of ITBS (van der Worp et al., 2012; Noehran et al., 2014). Other variables also impact kinematics of an individual and require study participants to be accurately matched to determine normalized action and variation. Taller, shorter, heavier, and lighter individuals all demonstrate differences in how the lever mechanics of human limbs function (Grau et al., 2008). These all impact running styles and should be better considered and matched when testing to determine how ITBS arises. As subjects are more closely matched to eliminate variation in everything from age to weight and gender, accuracy in standard measurement increases. The potential for sex differences was also found in comparison studies that reported no differences in the strength of hip abductors between patients with ITBS and asymptomatic controls (Grau et al., 2011).

Future studies were recommended, with an emphasis on wider studies (>30) of the hip abductors in presenting patients. The question that remains when examining biological contributions was whether weakness in the hip abductors caused ITBS, or whether ITBS caused weakness in the hip abductors. When examining the biomechanics of runners, van der Worp et al. (2012) noted that those with and without ITBS demonstrated biomechanical differences when running, but that this difference depended on individual variables such as weight, height, and sex. Researchers questioned whether differences in biomechanics is present in both sexes, or if it sex specific to females. Male runners did demonstrate diminished ITB length, variation in their hip and knee kinematics, and diminished hip strength (Noehran et al., 2014). However, the degree of difference in ITB length between presenting patients and asymptomatic controls was only 1.2°. Greater hip internal rotation, weaker hip external rotators, and greater knee adduction or knee valgus were consistent with biomechanical variations contributing to ITBS in the literature.

1.8 Treatment.

Treatment for ITBS can be either surgical or non-surgical. Preference, however, should be towards non-surgical options and only after long-term conservative therapy has proven to be ineffective should surgery be considered.

1.8.1 Non-surgical Treatment Options

Symptomatic women often presented with chronic pain that could not be dealt with using non-intrusive means. Non-intrusive or conservative means of intervention typically included the ingestion of non-steroidal anti-inflammatory drugs (NSAIDs), deep friction massages, phosophoresis, ice, ultrasound, stretching, and corticosteroid injection. These treatments often took place within clinical practices and are suggested courses of treatment in the literature (Ellis et al., 2004). However, these suggested courses of actions have not been based on empirical demonstrations of efficacy and their use has been based on no firm rationale. Therefore, they have been of limited use when dealing with pain associated with ITBS and PFP related to the weight bearing activity involved in running.

Examinations conducted on a group of 20 subjects examined the effectiveness of rest, ice twice a day, and physical therapy that included stretches of the ITB (van der Worp et al., 2012). Reports by participants indicate that there are significant reductions in pain following treatment.

However, studies conducted by Ellis et al. (2004) suggested that each form of treatment only possessed efficacy at varying stages of the ITBS. Each form of intervention has a maximal efficacy period, during which results are magnified. However, the body of literature did suggest that conservative treatment of ITBS produced positive health outcomes, although randomized trials have not determined the efficacy of any in isolation (van der Worp et al., 2012).

Rest that allows the patient to recover from pain is the earliest recommended response to ITBS. Refraining from the activity that incites the pain is considered to be a first response, and may end with pain resolving (Strauss et al., 2011). Activity may gradually be resumed over time. The period when pain is first perceived is considered the acute stage, during which inflammation in the ITB is first underway. Acute stages of ITBS seem to respond most positively to corticosteroid injections alone (Ellis et al., 2004), while latter stages traditionally require the use of anti-inflammatory and analgesic medications, which can present complications for long term runners as the use of these medicines is associated with negative health outcomes when taken indefinitely. The primary treatment goal during the acute stage of ITBS is pain relief and the reduction of local inflammation (Fredericson and Weir, 2006).

During the acute stage, the athlete may remain active within the activity they participate in if they modify their activity to stay below recommended time frames and distance. Since ITBS pain is replicable and symptom onset occurs after a regular time interval, this is a necessary step. In more severe cases, the activity must cease and be replaced with a non-aggravating activity, such as swimming. Van der Worp et al. (2012) reported that subjects given corticosteroid injections, in conjunction with daily ice therapy over a 14-day resting period, produced significantly decreased pain in the injection group. Strauss et al. (2011) considered the use of NSAIDs to be ineffective when used alone. However, when used in conjunction with other forms of treatment, including physical therapy, NSAIDs were beneficial in managing pain. The element of physical therapy is important in dealing with ITBS. To enhance the efficacy of treatment, physicians recommended the use of muscle strengthening exercises as a direct response to the observed relationship between hip weakness and knee injury (Lavine, 2010). Sixteen subjects, including five men and 11 women between the ages of 20 and 53, demonstrated significant differences in hip abductor strength and injuries throughout the entire group. As hip abductor strength was increased, physical function capacity increased (Beers et al., 2008). Strengthening of the hip abductor muscles appeared to be positively linked with a decrease in symptoms and acted both as a preventer of injury as well as a means of resolving injury.

While pain medication was moderately effective in treating the acute stages of ITBS, long-term responses often involved strengthening the hip abductors, stretching the ITB and the surrounding structures, and manipulating the connective tissue of the knee. Strength-training of the hip abductors was a commonly recommended response to ITBS and was associated with long term improvement of pain. NSAIDs could also be used in conjunction with in-office therapies, such as laser, microcurrent, and medical acupuncture (Falvey et al., 2010; Fredericson and Wolfe, 2005). These treatment tools helped accelerated healing of the ITB and could be used alongside stretch-based exercises.

Standard responses to the treatment of ITBS include a regiment of anti-inflammatory medication (Ellis et al., 2004; Fredericson and Wolf, 2005). These can be supported with ITB stretches (Fredericson and Wolf, 2005). However, muscle imbalance in the lateral hip muscles that creates distal pain in the knee can also be managed using specific deep tissue massage therapy and strengthening exercises. Lavine (2010) asserted that Fredericson and Wolf (2005) described a series of stretches that optimally addressed ITBS during the subacute phase, described as the period immediately after acute inflammation has subsided. These exercises included three sets of 7-second submaximal contractions with a post-set 15-second stretch. The purpose of these exercises was to increase the length of the ITB. These stretches included (1) arms at sides stretch to the left and right, (2) arms overhead stretch to the left and right and (3) arms reaching diagonally downward. For all three stretches, ITB tissue was lengthened most using an overhead stretch, although all three demonstrated some degree of stretching on the ITB tissue. Once inflammation was resolved Fredericson and Wolf (2005) recommended strengthening exercises. Follow up studies determined that the use of stretching increased the length of the ITB tissue, which resulted in greater force generated within the stretched complex (Fredericson and Wolf, 2006).

The effectiveness of stretching interventions was questioned by Falvey et al. (2010). While Fredericson and Weir (2006), quantified the lengthening of the ITB during his proscribed stretching exercises, Falvey et al. used ultrasound measurements to determine that the ITB stretches only minimally during stretching exercises. The average measure movement during an exercise represented only a 0.2% increase in length. While the body of existing literature recommends stretching as an effective long term treatment, Falvey et al. (2010) suggest that such a response produces negligible results. These findings were reinforced by Fairclough et al., (2007), who asserted that not only is the range of motion of the ITB small, but that its ability to stretch is negligible. In his view, the ITB would need to be stretch in conjunction with the FL, the lateral intermuscular septum, and the distal fibrous bands. This combined lengthening is not observed when patients use stretching as an intervention with ITBS, and the assertions that stretching assists healing is met with resistance in the literature.

Instead, Fairclough et al., (2007) asserted that perceived relief was due to unconscious tensing of the hip adductors, which can be related to temporarily providing some relief in the ITB.

However, it is not permanent. Instead, Falvey et al. (2010) recommended biomechanical corrections through massage therapy along the gluteus maximus and TFL, which he hypothesized would result in greater muscle flexibility. Weakness along the GM muscle was identified as a leading factor in causing the hip to push out against it (Fredericson et al., 2000) which could be corrected through strengthening of the muscle.

The types of exercises claiming to strengthen muscles related to ITBS encompass a number of stretches, and the lack of a credible, replicable form of therapeutic intervention with consistently observed positive health outcomes was reinforced by Fredericson et al. (2000) and Fredericson and Wolf (2008) who attempted to identify commonalities pertinent to ITBS and develop a successful prevention and management program. Stretching was again recommended when dealing with ITBS, and the ITB itself could best be stretched by crossing the affected leg over the non-affected leg. This was followed by reaching the arm on the affected side above the head while turning the waist away from the symptomatic side. Fredericson et al. (2002) suggested that these were an effective preventative measure. Strengthening of the GM was found to generate positive health outcomes in 90% of patients that underwent treatment.

Newly suggested modes of treatment were proposed that emphasized increasing the range of motion at the hip (Grau et al., 2011). A decrease in frontal range of motion (ROM) at the hip was associated with the development of ITBS, and recommended stretches were consistent with previous suggestions. While Grau et al. heavily emphasized increasing frontal ROM, a focus on massaging the ITB and hip abductors was also suggested. This was consistent with previous interventions in the literature that identified the hip abductors as critical in the development and source of treatment in ITBS.

Following the subacute period of ITBS, athletes enter the strength-recovery phase. The exercises involved during this period included side-lying leg lifts and single-leg balance step downs (Fredericson and Weir, 2006). In a study of 24 injured runners, 22 were able to return to activity without symptoms after 6 months. Unlike Ellis et al. (2004), who generally suggested weight training as an intervention, Fredericson and Weir, described stretch based exercises with weight concentrated on one side of the body. Patients were asked to rotate their bodies to increase range of motion, and the natural weight increase helped produce increased strength in the ITB. A patient could only return to running after six weeks of recovery, after which a typical patient reported a lack of pain. Interestingly, faster paced running was less likely to aggravate ITBS because the knee stretched beyond the zone of impingement described by Fredericson and colleagues in two separate studies (Fredericson et al., 2000; Fredericson and Wolf, 2005).

The return to running phase was the final stage of recovering from ITBS, and was varied depending on the chronicity of the condition. Most patients achieve full recovery after six weeks (Fredericson and Weir, 2006). A patient was considered clear to run once they were capable of performing open-chain and closed-chain strengthening exercises. During this time, the patient must demonstrate proper form, and the exercise must be conducted without pain. Regardless of the means by which strength was recovered, it was critical for patients to correct strength imbalances between their dominant leg and non-dominant leg, since the non-dominant leg was prone to injury as a result of this imbalance (Jacobs et al., 2005).

Anatomical observations of the ITB has revealed a thickening of FL, which can completely envelope the leg (Falvey et al., 2010), however these same observations did not reveal the presence of bursa between the ITB and LFC. This complicates the current mode of treatment, which is centered on the hypothesis that inflammation of the ITB is related to bursa within the leg. The lack of lateral bursa brought to question the use of NSAIDs as an effective means of treatment when dealing with ITBS. The effectiveness of NSAIDs are predicated on the presence of inflamed bursa, and the lack of physiological detection of these structures requires further study into the general application and effectiveness of NSAIDs as a mode of treatment. The lack or role that bursa plays in ITBS is reinforced by Fairclough et al. (2007), who determined that the region between the ITB and the femur is where inflammation was mostly likely to occur. He dismissed entirely any form of bursa resulting from ongoing friction, which he did not observe in his studies of ITBS patients.

Simpler responses to the presence of ITBS included helping runners increase control over their stride through muscle contraction training (Strauss et al., 2011). Proper running form can be taught and used to help prevent future injuries. The need to assert greater neuromuscular control of the hips during running was reasserted by Noehren et al. (2014), who detected greater hip internal rotation and knee adduction while running in patients presenting with ITBS. This could be countered through simple changes in stance and motion.

Runners who run uphill, downhill, and at slower paces tend to decrease their angle of knee flexion at foot strike, thereby spending more time in the impingement zone and, thus, experiencing worse ITBS symptoms (Strauss et al., 2011; Fredericson and Wolf, 2005). Biomechanical studies have shown that faster-paced running is less likely to aggravate the ITB (Strauss et al., 2011; Fredericson and Wolf, 2005). Van der Worp et al. (2012) also reported four solutions for long-term prevention of ITBS: (1) the use of softer running shoes with in-shoe supports, which removes the outside heel flare on injured side of the knee, (2) the addition of material inside of a shoe to balance legs, so that both legs are of even length, (3) the reduction of training distance, decreased running speed and amounts of hill running, and a lengthening of recovery days, and (4) ice application to injured areas two a day, for 30 minutes a day. Using these interventions, 44% of those reporting ITBS symptoms reported being 100%, 22% were 75% cured, and 34% were 50% cured or less. Shoe design was linked to injury in separate studies (Taunton and Clement, 1981). Shoe soles that provided little shock absorption in the fore-foot, with little flexibility and arch support, were all linked to injury. Attempts to improve the quality of footwear may lead to a decrease of some injuries along the foot and lower leg (Macintyre et al., 1991). However, the change in design may actually lead to an increase in injuries around the ITB due to the runner overcorrecting as a result in the change in footwear. The overall change of shoes, with added support for rear foot stability, has been cited as a potential change in overall supination during the midstance phase of a run (Macintyre, et al., 1991). This increased tension on the ITB and may be one reason for observed increases in ITBS.

The literature suggests that, due to a number of complicating factors leading to ITBS, there is no single response that works best to reduction of symptoms. The advice to shorten running distance and speed seemed to contradict previous observations that a quicker running pace was beneficial (Fredericson and Wolf, 2005).

1.8.2 Surgical Treatment

In extreme cases, patients with ITBS may resort to surgical intervention for relief (Strauss et al., 2011). Patients who undergo surgical interventions are typically symptomatic for greater than six months despite the consumption of NSAIDs, routine physical therapy, and corticosteroid injection. Patients with a strong positive response to corticosteroid injections also had a strong positive correlation in response to surgery. Surgical procedures involve incisions in the ITB to loosen and lengthen it. Other forms of surgical intervention involve removing bursa when they do become present beneath the ITB. Fairclough et al. (2007) agreed that surgery produces positive health outcomes and post-operative improvement. However, he warned that due to the interrelated nature of the musculoskeletal system and the connection between the ITB and a person's hip, that any surgical intervention might result in unforeseen complications with hip musculature. He further argued against surgical intervention on the basis that, given a lack of inflamed bursa, there would be no need to operate in order to remove any damage. Surgery is commonly performed on the lateral femoral epicondyle to decrease impingement of the ITB, which requires resecting the ITB from the area over the LFE (Fredericson and Weir, 2006).

Despite the warning of potential complications, van der Worp et al. (2012) reported generally positive responses to surgery. In a small study of 11 patients (7 men and 4 women), bursectomy was performed. At the 20-month follow-up, all patients reported less pain and a return to their pre-injury activity level. This form of surgery is predicated on the observation of inflamed bursa that is not always present (Fairclough et al., 2007). Another small study of 33 patients (15 women, 21 men: mean age 31.1. years, range 19-44 years) was conducted to examine the effectiveness of arthroscopic re-sectioning of the lateral synovial recess. Patients were typically symptomatic for 18 months with a general range of 1-7 years. Patient reports to the surgery were 80% good, 17.1% good, and 2.9% fair, with all but one patient saying they would retrospectively recommend the procedure (van der Worp et al., 2012).

1.9 PREVENTION.

Age, distance, and knowledge-matched runners were examined to determine whether warm-up, cool-down, and stretching exercises could prevent injury (van Mechelen et al., 1993). Injuries were found to be slightly less in runners that did not change their running routines versus those that did modify their routines to include new warm-up, cool-down, and stretching exercises (4.9 per 1,000 and 5.5 per 1,000, respectively). While general knowledge of such activities increased, the impact of introducing new elements to a runner's routine was negligible. It may even be hypothesized that the introduction of new components increased the likeliness of injury. In female runners, stretching is not associated with any benefit to running economy or distance performance in female runners (Mojock et al., 2011). It demonstrated some impact on flexibility, but female runners did not receive positive benefits to their running capabilities. While runners may receive some psychological benefit to retaining a particular routine, the addition of new stretches does not benefit their running capability or resistance to injury. Although findings on the benefits of stretching have been inconsistent, stretching has played an important role in rehabilitation following ITBS symptoms (Beers et al., 2008). When included as part of a rehabilitation program, stretching was linked with the resolution of symptoms. This occurred as part of an overall attempt to strengthen hip abductor muscles.

Runners may want to divert their attention toward acquiring a proper running technique as the first line of prevention (Wong, 2009). This is relevant considering the observed biomechanical component of ITSB and the suggestion that runners would benefit from greater neuromuscular control (Noehren et al., 2014). Elite running emphasizes foot contact that occurs near midfoot, underneath a bent knee, after the leg has begun to swing back under the body. The upper body should carry over the foot and the chest should push forward. Hips and knees should be relatively straight in order to generate greater propulsion.

1.10 SUMMARY

The pathology of ITBS remains undetermined. Traditionally, it is attributed to friction caused by the sliding of the ITB over the lateral femoral epicondyle. However, this has recently been disputed. The cause of ITB has been attributed to both weak hip abductors and weakness in the gluteus maximus, but these findings have varied across studies. Results of investigation into ITBS are complicated by variables such as age and sex, though there the literature suggests that there are not only existing differences in baseline hip abductor muscle strength, but also differences in how variables, such as running distance, impact males and females.

As a result of complicated attributions of pathology in the literature, treatment is also complicated. The most commonly recommended noninvasive treatments, including rest and ice therapy, is widely used but is based on little empirical evidence. Neither have any of these treatments been examined in isolation to determine their effectiveness. The role of stretching continues to be debated as well. While commonly used as a treatment, extension of the ITB during these routines seems limited, despite self-reported decreases in levels of pain. Treatments of corticosteroids and NSAIDs can also inhibit pain, but seem best targeted during phases of ITBS.

There is a gap in the literature concerning how lower extremity injuries specifically impact females. Studies have not consistently clarified between male and female runners, have produced complicated predictors that apply in some but not all cases, and led to therapies that are not always based on empirical evidence. The state of the literature is complicated by the continued mixed focus of studies to the exclusion of one sex or the other, which produces an inconsistent means for predicting risk factors and suggesting treatments in females. There is also no gender differentiated treatment regimen that tailored to specifically to females, which is consistent with the historical approach to ITBS that considers the disorder without properly isolating variables such as sex.

1.10.1 Rational

Integration of varying complexity is the essence of functional movement. Integration exercises are multi-jointed and multiple muscles are used to create movement. Integration exercises for the core are integrated with lower extremity exercises and upper extremity exercises to be able to transfer it to a movement or target. Weak hip abductors have been shown to increase the risk of developing ITBS; Research has demonstrated that strengthening the GM can reduce the risk for lower extremity injuries, more specifically, ITBS (Fredericson et al., 2000). The exercises that have been chosen in previous research for ITBS have a large focus on isolating the GM in side-lying or weight-bearing in single leg stance, with little progressions given (Presswood et al., 2008; Beers, 2008). Out of all the exercise regimens, "progressive 3-phase model" seems to be the most effective (Presswood et al., 2008). Phase one consists of seated hip strengthening exercises that utilize self-stretching, balance exercises, step ups, and upper extremity reaches. In phase two, exercises in phase one are continued but with increasing intensity in balance exercises. Finally, at the completion of phases one and two the exercises are stopped. Phase three begins by the replacement of plyometric and agility exercises—with the patient encouraged to slowly return to normal sport activities (Tyler et al., 1998). Progression to exercise is unique in that it utilizes so called "clinical milestones" where the patients are accessed through out their treatment and only progress to the next stage of more difficult activities if the milestone is met (Tyler et al., 1998). This progression regimen is deemed to be more effective by multiple research parties that advocate a functional rehabilitation of the lower extremity (Presswood et al., 2008).

By improving muscular conditioning and neuromuscular coordination, patients can reduce several risk factors that are associated with the development of ITBS. Strengthening of hip abductors is recommended as a strategic therapy to be used in concert with other treatments and have been shown to reduce symptoms of ITBS (Beers, 2008; Fredericson & Wolf, 2005). Moreover, improving neuromuscular coordination, and consequently, being able to employ greater control over gait (which is neuromuscular dictated) is also an effective treatment. Exercises involving complex movement of the joints in multiple dimensions together with weight shifting on the hip abduction complex can increase the patient's neuromuscular innervations and is posited to be beneficial (Fredericson and Wolf, 2005). Although their theory is not conclusively supported, Pettitt and Dolski suggest that treatment techniques combining weight bearing and non-weight bearing therapeutic exercises together with neuromuscular electric simulation can correct the muscle tone in an athlete's walking gait (Pettitt & Dolski, 2000). The exercises chosen were designed by a kinesiologist and strength and conditioning coach, certified by the National Strength and Conditioning Association (NSCA). The exercises chosen for the experimental group were built upon previous research from side-lying exercises and were designed to progressively increase in complexity over the 8-weeks. The complexity was increased by adding multi-jointed exercises, advancing from side-lying to standing positions, bilateral to unilateral and adding some upper extremity movements.

CHAPTER 2: METHODOLOGY

2.1 Objective

i) To determine a relationship between hip strengthening and (1) pain associated with ITBS, (2) Y-balance functional outcome, (3) single leg mini squat as a functional outcome and (4) the self-reported questionnaire, LEFS scale.

ii) To examine differences between groups assigned ITB Stretching, conventional hip rehab and experimental hip strengthening exercise, and their effects on the above outcome measures.

iii) To examine the difference of all three treatment groups, stretching, conventional and experimental exercise on the injured verse non-injured leg.

2.2 Hypothesis

i) Hip strengthening will have a positive effect on (1) pain, (2) functional outcomes and (3) self-reported questionnaire, LEFS scale.

ii) The experimental group will have equal or greater difference when compared to the conventional and stretching group.

2.3 Methods

This study was designed to determine the difference between the three exercises groups; and determine if participants experienced a reduction in pain and improved strength and function over an 8-week period. A separate analysis was completed for each of the five response variables: Y Balance, single leg mini squats, dynamometer readings, lower extremity functional scale (LEFS), and numeric pain scale for run test. Table 1 below, shows the different times of each measurement. Study limbs of participants were examined for both left and right and remained blinded to the examiner as to which limb was affected.

Measurement	**Times of Measurement**
Y Balance	Weeks 0 and 8
Single leg mini squats	Weeks 0 and 8
Dynamometer readings	Weeks 0, 2, 4, 6, 8
Lower extremity functional scale (LEFS)	Weeks 0 and 8
Numeric pain scale	Weeks 1, 2, 3, 4, 5, 6, 7, 8

Table 1: Times at Which Each Measurement Was Taken.

2.3.1 Recruitment

Recruitment flyers (Appendix A) were distributed to various locations involved in the running community such as North Shore Athletics, Lady Sport, Running Room (North Vancouver and Downtown Vancouver), Optimal Performance Clinic, Avita Health Clinic and Paris Orthotics. The recruitment flyer provided information about the study and advised anyone interested in participating, to call for additional information and/or communicate via e-mail. A letter of initial contact (Appendix B) was e-mailed to the potential participants and included information about the study. If participants wished to opt-out of receiving more information about the study they were given the option to call or email the address provided and request to be excluded from any further contact regarding the study. Subjects who wished to participate in the study were presented with a research ethics board (REB) approved consent form (Appendix C) to be signed before their first assessment visit.

2.3.2 Inclusion and Exclusion Criteria

Inclusion criteria for the study were: female distance runners 19-45 years of age (Ferber et al., 2010), self-classification as recreational, outdoor runners, and the presence of unilateral ITBS for no less than 3-months. The study population was comprised of recreational female distance runners, characterized by running a minimum average of 15 running kilometers per week. ITBS diagnosis was determined by a licensed chiropractor (Examiner A), during the initial visit (Appendix D), post-recruitment, for medical history and physical exam. The prominent symptom in all runners was lateral knee pain that worsened with running, especially downhill. The diagnosis was confirmed by the presence of local tenderness to palpation over the lateral epicondyle, reproducible pain with Nobel's Compression Test, pain with flexion and extension of the knee while exerting pressure over the lateral femoral condyle with maximal pain at about 30° of knee flexion and the absence of any other knee joint pathologies such as meniscal injury, arthritis, ligament injury and popliteal tendonitis. Exclusion criteria included–history of previous knee trauma or knee surgery; symptoms on exam of other knee abnormalities including patellofemoral joint pain, popliteus tendinitis, lateral meniscal injury, degenerative joint disease and lateral collateral ligament sprain to the affected side; and any previous treatment for ITBS.

2.3.3 Sample Size

Thirty-four participants presenting to physiotherapy at Avita Health and Massage Centre and Optimal Performance Clinic with unilateral ITBS were recruited to participate in the study. ITBS was diagnosed in twenty-eight of the participants, three participants did not have ITBS as a diagnosis; three participants did not show up for the initial diagnostic assessment and four participants dropped out mid study, resulting in twenty-four participants that completed the study, with a diagnosis of ITBS. Each of the three treatment groups (see 2.3.5) had eight participants (n=8) (Figure 1). The Clinical Research Ethics Board of the University of British Columbia (UBC-REB) approved this study (H13-01816). All participants were required to provide informed consent prior to taking part in the study, by signing a UBC-REB approved consent form.

A sample size of 12 patients for each treatment group was required for a power of 85%. We performed a power analysis based on a t-test for each coefficient estimate of our ANOVA model. In another study by Fredericson et al. (2000) used 10 female and 14 male patients. Dynamometer readings were recorded at the end of a 6-week period. Baseline was calculated to be 7.26% BWh, and post treatment to be 10.45% BWh. A strong effect according to Cohen (1988) would be to obtain a control treatment of 8.67% BWh (calculated by a weighted average of males and females). This leads to a difference in means of treatments to be 1.88% BWh. Since we are using an ANOVA model, a conservative method to estimate the standard error of the coefficients is to use the pooled standard deviation between treatment groups. We found the pooled standard deviation to be 2.34% BWh. Significance level of 0.05 and a one-sided alternative hypothesis was used for our power analysis.

2.3.4 Study Groups: Randomization and Allocation to Treatment Groups

Each consented participant was given a unique identification (UI) code, by Examiner A, after the diagnosis of ITBS was made. Our statistician created the UI codes. A computer generated, stratified, blocked, randomization list using participants' UI numbers, was made by our statistician and given to Examiner A (Chiropractor) who distributed the UI to those that met the inclusion criteria for our study.

2.3.4.1 Treatment Groups

The three treatment groups were: ITB stretching (treatment A-**Table 2);** conventional hip rehab (treatment B- **Table 3**); and experimental hip strengthening exercise group (treatment C-**Table 4 A-D**). Treatment **A** consisted of four stretches for the ITB including: ITB stretch with trunk side bend, ITB stretch with trunk side bend and upward lateral reach, trunk side bend with downward lateral reach and side lying leg adduction. **Table 2** summarizes the description and weekly progression for these stretches. Treatment **B** consisted of four conventional exercises involving the gluteal muscle groups. The exercises included for this group were clams, side-lying abduction, reverse clams and supine bridge. **Table 3** summarizes the weekly progressions of these exercises. All three treatment groups were supervised by either a licensed chiropractor or physiotherapist involved in the study.

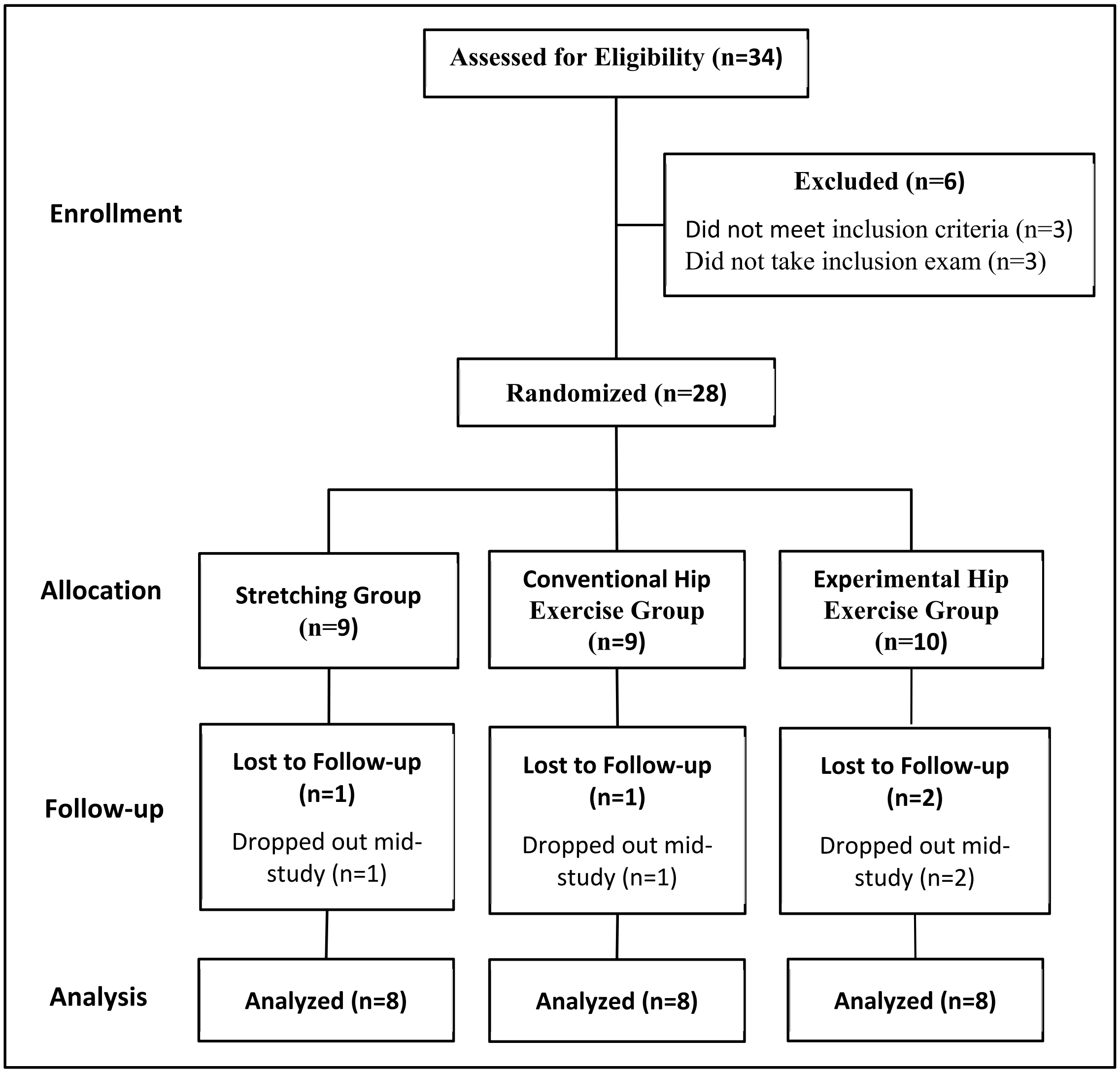


Figure 1: Flow Diagram of Subject Inclusion, Exclusion and Sample Size

	ITB Stretch #1 Trunk side bend ITB stretch	ITB Stretch #2 Trunk side bend with reach-ITB stretch	ITB Stretch #3	ITB Stretch #4 ITB hip abductor stretch
Exercises				
Start Position/ Execution	Cross legs with the leg that is being stretched placed behind the other. Side bend to the opposite side of the leg being stretched while gently gliding the pelvis/hip of the stretched leg to the side	Cross legs with the leg that is being stretched placed behind the other. Side bend to the opposite side of the leg being stretched while gently gliding the pelvis/hip of the stretched leg to the side, reaching arms up towards the opposite side of the leg being stretched.	Cross your legs with the leg that is being stretched placed behind the other. Side bend to the opposite side of the leg being stretched while gently gliding the pelvis/hip of the stretched leg to the side, reaching arms down towards the opposite side of the leg being stretched.	Lie on the good hip, with back all the way at the edge of the bed. Extend the top leg backward then relax and let the foot fall toward the floor behind you.
Duration (sec): Week 0-2 Week 2-4 Week 4-6 Week 6-8	 30 30 40 40	 30 30 40 40	 30 30 40 40	 30 30 40 40
Frequency (3-days/wk): Week 0-2 Week 2-4 Week 4-6 Week 6-8	Week 2x per day Week 2x per day Week 3x per day Week 4x per day	Week 2x per day Week 2x per day Week 3x per day Week 4x per day	Week 2x per day Week 2x per day Week 3x per day Week 4x per day	Week 2x per day Week 2x per day Week 3x per day Week 4x per day

Table 2: Control Group/Stretching: Group A

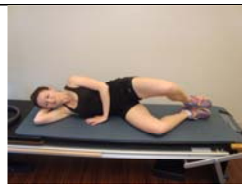
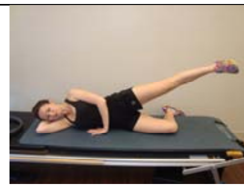
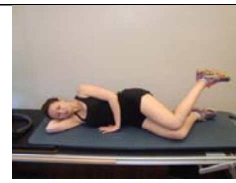
	Ex. #1 Clams	Ex. #2 Side- Lying Abduction	Ex. #3 Reverse Clams	Ex. #4 Supine Bridge
				
Start Position	Start lying on side with head rested on arm and knees bent.	Start lying on side with head rested on arm. The bottom leg can be bent to stabilize body.	Start lying on side with head rested on arm and knees bent.	Begin in the supine position with knees bent and feet flat on the floor. Place feet hip width apart.
Execution	While lying on side with knees bent, draw up the top knee while keeping contact of feet together.	Slowly raise up top leg to the side. Keep knee straight and maintain toes pointed forward the entire time. Complete the prescribed number of reps on the right and then repeat on the opposite side.	While lying on side with knees bent, raise top foot towards the ceiling while keeping contact of knees together. Then, lower back down to original position. Do not let pelvis roll forward during the lifting movement.	While lying on back, tighten lower abdominals, squeeze buttocks and then raise buttocks off the floor/bed as creating a "Bridge" with body.
Coaching Keys	Do not let pelvis roll back during the lifting movement.		Do not let pelvis roll back during the lifting movement.	
Week	Week 0-2: 10 x 2 Week 2-4: 10 x 3 Light Theraband Week 4-6: 15 x 3 Week 6-8: 15 x 3 Medium Theraband	Week 0-2: 10 x 2 Week 2-4: 10 x 3 Week 4-6: 15 x 3 Week 6-8: 20 x 3	Week 0-2: 10 x 2 Week 2-4: 10 x 3 Week 4-6: 15 x 3 Week 6-8: 20 x 3	Week 0-2: 10 x 3 Week 2-4: 10 x 3 Light Week 4-6: 15 x 3 Week 6-8: 15 x 3 Medium
Frequency	3x/wk	3x/wk	3x/wk	3x/wk

Table 3: Conventional Hip Exercise: Group B

Treatment **C** (**Tables 4, 5, 6, 7**) was an experimental exercise group. The program design for this group was cultivated from conventional GM exercise principles for rehabilitation of lower extremity injuries and recommendations from the American College of Sports Medicine (ACSM) for quality and quantity of exercise, for developing musculoskeletal strength and core training. Tables 4, 5, 6 and 7 summarize the description and weekly progressions. A licensed physiotherapist supervised and instructed each participant at 2-week intervals for a total of 8-weeks. The remaining two exercises sessions were recommended as home care. Participants were asked to keep track of their home care exercises on a checklist.

Participants were also instructed to keep a daily activity log (Appendix E) that was used to monitor and promote adherence to the rehabilitation program. The exercise guidelines were based on the recommendations of the ACSM for resistance training and lower extremity injuries. In addition, participants were educated and asked to avoid painful activities (e.g., no running) until their pain was controlled, and then gradual reintroduction of activity was recommended.

EX. #1	Ex. #1 Modified Side Plank	Progression # 2 Modified side plank with clam	Progression #3 Side Plank	Progression #4 Side Plank with Abduction
				
Start Position	Start lying on one side with elbow directly beneath shoulder and legs stacked. Bend knees back to 90°	Start lying on one side with elbow directly beneath shoulder and legs stacked. Bend knees back to 90°.	Lie on one side with elbow directly beneath shoulder and legs stacked. Push body up until there is a straight line from head to feet. The elbow is positioned directly beneath the shoulder.	Lie on one side with elbow directly beneath shoulder and legs stacked. Push body up until there is a straight line from head to feet. The elbow is positioned directly beneath the shoulder.
Execution	Lift torso up, keeping shoulders and hips in line. Hold the modified side bridge for the prescribed amount of time.	Lift torso up, keeping shoulders and hips in line. Open and close knees keeping feet together and rest down between sets.	Hold the side bridge for the prescribed amount of time.	Lift the top leg as far up as you can. Return to the starting position. Perform the prescribed number of repetitions and switch sides.
Coaching Keys	Place upper hand on the hip and prevent the shoulder from rolling forward.	Place upper hand on the hip and prevent the shoulder from rolling forward.	Place upper hand on the hip and prevent the shoulder from rolling forward. If performing the exercise with both feet stacked is too difficult, you can place both feet on the floor to add stability.	Keep the toes of the upper leg pointing forward. Place upper hand on the hip and prevent the shoulder from rolling forward.
Duration (sec & reps x sets)	**Week 1:** 30 x 2 (each side) **Week 2:** 40 x (each side)	**Week 3** 10 reps x 2 Light Therabend **Week 4** 15 reps x 3 Light Theraband	**Week 4-6** 15 sec x 2 (each side) 20 sec x 3 "	**Week 6-8** 10 reps x 2 10 reps x 3
Frequency	3x/wk	3x/wk	3x/wk	3x/wk

Table 4: Week 1 Integrated Exercise Program

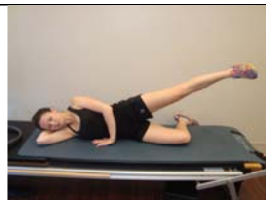
<u>EX. #2</u>	**Ex. #2 Side-lying abduction**	**Progression # 2 Lateral Monster Walk**	**Progression #3 Monster walk with shoulder external rotation**	**Progression #4 Monster X walk**
				
Start Position	Start lying on side with head rested on arm. The bottom leg can be bent to stabilize your body.	Place feet together and tie the Theraband around the ankles	Place both feet shoulder-width apart inside a Theraband. Place your arms to your sides and elbows bend to 90° pull your hands away from each other	Place both feet shoulder-width apart inside a Theraband. Cross the band to form an X and press your arms overhead. Assume a quarter squat position.
Execution	Slowly raise up top leg to the side. Keep knee straight and maintain toes pointed forward the entire time. Complete the prescribed number of reps on the right and then repeat on the opposite side.	Take a step to the right with the right leg and follow with the left leg. Take the prescribed number of steps to the right and then repeat on the opposite side.	Take a step to the right with the right leg and follow with the left leg. Take the prescribed number of steps to the right and then repeat on the opposite side.	Take a step to the right with the right leg and follow with the left leg. Take the prescribed number of steps to the right and then repeat on the opposite side.
Coaching Keys	Keep toes forward	Maintain the quarter squat position throughout the entire exercise. Avoid that the knees move inward. Keep the knee well aligned between hip and ankle. Keep the toes pointed forward. Keep your feet at least shoulder-width apart, so there is always tension on the Theraband. Maintain a level pelvis through set.	Maintain the quarter squat position throughout the entire exercise. Avoid that the knees move inward. Keep the knee well aligned between hip and ankle. Keep the toes pointed forward. Keep your feet at least shoulder-width apart, so there is always tension on the Theraband	Maintain the quarter squat position throughout the entire exercise. Avoid knees moving inward. Keep the knee well aligned between hip and ankle. Keep the toes pointed forward. Keep feet at least shoulder-width apart, so there is always tension on the Theraband
Duration (reps x sets)	Week 1 10 x 2 Week 2 10 x 3	Each direction Week 3 15 x 2 Light Theraband Week 4 15 x 3 Light Theraband	Each Direction Week 5 15 x 2 Light Theraband Week 6 15 x 3 Medium Theraband	Each direction Week 7 15 x 2 Light Theraband Week 8 15 x 3 Medium Theraband
Frequency	3x/wk	3x/wk	3x/wk	3x/wk

Table 5: Week 2 Progression of Hip Exercises

<u>**EX. #3**</u>	**Ex. #3 Hip Hikes**	**Progression # 2 Single leg squat**	**Progression #3 TKE-Terminal Knee Extension with Theraband-Hip Abduction**	**Progression #4 Skater**
				
Start Position	Start with one leg on a stair or aerobic stepper. Can use wall for assistance if needed.	Start by standing on one leg in front of a stable support for assisted balance	Wrap an elastic band around your stance leg as shown so that it is pulling the knee across the front of your body.	Begin either on one leg or with just the toes touching of the other leg.
Execution	Keeping both knees straight, lower the non-weight bearing leg by “dropping” the hip. Slowly raise the non-weight-bearing hip using the glute muscles on the weight bearing side. Repeat prescribed number of repetitions.	Bend your knee and lower your body towards the floor. Return to a standing position.	Bend your stance knee and lower your body towards the floor. Return to a standing position. Your stance knee should bend in line with the 2nd toe and not pass the front of the foot. Repeat prescribed number of repetitions.	Squat down on one leg like you are taking off skating. Repeat prescribed number of repetitions.
Coaching Keys	Maintain upright posture. Do not hike the opposite hip, come to a neutral level.	Knee should bend in line with the 2nd toe and not pass the front of the foot. Knee flexion up to 100°	Bend the stance leg-knee to about 45°.	Maintain a level pelvis throughout the exercise.
Duration (reps x sets)	Each leg Week 1 10 x3 Week 2 20 x 3	Each leg Week 3 10 x 2 Week 4 12 x 3	Each leg Week 5 12 x 2 Light Theraband Week 6 12 x 3	Each leg Week 7 15 x 2 Week 8 15 x 3
Frequency	3x/wk	3x/wk	3x/wk	3x/wk

Table 6: Week 3 Progression of Hip Exercises

EX. #4	Ex. #4 Supine Bridge with Theraband Progression #1	Progression # 2 Cook hip lift	Progression #3 Glute Bridge with single leg march	Progression #4 Double leg hip thrust- bottom up
				 
Start Position	Begin in the supine position with your knees bent and feet flat on the floor. Place your feet hip width apart.	Begin in the supine position with your knees bent and feet flat on the floor. Place your feet hip width apart and pull your toes up to put more weight on the heels. Pull your left knee to your chest and hold with your hands.	Begin in the supine position with your knees bent and feet flat on the floor. Place your feet hip width apart.	Start by elevating shoulders on a bench. Rest upper back against the bench and arms out by your side and your buttocks on the ground.
Execution	While lying on back, tighten lower abdominals, squeeze buttocks and then raise buttocks off the floor/bed as creating a "Bridge" with body.	Put right foot close to buttocks, squeeze gluteal muscles and push hips into the air. Pause at the top and then lower yourself to the ground. Repeated on other side for prescribed number or repetitions.	While maintaining the bridge position, alternate legs keeping the raised knee bent to 90° for the prescribed number of repetitions.	Squeeze buttocks and raise yourself off the ground creating a bridge until chest and hips are in-line. Slowly lower back down to ground bring head and neck into slight flexion to follow the movement. Repeat the prescribed number of repetitions.
Coaching Keys	Keep the core tight throughout the movement.	Keep the core tight throughout the movement.	Keep the core tight throughout the movement.	Keep the core tight throughout the movement.
Week (reps x sets)	Week 1 10 x 3 Medium Theraband Week 2 15 x 3	Each leg Week 3 10 x 2 Week 4 10 x 3	Each leg Week 5 10 x 2 Week 6 12 x 3	Week 7 12 x 2 Week 8 15 x 3
Frequency	3x/wk	3x/wk	3x/wk	3x/wk

Table 7: Week 4 Progression of Hip Exercises

Gradual reintroduction of running began once participants achieved pain free status, after a 30 min fast walk (**Table 8**). The gradual reintroduction program was designed to slowly return subjects to running, following injury. The gradual, progressive approach of this program gives the body an opportunity to continue healing without causing further damage.

Week	Day (Alternating)	Walk (min)	Run (min)	Frequency of Interval	Total Time (min)
1	Monday	4.5	0.5	6	30
	Wednesday	4.0	1.0	6	30
	Friday	3.5	1.5	6	30
2	Monday	3.0	2.0	6	30
	Wednesday	2.5	2.5	6	30
	Friday	2.0	3.0	6	30
4	Monday	1.5	3.5	6	30
	Wednesday	1.0	4.0	6	30
	Friday	0.5	4.5	6	30
5	Monday	0.0	30.0	1	30

*If any participant experiences pain, they are instructed to return to pain free running interval and continue with that for 2 days before progressing.

Table 8: Gradual Return-to-Run Program

2.3.5 Outcome Measures

2.3.5.1 Numeric Rating Scale for Pain

The numeric pain rating scale (NPRS) is a universal pain screening rating scale, 0-10, for measuring pain intensity. The NPRS is short, easy to administer, and has been validated as a measure of pain intensity in populations with known pain (Jensen et al., 1999; Kreb et al., 2007). The NPRS documentation sheet (Appendix F) for pain was given to all participants weekly and participants were asked to rate their current pain on a 0 to 10 point pain scale where 0 is “no pain” and 10 is “worst possible pain”.

2.3.5.2 Lower Extremity Functional Scale (LEFS)

All subjects were required to complete the LEFS sheet (Appendix G) at two-week intervals during the data collection for hip strength. The LEFS tool is a commonly used reliable outcome measure for individuals with a broad spectrum of lower extremity injuries (Binkley et al., 1999).

2.3.5.3 Handheld Dynamometer: Testing Set-Up

The testing was performed in a clinical examination room at Avita Health and Massage Center and Optimal Performance Clinic. The testing set-up included a portable hand-held dynamometer (HHD) and an examination table. Hip abductor strength was tested at 2-week intervals, at weeks 0, 2, 4, 6, and 8. We used the MicroFET 2™ (Hoggan Health Inc., UT, USA) wireless digital handheld manual muscle testing dynamometer (HHD), a load-cell recording device that displays a digital readout in pounds of force and length of time of muscle contraction. The device, which is factory-calibrated, also contains 3 interchangeable contact pads for patient comfort. Test–retest reliability of hand-held dynamometer muscle testing in the lower extremities has shown intra-class correlation coefficient (ICC) values of 0.95 to 0.99 (Wang et al., 2002), 0.68 to 0.79 (Kimura et al., 1996) 0.84 to 0.91 (Bohannon and Andrews, 1987) and 0.74 to 0.80 (Angre Magnus et al., 1987).

A chiropractor (Examiner B) with previous experience using the HHD performed all the testing at each 2-week interval, for all subjects. All strength tests were isometric strength tests, also known as make tests (Sisto & Dyson-Hudson, 2007).

2.3.5.4 HHD Testing Procedures

The test position for measuring bilateral hip abduction strength was in the supine position (Thorborg, et al., 2010). The landmark for the HHD placement was 5 cm proximal to the proximal edge of the lateral malleolus (Thorborg et al., 2010) **(Figure 2).** Each participant completed 3-

consecutive trials with a 30-second rest in between each trial as per previously described methods (Beers et al., 2008; Thorborg et al., 2010; Sisto & Dyson-Hudson, 2007). The examiner applied resistance in a fixed position as the participant exerted 5 seconds of isometric maximum voluntary contraction (MVC) against the HHD and the examiner (Reese, 1999; Thorborg et al., 2010). The examiner and recorder were blinded as to the identity of the injured leg and treatment group until all measurements were completed at the end of week 8. All HHD measurements were recorded in Newtons (N).

The Participants were given verbal instructions for the HHD procedure, prior to testing. Participants were asked to perform one isometric sub-maximal contraction into the examiner's hand, to ensure that the correct action was performed by the participant. No encouragement was provided during the tests.

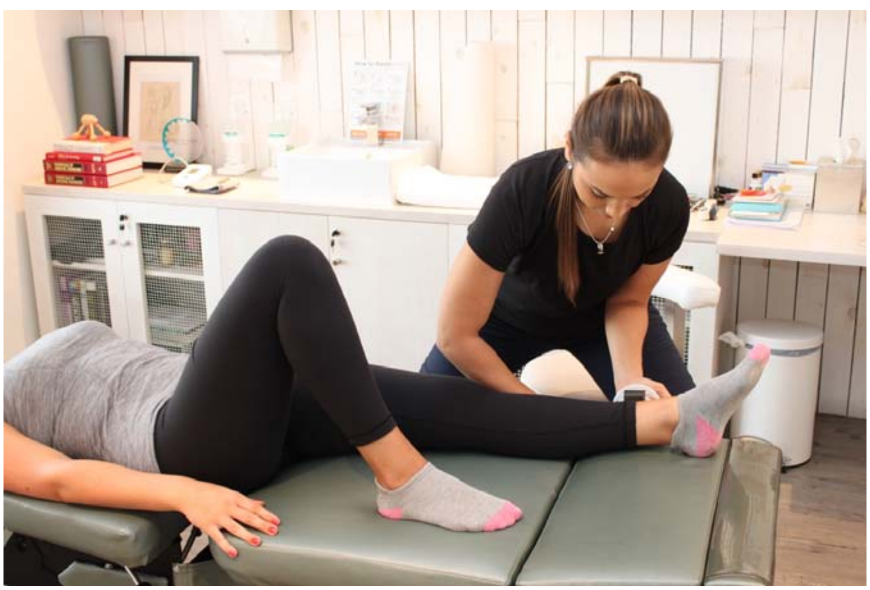
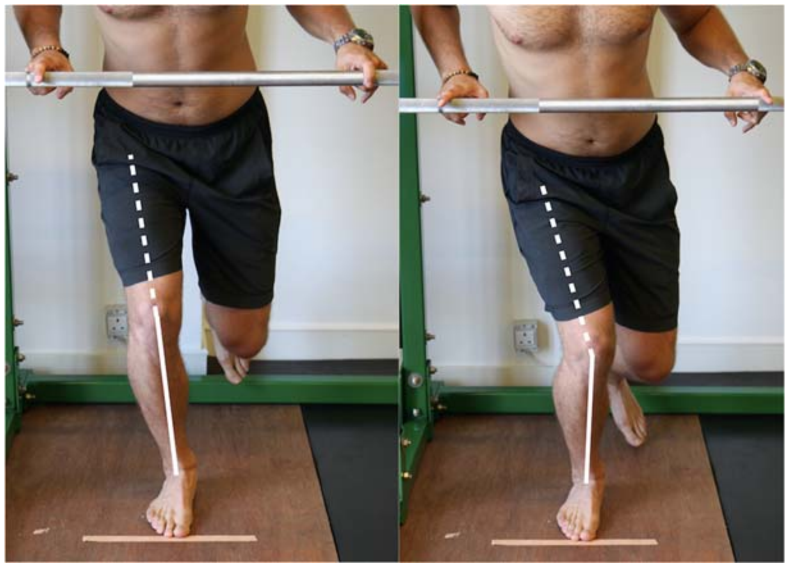


Figure 2: Hip Abduction Strength, Supine Position.

2.3.5.5 Single-Limb Mini Squat: Testing Procedures

Bilateral single-limb mini squat was used to assess quality of movement and was measured at weeks 0 and 8. The single-limb mini squat has been validated as a clinical test for assessing quality of movement by visual analysis (Ageberg et al., 2010). Participants were unaware of what was being assessed during the test and were instructed to be barefoot during each test. The examiner was blinded as to which leg was injured and the treatment group. A licensed physiotherapist performed the single-limb mini squat test on each participant and recorded scores for knee position, in relation to foot position. The test procedure and evaluation was based on a prior study by Ageberg et al. (2010) for the single-limb mini squat test (Ageberg et al., 2010; Bermader et al., 2007). The single-limb mini squat was performed 5 times at a predefined speed of 20 squats/minute (i.e., 3 seconds for the full cycle, from the start to the end position), using a metronome (Ageberg et al., 2010). The physiotherapist stood 5 meters directly in front and facing the participant and scored the test by the position of the knee in relation to the foot. The subjects were scored as either having a knee-over-foot position or a knee-medial-to-foot position using a set data sheet (Appendix H). A knee-over-foot position was scored when the knee is well aligned over or lateral to the 2nd toe in three or more of five trials (**Figure 3 a**). A knee-medial-to-foot position was scored when the knee is placed medial to the 2nd toe in three or more of five trials (**Figure 3 b**).



a b

Figure 3 : a) Knee-Over-Foot Position; b): Knee-Medial-to-Foot Position.

2.3.5.6 Y Balance Test™

The Y Balance Test™ (YBT™) is an instrumented version of components from the star excursion balance test (SEBT) and was developed to improve the repeatability of measurements and standardization for performance of the test. The device utilizes the anterior, posteromedial, and posterolateral components of the SEBT. The testing protocol was developed to address potential sources of error and to describe a standard testing procedure so that results can be compared among studies as well as among clinicians. This device and protocol attempt to address the common sources of error and method variation including whether touchdown is allowed with the reach foot, where the stance foot is aligned, movement allowed of the stance foot, instantaneous measurement of furthest reach distance, standard reach height from the ground, standard testing order, and well defined pass/fail criteria. The YBT™ can be separated into lower and upper quarter. We used the lower quarter (LQ) to evaluate the participants' lower extremity and pelvis function, specific to the sport of running. The YBT™-LQ has demonstrated good to excellent, intra-rater and inter-rater reliability (Pilsky et al., 2009). Inter-rater test–retest reliability of the maximal reach had intra-class correlation coefficients (Shaffer et al., 2013; Pilsky et al., 2009) of 0.80 to 0.85 with a standard error of measurement ranging from 3.1 to 4.2 cm for the three reach directions (anterior, posteromedial, and posterolateral). Inter-rater test–retest reliability of the average reach of three trails had an intra-class correlation coefficient range of 0.85 to 0.93 with an associated standard error of measurement ranging from 2.0 to 3.5cm (Shaffer et al., 2013; Pilsky, 2009; Smith et al., 2014).

2.3.5.6.1 Y Balance Test Kit™

The YBT Kit™ consists of a stance platform to which three pieces of poly vinyl chloride (PVC) pipe are attached in the anterior, posteromedial, and posterolateral reach directions (**Figure 4**). The posterior pipes are positioned at 135 degrees from the anterior pipe with 45 degrees between the posterior pipes. Each pipe is marked in 5-millimeter increments, for measurement. The participant pushes a target (reach indicator) along the pipe, which standardizes the reach height (i.e. how far off the ground the reach foot is), and the target remains over the tape measure after performance of the test, making the determination of reach distance more precise.

2.3.5.6.2 Y Balance Test™: Testing Procedure

The protocol for the YBT™-LQ was based on research conducted by Pilsky et al. (2009) and Hertel et al. (2000). Each participant viewed a standard instructional video that demonstrated the test and testing procedure as explained by Pilsky (2009) and Hertel et al. (2000). The participants had six practice trials on each leg in each of the three reach directions prior to formal testing. The participants were tested within 20 minutes of practicing. All participants were instructed to wear their running shoes during the test. The participants stood on one leg on the center foot plate with the most distal aspect of the running shoe at the starting line. While maintaining single-leg stance, the participant was asked to reach with the free limb in the anterior (**Figure 4a**), posteromedial (**Figure 4b),** and posterolateral (**Figure 4c**) directions in relation to the stance foot. In order to improve the reproducibility of the test and establish a consistent testing protocol, a standard testing order was developed and utilized (see Appendix I for score sheet). The testing order was: three trials standing on the right foot reaching in the anterior direction (right anterior reach), followed by three trials standing on the left foot reaching in the anterior direction. This procedure was repeated for the posteromedial and the posterolateral reach directions. The participants were instructed to stand on the platform with toes behind the line and to push the reach indicator in the red target area in the direction being tested. This was the only set of instructions given to the participants. The examiner was blinded as to the identity of the injured leg and the treatment group. A licensed physiotherapist performed the YBT™ on each subject and was required to complete the YBT™ certification prior to this study. To reduce bias, the examiner recorded the reach distance regardless of whether the examiner thought the trial would be successful. After three trials in one reach direction, the examiner was asked if he had at least one successful trial. If the examiner did not have at least one successful trial, the participant was asked to perform an additional trial until a successful reach was completed. If the subject was unable to perform the test according to the above criteria in six attempts, the subject failed that direction.

Figure 4 : a) Anterior Reach; b) Posteromedial Reach; c) Posterolateral Reach

The maximal reach distance was measured by reading the tape measure at the edge of the reach indicator, at the point where the most distal part of the foot reached. The trial was discarded and repeated if the subject: (1) failed to maintain unilateral stance on the platform (e.g. touched down to the floor with the reach foot or fell off the stance platform); (2) failed to maintain reach foot contact with the reach indicator on the target area while it was in motion (e.g. kicked the reach indicator); (3) used the reach indicator for stance support (e.g. placed foot on top of reach indicator); or (4) failed to return the reach foot to the starting position under control. The starting position for the reach foot was defined by the area immediately between the standing platform and the pipe opposite the stance foot. The process was repeated while standing on the other leg. The specific testing order was right anterior, left anterior, right posteromedial, left posteromedial, right posterolateral, and left posterolateral. The greatest successful reach for each direction, for each examiner, was used to analyze reach distance in each direction. Also, the greatest reach distance from each direction was summed to yield a composite reach distance for analysis of overall test performance. Composite reach was calculated using the formula below.

Composite Reach (%) =

(Anterior + Posteriormedial + Posteriorlateral /3 x Limb Length) x 100.

2.3.6 Statistical Analysis

Since measurements on the same subjects were taken at different time points, a two-way factorial, repeated measures, Analysis of Variance (ANOVA) model was used. The two factors were treatment and time of measurements. Variability was controlled between subjects by including age, gender and leg of injury in our model. Hip dynamometer strength measures and Lower extremity functional scale (LEFS) measures were controlled for, at week 0, as an intercept in the repeated measurements model. A significant difference between the treatment effects was found, therefore, pairwise t-tests were performed to determine differences between treatments of interests. For Y balance, single leg mini squats, and LEFS, we applied pair-wise t-tests on each treatment comparing the improvements from pre to post treatment. For dynamometer readings and pain scale, we employed a mixed effects model controlling for repeated measurements from each participant. All statistical procedures were performed using the R Project for Statistical Computing (R Core Team, 2015).

CHAPTER 3: Results

3.1 Sample Size and Demographics

The original sampling calculation was designed to achieve a power of 85% with 12 participants in each treatment group. Our study could not be completed to achieve N=12 per group due to unforeseen circumstances therefore we concluded the study at N=8 for each of the three groups. Due to dropouts during the study, a re-randomization was done by our statistician to ensure we had equal number of participants in each of the three groups to have N=8 instead of N=12. This results in slightly less power than originally anticipated. Of the 38 participants, 6 (16%) were ineligible or chose not to participate. In total, 24 participants (n=8 stretching group, n=8 conventional exercise group and n=8 experimental exercise group) were randomized (Fig 1- flow chart for subjects, inclusion, exclusion and sample size). The baseline characteristics of the participants were similar between groups (Table 9).

Characteristic	Stretching	Conventional	Experimental
Left Leg Injured [count (%)]	6 (75)	5 (62.5)	4 (50)
Right Leg Injured [count (%)]	2 (25)	3 (37.5)	4 (50)
Age	30.250 ± 3.56	32.875 ± 6.79	34.500 ± 4.93
Mass (lbs)	137.375 ± 8.85	143.000 ± 7.01	137.375 ± 8.85
Mass (kg)	62.44 ± 4.42	64.375 ± 3.27	63.409 ± 3.90
Height (cm)	167.750 ± 3.73	168.375 ± 2.88	167.500 ± 5.04
Height (m)	1.678 ± 0.04	1.68 ± 0.03	1.675 ± 0.05
BMI kg/m^2	22.17 ± 1.06	22.702 ± 0.99	22.64 ± 1.74

All statistics are in the form of mean ± standard deviation, unless otherwise specified

Table 9: Demographic and Clinical Characteristics of the Stretching, Conventional and Experimental Exercises Groups.

3.2 Analysis by Outcome Measures

Table 10 shows the differences in pre and post outcome measures by group.

	Stretching (n=8)				Conventional (n=8)				Experimental (n=8)			
	Week 0		Week 8		Week 0		Week 8		Week 0		Week 8	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Composite YBT %												
Uninjured	97.66	5.37	97.95	5.05	93.51	11.44	96.42	9.85	92.89	7.9	96.92	7.58
Injured	96.34	4.33	97.81	4.71	88.88	12.4	91.8	13.67	89.3	9.88	95.11	7.37
Y Balance Test YBT (cm)												
Uninjured Anterior	59.31	8.17	59.75	9.15	56.12	6.5	57.81	5.34	53.38	4.01	55.62	4.45
Injured Anterior	59.19	6.63	59.06	9.28	51.56	6.29	54.31	7.67	52.19	4.78	53.88	4.52
Uninjured Posterior Medial	96.06	6.94	94.75	5.18	89.31	11.64	92	11.25	93.25	10.97	96.94	8.71
Injured Posterior Medial	95.56	5.36	95.12	5.23	88	10.46	88.56	11.48	87.94	12.32	95.06	8.72
Uninjured Posterior Lateral	91.12	5.74	92.88	6.73	85.62	10.34	88.75	11.04	86.88	9.65	90.94	8.39
Injured Posterior Lateral	88.56	6.49	92.94	6.85	80.06	13.93	84.12	16.02	84.13	10.68	90	8.63
Dynamometer DN (N)												
Uninjured	93.67	26.09	104.84	33.85	92.31	39.76	109.4	37.16	94.14	28.48	121.57	30.42
Injured	86.5	23.11	97.94	31.78	90.33	39.55	102.45	40.39	92.99	31.35	128.37	28.21
LEFS %												
LEFS	80.16	14.43	81.25	15.35	82.5	18.32	88.59	11.98	88.91	6.66	94.38	4.77
NPRS (0-10)												
NPRS **Rest**	1.12	1.36	0.75	1.04	0.75	1.75	0.12	0.35	0.88	1.25	0.38	0.74
NPRS Run	2.62	2.07	1.44	0.98	3.5	2.78	1.25	1.16	4.22	4	1	1.07

	Stretching (n=8)		**Conventional (n=8)**		**Experimental (n=8)**	
	Week 0	Week 8	Week 0	Week 8	Week 0	Week 8
Single Leg Mini Squats SLMS						
Injured Knee-Foot/Knee-Med-Foot (N)*	4/4	7/1	4/4	3/5	2/6	8/0
Uninjured Knee-Foot/Knee-Med-Foot (N)*	2/6	4/4	2/6	4/4	5/3	7/1

*N number of participants in each group, knee medial to foot and knee over foot positions

Table 10. Differences in Pre and Post Outcome Measures by Group

	Within Group Differences Post-Pre (Week 8-Week 0)					
	Stretching Group		Conventional Group		Experimental Group	
	Mean Difference	95% CI	Mean Difference	95% CI	Mean Difference	95% CI
Composite YBT%						
Uninjured	0.29	(-0.96, 1.53)	2.91	(-2.1, 7.92)	4.04	(0.11, 7.96)*
Injured	1.48	(-0.26, 3.21)	2.93	(-1.43, 7.28)	5.81	(1.94, 9.68)*
Y Balance Test YBT (cm)						
Uninjured Anterior	0.44	(-1.73, 2.61)	1.69	(-0.85, 4.22)	2.25	(-0.62, 5.12)
Injured Anterior	-0.13	(-3.6, 3.34)	2.75	(0.27, 5.23)*	1.69	(-2.43, 5.8)
Uninjured Posterior Medial	-1.31	(-4.07, 1.44)	2.69	(-0.56, 5.93)	3.69	(-1.21, 8.58)
Injured Posterior Medial	-0.44	(-2.26, 1.38)	0.56	(-3.88, 5)	7.13	(3.2, 11.06)*
Uninjured Posterior Lateral	1.75	(-0.57, 4.07)	3.13	(-4.68, 10.93)	4.06	(0.4, 7.72)*
Injured Posterior Lateral	4.38	(1.47, 7.28)*	4.06	(-3.14, 11.27)	5.88	(-0.06, 11.81)
Dynamometer DN (N)						
Uninjured	11.17	(-7.11, 29.45)	17.1	(4.8, 29.39)*	27.43	(8.1, 46.76)*
Injured	11.44	(-3.96, 26.85)	12.11	(-7.8, 32.02)	35.38	(15.4, 55.36)*
LEFS %						
LEFS	1.09	(-5.58, 7.76)	6.1	(-0.14, 12.23)	5.47	(0.05, 10.88)*

	Within Group Differences Post-Pre (Week 8-Week 0)					
	Stretching Group		Conventional Group		Stretching Group	
	Mean Difference	95% CI	Mean Difference	95% CI	Mean Difference	95% CI
NPRS (0-10)						
NPRS Rest	-0.38	(-1.14, 0.39)	-0.63	(-1.8, 0.55)	-0.5	(-1.68, 0.68)
NPRS Run	-1.19	(-2.8, 0.42)	-2.25	(-4.02, -0.48)*	-3.22	(-6.02, -0.42)*
Single Leg Mini Squats SLMS						
Injured Knee-Foot	1.88	(0.66, 3.1)*	0.5	(-0.27, 1.27)	2.63	(1.21, 4.03)*
Injured Knee-Med-Foot	-1.88	(-3.1, -0.66)*	-0.5	(-1.27, 0.27)	-2.5	(-3.84, -1.16)*
Uninjured Knee-Foot	1.13	(0.18, 2.07)*	1.25	(-0.15, 2.65)	1.25	(0.01, 2.5)*
Uninjured Knee-Med-Foot	-1.13	(-2.07, -0.18)*	-1.25	(-2.65, 0.15)	-1.25	(-2.5, -0.01)*

*Significant difference between pre and post measurements at a significance level of α=0.05.

Table 11. Mean Differences in Outcome Measures Within Groups

Table 11 shows that there were no within group differences in the Stretching group for the Composite YBT™, YBT, DN, LEFS or the NPS except the YBT showed within group differences for the Injured Posterior Lateral [mean difference 4.38 (95% CI 1.47,7.28, $P < 0.05$)] and the SLMS for the Injured Knee-Foot [mean difference 1.88 (95% CI 0.66, 3.1, $P < 0.05$)], Injured Knee-Medial-Foot [mean difference -1.88 (95% CI -3.1,-0.66, $P < 0.05$)], Uninjured Knee-Foot [mean difference 1.13 (95% CI 0.18, 2.07, $P < 0.05$)] and Uninjured Knee-Med-Foot [mean difference -1.13 (95% CI -2.07, -0.18, $P < 0.05$)]. The observed within group difference showed a difference for the injured leg Posterior Lateral reach which could be attributed to a reduction in tension of the ITB complex (Fredericson et al., 2002). The observed within group differences for the injured SLMS shows that the participants that started with the knee-med-foot during pre-testing resulted in a change-over to knee-over-foot post-testing. This could have been attributed to the reduction in muscle tension and regaining of myofascial extensibility improving global muscle function (Comerford and Mottram, 2001). These observed changes do have practical importance in a clinical setting.

Table 11 shows that there were no within group differences in the Conventional Group for the composite YBT™, YBT Uninjured Anterior, Uninjured Posterior Medial, Injured Posterior Medial, Uninjured and Injured Posterior Lateral except there was a difference within group for the YBT Injured Anterior [mean difference 2.75 (95% CI 0.27, 5.23, $P < 0.05$)]. There were no within group difference for the Conventional Group for the DN in the Injured Leg. There were within group differences for the Uninjured DN outcome measure [mean difference 4.8 (95% CI 4.8, 29.39, $P < 0.05$)]. There were no within group differences for the LEFS and NPS REST. There was a difference in the NPS Run [mean difference -2.25 (95% CI -4.02,-0.48, $P < 0.05$)]. There were no differences within group for the SLMS. The observed difference for the Injured Anterior within groups could have been attributed strength gains from the conventional hip rehabilitation program.

Table 11 shows that there were no within group differences in the Experimental group for the YBT Uninjured and Injured Anterior, Uninjured Posterior Medial, Injured Posterior Lateral and NPS Rest. There were differences within group for the Composite YTB Uninjured [mean difference 4.04 (95%CI 0.11, 7.96, $P<0.05$)], Injured [mean difference 5.81 (95% CI 1.94, 9.68, $P < 0.05$)]. There were differences within group for the YBT Injured Posterior Medial [mean difference 7.13 (95% CI 3.2, 11.06, $P < 0.05$)], Uninjured Posterior Lateral [mean difference 4.06 (95% CI 0.4, 7.72, $P < 0.05$)]. Differences were shown for the DN Uninjured [mean difference 27.43 (95% CI 8.1, 46.76, $P < 0.05$)] and Injured [mean difference 35.38 (95% CI 15.4, 55.36, $P < 0.05$)]. There was a difference shown in the LEFT [mean difference 5.47 (95% CI 0.05, 10.88, $P < 0.05$)] and NPS Run [mean difference -3.22 (95% CI -6.02, -0.42, $P < 0.05$)]. Differences were shown in the SLMS for the Injured Knee-Foot [mean difference 2.63 (95% CI 1.21, 4.03, $P < 0.05$)], Injured Knee-Med-Foot [mean difference -2.5 (95% CI -3.84, -1.16 $P < 0.05$)], Uninjured Knee-Foot [mean difference 1.25 (95% CI 0.01, 2.5, $P < 0.05$)] and Uninjured Knee Med-Foot [mean difference -1.25 (95% CI -2.5, -0.01, $P < 0.05$)]. The observed within group differences and the 95% CIs indicated that the ranges of plausible within group differences are likely due to the progressing complexity of the exercises in the experimental group and does indicate that it may have a practical importance in the management of chronic ITBS.

	Between Group Differences					
	Conventional - Stretching		Conventional - Experimental		Experimental-Stretching	
	Mean Difference	95% CI, p-value	Mean Difference	95% CI, p-value	Mean Difference	95% CI, p-value
Composite YBT						
Uninjured %	-2.84	(-8.85, 3.17), 0.34	0.06	(-6.60, 6.72), 0.99	-2.9	(-7.66, 1.86), 0.22
Injured %	-6.74	(-13.79, 0.31), 0.06	-1.87	(-9.84, 6.10), 0.63	-4.87	(-10.04, 0.31), 0.06
Y Balance Test (YBT)						
Uninjured Anterior	-2.56	(-7.80, 2.67), 0.32	2.47	(-1.22, 6.16), 0.18	-5.0	(-9.90, -0.16)*, 0.04
Injured Anterior	-6.19	(-11.51, -0.86)*, 0.02	-0.1	(-4.36, 4.17), 0.96	-6.1	(-10.75, -1.43)*, 0.01
Uninjured Posterior Medial	-4.75	(-11.29, 1.79), 0.15	-4.44	(-12.01, 3.13), 0.24	-0.32	(-6.20, 5.58), 0.91
Injured Posterior Medial	-7.06	(-13.18,-0.95)*, 0.03	-3.22	(-11.00,4.56), 0.41	-3.84	(-10.12, 2.43), 0.22
Uninjured Posterior Lateral	-4.81	(-11.06, 1.43), 0.13	-1.72	(-8.76. 5.33), 0.62	-3.09	(-8.67, 2.49), 0.27
Injured Posterior Lateral	-8.66	(-17.05, -0.26)*, 0.04	-4.97	(-14.03, 4.10), 0.27	-3.69	(-9.84, 2.47), 0.23
Dynamometer (DN)						
Uninjured	1.61	(-23.19, 26.40), 0.90	-7	(-32.41, 18.42), 0.58	8.6	(-13.64, 30.84), 0.44
Injured	4.17	(-20.36, 28.70), 0.73	-14.29	(-40.81, 12.23), 0.28	18.46	(-3.94, 40.88), 0.10

	Between Group Differences					
	Conventional - Stretching		Conventional - Experimental		Conventional - Stretching	
	Mean Difference	95% CI, p-value	Mean Difference	95% CI, p-value	Mean Difference	95% CI, p-value
LEFS						
LEFS %	4.85	(-5.88, 15.57), 0.36	-6.09	(-14.71, 2.52), 0.16	10.94	(2.76, 19.12)*, 0.01
NPRS						
NPRS Rest	-0.5	(-1.38, 0.38), 0.26	-0.19	(-1.02, 0.64), 0.65	-0.31	(-1.11, 0.49), 0.43
NPRS Run	0.35	(-1.14, 1.83), 0.64	-0.23	(-2.31, 1.84), 0.82	0.58	(-1.33, 2.49), 0.54

***Significant difference between measurements from the two groups at a significance level of α=0.05.**

Table 12: Mean Differences in Outcome Measures Between Groups

Table 12 shows there were no differences between groups for the Conventional and Stretching for the Composite YBT™, YBT Uninjured Anterior, YBT Uninjured Posterior Medial, YBT Uninjured Posterior Lateral, Injured and Uninjured for the DN, LEFS, NPS REST/RUN and the SLMS. There were no between group differences shown for the Conventional and Experimental groups. There were no between group differences shown for the Experimental and Stretching groups for the Composite YBT™, YBT Uninjured/Injured Posterior Medial, YBT Injured Posterior Lateral, YBT Uninjured Posterior Lateral, DN Uninjured/Injured, NPS Run/Rest and SLMS Injured Knee-Foot and SLMS Injured Knee-Med-Foot. There were differences between Experimental and Stretching shown for the YBT Uninjured Anterior [mean difference -5.0 (95% CI -9.90, -0.16, $P < 0.05$)], YBT Injured Anterior [mean difference -6.1 (95% CI –10.75, -1.43, $P < 0.05$)], LEFS [mean difference 10.94 (95% CI -2.76, 19.12, $P < 0.05$)], SLMS Uninjured Knee-Foot [mean difference 1.81 (95% CI 0.41, 3.21, $P < 0.05$)] and SLMS Uninjured Knee-Med Foot [mean difference -1.81 (95% CI -3.21, -0.41), $P < 0.05$)]. The ranges of the 95% CIs indicate that it is likely there are between group differences. The between group differences showed that the stretching and experimental groups demonstrated strong performance in most of the outcome measurements which may indicate practical importance.

	Stretching	Conventional	Experimental	Conventional -Stretching	Conventional-Experimental	Experimental -Stretching
Composite YBT %						
Uninjured	0.06	0.27	0.52	0.31	-0.12	0.57
Injured	0.32	0.22	0.67	0.15	-0.26	0.63
Y Balance Test YBT (cm)						
Uninjured Anterior	0.05	0.28	0.53	0.17	-0.11	0.26
Injured Anterior	-0.02	0.39	0.36	0.38	0.18	0.28
Uninjured Posterior Medial	-0.21	0.24	0.37	0.44	-0.09	0.61
Injured Posterior Medial	-0.08	0.05	0.67	0.12	-0.61	0.90
Uninjured Posterior Lateral	0.28	0.29	0.45	0.16	-0.09	0.30
Injured Posterior Lateral	0.66	0.27	0.60	-0.03	-0.14	0.18
Dynamometer DN (N)						
Uninjured	0.37	0.44	0.93	0.17	-0.30	0.54
Injured	0.41	0.30	1.19	0.02	-0.66	0.83
LEFS %						
LEFS	0.07	0.39	0.94	0.33	0.05	0.39
NPRS (0-10)						
NPRS Rest	-0.31	-0.50	-0.49	-0.21	-0.11	-0.12
NPRS Run	-0.73	-1.06	-1.10	-0.57	0.38	-0.86

	Stretching	Conventional	Experimental	Conventional -Stretching	Conventional-Experimental	Experimental -Stretching
Single Leg Mini Squats SLMS						
Injured Knee-Foot	1.19	0.24	1.61	-0.74	-1.13	0.47
Injured Knee-Med-Foot	-1.19	-0.24	-1.54	0.74	1.06	-0.39
Uninjured Knee-Foot	0.56	0.68	0.69	0.07	-0.01	0.07
Uninjured Knee-Med-Foot	-0.56	-0.68	-0.69	-0.07	0.01	-0.07

Large Effect Size (Greater than ±0.8),
Moderate Effect Size (Between ±0.2 and ±0.8),
Small Effect Size (Less than ±0.2)

Table 13: Effect Sizes of Post and Pre Comparisons Within and Between Groups

Table 13 shows the effect size for the within and between groups. The groups and outcome measures with a large effect size, with statistical significance, show that the results are more robust and may have statistical and clinical importance. The within group differences show a large effect size and statistical significance for the SLMS for the stretching and experimental group. The between group differences with large effect size and statistical significance show that the experimental group had better functional outcomes for the LEFS. The differences observed in the experimental group showed improvements in the SLMS, had a small effect size, and there were no difference between groups when comparing experimental and conventional groups. This could be due to a small sample size and short duration of rehabilitation program.

3.3 ADHERENCE

The mean and median for the number of rehab sessions completed each week was 2.75 and 3 for the stretching group; 2.63 and 3 for the conventional group; 2.50 and 2.5 for the experimental group out of 3 rehab sessions per week over a span of 8-weeks.

3.4 DYNAMOMETER

3.4.1 Injured Leg

Figure 5 shows the mean dynamometer readings for the injured leg at different time intervals for the three treatments. Visually there are improvements; the improvements in experimental treatment were not statistically significantly. However, greater strength gains were shown over the 8-week intervention for the experimental group when compared to the stretching and conventional groups. Similarly, participants improved quicker with the conventional treatment versus stretching.

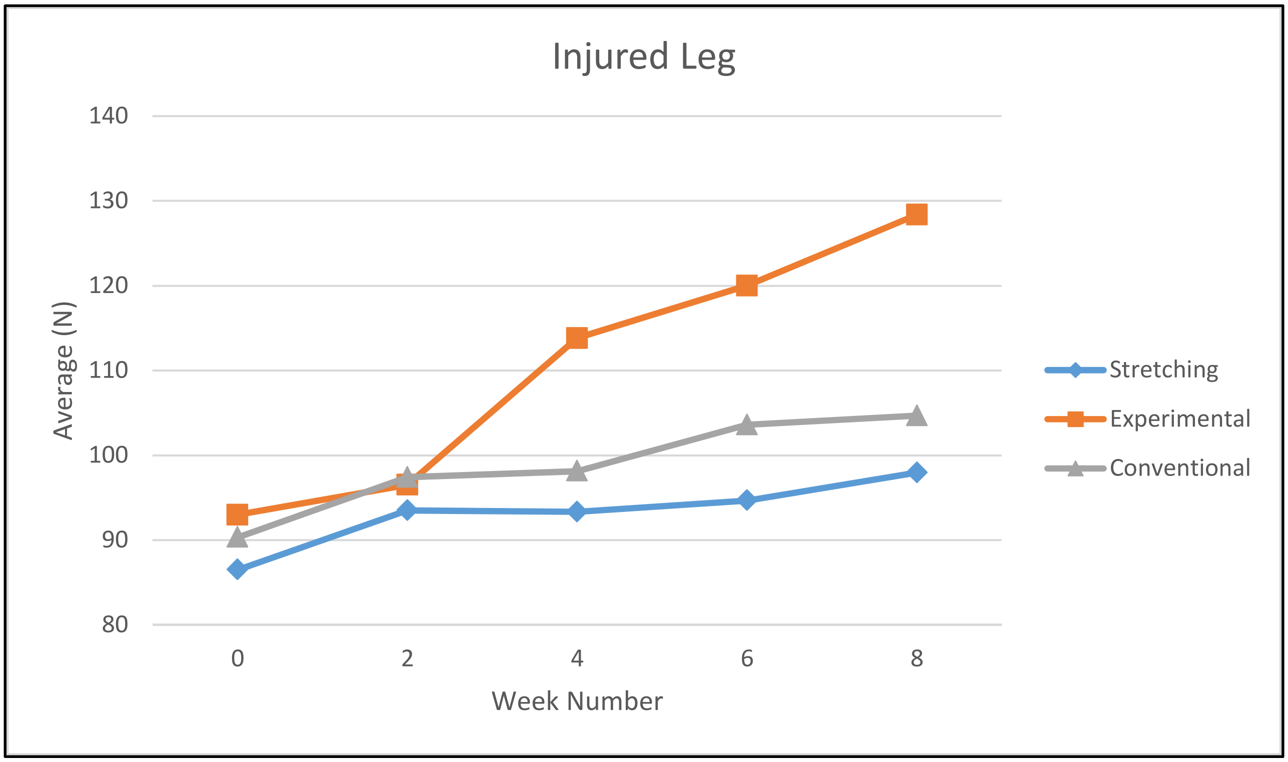


Figure 5: Dynamometer Readings for Injured Leg

3.4.2 Uninjured Leg

Figure 6 shows the mean dynamometer readings for the uninjured leg at different time intervals for the three treatments. Visually there are improvements; the improvements in experimental treatment were not statistically significantly when compared in between group differences. However, greater strength gains were shown over the conventional and stretching groups for the injured leg. The graph shows the stretching group reached their highest average by week 4, whereas the other two groups reached their highest average at week 8. The Stretching group saw the lowest improvements.

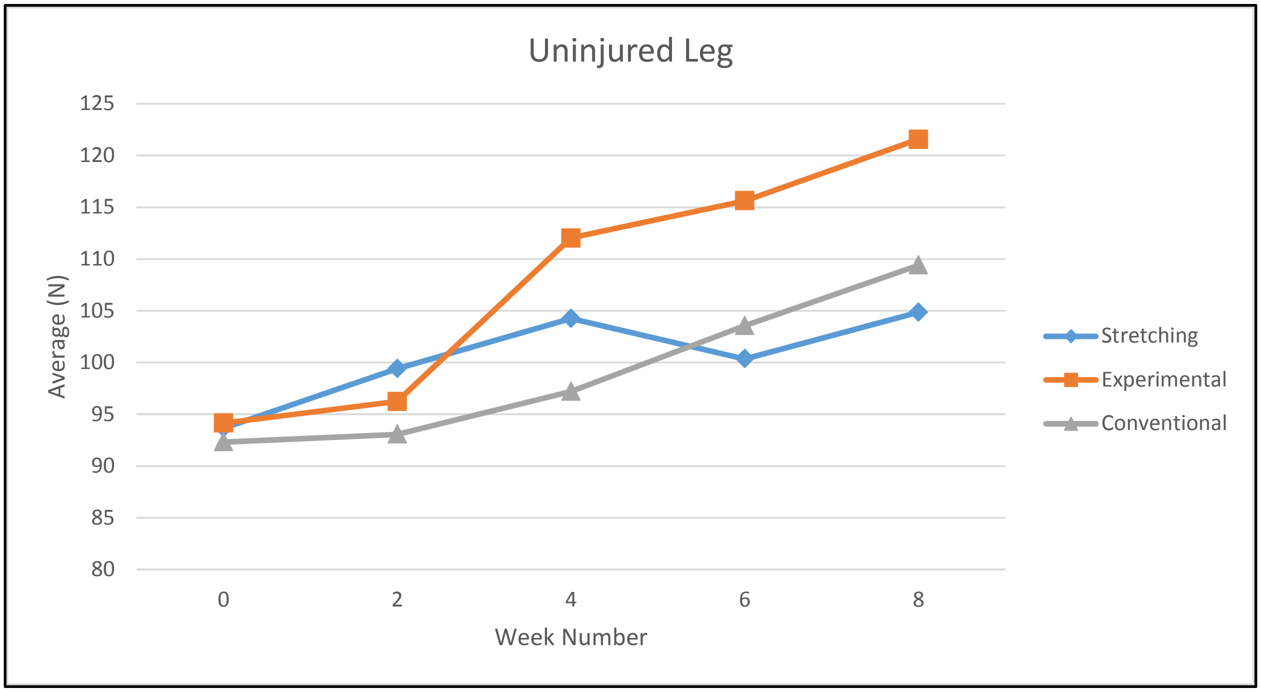


Figure 6: Dynamometer Readings for Uninjured Leg

3.5 Numeric Pain Rating Scale

Figure 7 shows the average pain when the participants are at rest for different time intervals for the three treatments. All three groups show a reduction in pain over 8-weeks.

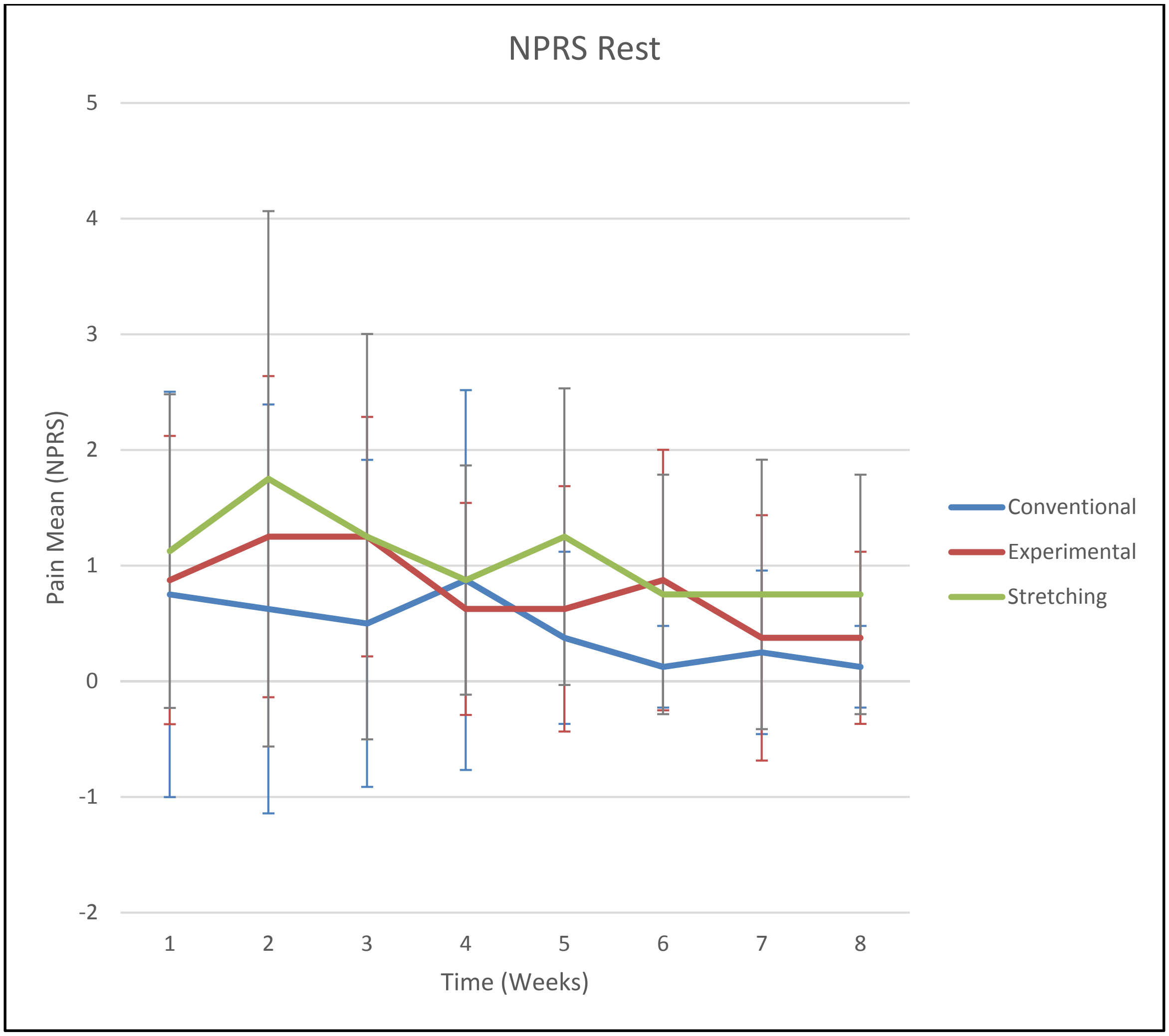


Figure 7: NPRS Rest

Figure 8 shows the average pain of participants when running for different times for the three treatments. We found no significant difference between the three treatments; however, the plot suggests that the recovery process based on pain is faster for the experimental over the other two treatments.

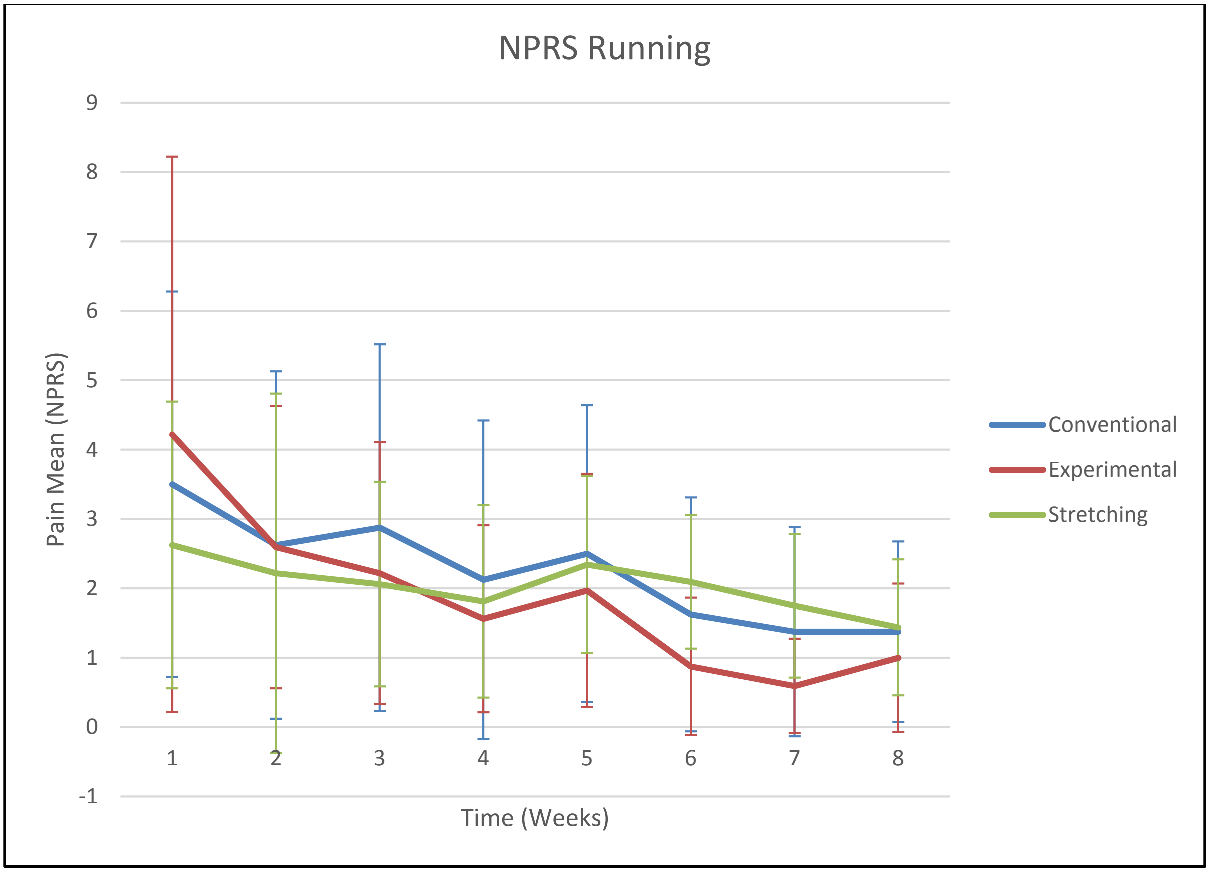


Figure 8: NPRS Running

CHAPTER 4: Discussion

The aim of this study was to determine the effect of three different rehab interventions (1) stretching of the ITB and associated muscles, (2) hip strengthening and (3) core strengthening with progressions. It was hypothesized that, by adding progressions core exercises over an 8-week period, the subject would experience less pain and improved function equal to or greater when compared to the other two groups.

This study showed that neither 8-weeks of stretching the hip or core strengthening significantly influenced the YBT™, DN muscle testing, LEFS, NPS and SLMS indices (Table 12)—which may be attributed to small sample sizes and short rehabilitation periods. However, all three groups produced improvements in clinical outcomes, including pain, function and strength; with the stretching and experimental group showing the greatest differences (Figures 5 and 6). The within group differences showed statistical significances and large size effects for the experimental and stretching groups (Table 13).

Study findings were consistent with previous data in the literature. Stretching exercises did demonstrate some improvement, which was previously illustrated in findings by Fredericson and Wolf (2005), although the limited improvement was also anticipated due to follow up studies by Falvey et al. (2010), who determined an increase of the ITB to be only in the amount of 0.2%. The length changes seen in the ITB complex may be explained by the reduction in tension of the muscles and fascia attached to the ITB complex (Fredericson et al., 2002). Traditional rehabilitation, which employed a mixture of isolated hip exercises, NSAIDs, icing, and reduction of aggravation, had been previously demonstrated to show improvement and was confirmed in the study (van der Worp et al., 2012). However, once again, the limited effectiveness was indicated by Ellis et al., (2004), who identified stages of ITBS during which each intervention manifested a maximum period of effectiveness. Due to the limited subject response during previous testing and highly conditional situations in which pain relief was achieved, the findings of this study were consistent with only the moderate improvement anticipated using conventional forms of therapy.

One central issue that continues to plague ITBS research is the varying conclusions reached concerning the cause of ITBS, which in turn prevents effective treatment. Although there are standard protocols for treatment, the results vary – probably due to not understanding and addressing the root cause(s) of an individual's ITBS. Therefore, it is not surprising that the five indices used to evaluate treatment success were not sufficiently discriminating. Indeed, each patient should be subjected to a thorough history: reviewing training age, gender, weight, previous injuries, training surface, training schedule, recovery schedule, proper tapering before competition, foot wear (i.e. examining shoe soles for uneven wear), running surface, and mileage accumulated over short or long time periods. After this evaluation, a biomechanical assessment of any compensatory patterns or movement asymmetries due to previous injuries or inherent skeletal muscular mechanics should be performed. These total assessments lead to a functional diagnosis complementing the orthopaedic diagnosis of ITBS. A Functional diagnosis can either be tissue extensibility dysfunction, stability/motor control dysfunction or joint mobility dysfunction and may include inflammation. Therefore a customized regimen maybe crafted including (1) rehab to improve stability or muscle weakness, (2) joint manipulations/mobilizations to address joint dysfunction, (3) appropriate shoe adjustments (including potential orthoses), and (4) acupuncture, soft-tissue therapy, stretching and/or instrument assisted soft-tissue mobilization.

Although the results of the study did not indicate that the experimental treatment was statistically significantly better in all trials, the experimental group did show improvements in function pain and strength. These findings are significant because they are a product of a body of research and present a new mode of treatment intervention into the literature. Moving forward, research can be focused on expanding the experimental procedure and its effectiveness among a greater number of runners combined with different weight, age, gender and other variables.

This study has a number of limitations such as a small sample size and short duration of exercises groups. A larger sample is recommended to detect statistical differences between and within groups. A longer study period such as 10-12 weeks would allow time for myofascial adaptations to the exercises interventions. Some of the information for adherence and use of other treatments outside of study were self-reported by the subjects, which may affect the accuracy of the treatment outcomes. Finally, this study did not account for fatigue, pain felt after a certain distance. Some of the runners did report that they did not feel pain until after 5 km. This would have affected the results of the numeric pain scale outcomes and the return-to-run program given as well as the functional questionnaire. Further research is needed to compare the experimental protocol and its effects on running biomechanics and fatigue.

4.1 PRACTICAL APPLICATIONS

ITBS has been associated with reduced gluteus medius strength. Research has demonstrated that a weakened gluteus medius muscle may contribute to lower extremity injuries such as ITBS. Given that one of the main roles of sports medicine practitioners and strength and conditioning coaches is to reduce the risk of injury and provide prevention strategies to their patients and clients. This study has introduced a new interventional progressive strengthening program that can be utilized in the management of chronic ITBS to reduce pain and improve function.

CHAPTER 5: CONCLUSION

With the increasing popularity in running and the associated running-related injuries, there are increasing requirements to develop therapeutic strategies to treat these injuries. This study has attempted to draw together much of the evidence available in the literature to develop a new intervention program for the management of chronic ITBS. Previous research has demonstrated that isolated hip exercises and stretching does have a positive effect on reducing the symptoms of ITBS. The results of our study demonstrate that the experimental group may be a good intervention based on the overall reduction in pain, improvement in strength and function for the experimental group in individuals with chronic ITBS.

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Appendices

Appendix A : Recruitment Flyer

The Evaluation of Treatment Factors in the Management of Chronic Iliotibial Band Syndrome in Female Distance Runners

We are trying to determine how an 8-week rehabilitation will help in the management of chronic iliotibial band syndrome in female distance runners.

Are you a female distance runner between the ages of 19-45?

What does the study involve?

This study requires you to be a recreational distance runner, defined as averaging a minimum of 20 km per week with lateral knee pain for no less than 3-months. A thorough history and physical exam will be done to determine you have chronic iliotibial band syndrome (pain on the outside of the knee). You will then be given an 8-week exercise program. Participants will be asked to stop current running programs until pain is controlled. Once pain is controlled, all participants will be instructed on how to properly return to run. Participants who display signs or symptoms of other pathologies such as meniscal injury, degenerative joint disease, patello-femoral pain and past knee surgical history will be excluded. During this study participants will be asked to stop regular running programs until pain is controlled and a return-to-running program will be provided.

NOTE: Functional testing and rehab will be held at 2 clinic locations, one in North Vancouver and the other downtown in Coal Harbour.

This study is being conducted **by the principle investigator, Dr. Jack Taunton and three co-investigators, Dr. Janine McKay, Dr. Rick Celebrini and Dr. Michael Hunt** in the faculty of Kinesiology at the University of British Columbia

If you are interested in receiving additional information or wish to participate in this study, please contact:

Dr. Janine McKay

Page **1** of **1**

Version 2: Dec. 5, 2014

Appendix B : Letter of Invitation

THEUNIVERSITY OF BRITISH COLUMBIA

Department of Kinesiology

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LETTER OF INVITATION

Jan 15, 2015

Dear Participant:

The Faculty of Kinesiology at University of British Columbia (UBC) would like to learn about the effectiveness of various exercises interventions in the management of chronic iliotibial band syndrome (pain on the outside of the knee). You are being invited to participate in a 8-week exercise program because you have pain on the outside of your knee during running and are female between the ages of 19-45 years.

As a part of this study, you will have an initial exam with a licensed chiropractor to determine if you m*et al*l the inclusion requirements. If you choose to take part in the study you will be required to commit to an 8-week exercise program. Afterwards you will be randomized (it is like tossing a coin) to either a group that receives stretching exercise, isolated hip exercises or integrated core exercise. The exercise sessions are about 20 minutes each three times per week. Two of the three sessions will be instructed by a licensed physiotherapist and strength & conditioning coach, the remaining day will be part of your home care program. During the study, you will be tested for hip strength, balance, function and pain intensity. After 8-weeks, you will have access to all the exercise programs at no cost to the participant. Additional visits beyond your three exercises sessions will take approximately 2 to 2.5 hours of your time in total.

If you are interested in learning more about this study, please feel free to contact Dr. Janine McKay at or via email at . Thank you for considering being part of our study.

Sincerely,

Principal Investigator
Dr. Jack Taunton

Appendix C : REB Approved Consent Form

PDF attachment starts on next page.

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Evaluation of Outcomes in Assessment of Iliotibial Band Syndrome Rehabilitation Programs
Consent to Take Part in Health Research

Co-Investigator:

Dr. Janine McKay BHK, RCCSS(C), DC
Optimal Performance/Avita Clinic
Vancouver/North Vancouver B.C.
Phone: [redacted]
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Principal Investigator:

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Co-Investigator:

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Chief Sport Officer
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Co-Investigator:

Dr. Michael Hunt BHK, MSc, MPT, PhD
Assistant Professor (UBC)
Department of Physical Therapy
Vancouver, BC
Phone: [redacted]
E-mail : [redacted]

Invitation

You are invited to participate in this study if you are a healthy, 19-45-year-old female distance runner. The information contained in this sheet will provide you with more details about the study so that you can decide whether you wish to participate.

Your Participation is voluntary

Your participation is voluntary. You have the right to refuse to participate in this study. If you decide to participate, you may still choose to withdraw from the study at any time without any

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negative consequences to the medical care, education, or other services to which you are entitled or are presently receiving.

Before you decide, it is important for you to understand what the research involves. This consent form will tell you why the research is being done, what will happen to you during the study and the possible benefits, risks and discomforts.

If you wish to participate, you will be invited to sign this form. If you do decide to take part in this study, you are still free to withdraw at any time and without giving any reasons for your decision.

Please take time to read the following information carefully and to discuss it with your family, friends, and doctor before you decide.

The researchers will:

- discuss the study with you
- answer your questions
- keep confidential any information which could identify you personally
- be available during the study to deal with problems and answer questions

Background

Running has grown in popularity over the years. With the increase in popularity, so does the rate of repetitive strain injuries. One of the most common injuries and the leading cause of lateral knee pain in long-distance runners is iliotibial band syndrome (ITBS). Although many factors may contribute to the development of ITBS, the condition is most often aggravated by repetitive strain and multifactorial events such as poor body mechanics, improper footwear, misaligned lower body and muscle imbalances. Moreover, distance runners suffering from ITBS typically exhibit limited ITB flexibility as well as weakness in the muscles of the side of the hip, that may result in repetitive strain injuries, such as ITBS. Findings from this study may be valuable in the treatment of ITBS and may help to identify areas to target for exercise interventions, thus improving the effectiveness and efficiency of the clinical management of this repetitive motion injury.

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Evaluation of Outcomes in Assessment of Iliotibial Band Syndrome Rehabilitation Programs
Consent to Take Part in Health Research

Who is conducting the Study?

This study is being conducted by the faculty of Kinesiology at the University of British Columbia and is part of a Masters thesis project. This study is not receiving funds from an external agency or sponsor.

Purpose of study

The purpose of this study is to compare and contrast different exercise interventions for the management of chronic ITBS; and to determine its effectiveness in reducing pain and improving function in female distance runners with chronic ITBS. It has been estimated that we need about 36 female participants for the study.

Inclusion in the Study:
You will be included in this study if you are:
1. Female between the ages of 19-45 years;
2. Have been diagnosed or been affected by ITBS (pain on the outside of the knee) for no less than 3 months;
3. A distance runner averaging a minimum of 20 Km per week of road running;

Exclusion from the Study:
You will be excluded from this study if you:
1. Have previous history of knee surgery or knee trauma to the affected side;
2. Have been diagnosed with any other knee injuries and/or conditions in the affected knee;

Study Procedures:

As a part of this study, you will have an initial exam with a licensed chiropractor to determine if you met all the inclusion requirements. If you choose to take part in the study you will be required to commit to an 8-week exercise program. Afterwards you will be randomized (it is like tossing a coin) to either a group that receives stretching exercise, isolated hip exercises or integrated core exercise. The exercise sessions are about 20 minutes each three times per week. Two of the three sessions will be instructed by a licensed physiotherapist and strength & conditioning coach, the remaining day will be part of your home care program. During the study, you will be tested for hip

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strength, balance, function and pain intensity. After 8-weeks, you will be given the other exercises programs used in the study for your review. Additional visits beyond your three exercises sessions will take approximately 2 to 2.5 hours of your time in total throughout the 8 week study period.

Visit # 1-Baseline Measurements

Baseline measurements will be taken on your second visit and should take about 30 minutes. There will be 2 locations to complete these measurements, downtown and North shore. The address is provided at the bottom of the consent form.

Dr. Ryan Gannon, licensed chiropractor will (first visit):

- Complete a medical history and physical exam with you. The results of the history and physical exam will help determine if you have a diagnosis of chronic iliotibial band syndrome. Once we have minimum number of participants, Dr. Gannon will contact you to advise you which exercise group you will assigned to and you will be given a study number. This is your identification number that will be used throughout the study, not your name;

- Record your baseline measurements for height, weight and leg of injury.

Dr. Janine McKay, licensed chiropractor will:

- Give you the numeric pain scale (NPS) to complete. This is a numeric scale that will ask you to rate your current pain intensity from 0 (“no pain”) to 10 (“worst possible pain”). This will be completed at the end of each week.

- Give you the Lower Extremity Functional Scale (LEFS) questionnaire to complete. The LEFS is a questionnaire containing 20 questions about a person’s ability to perform everyday tasks. This should be completed bi-weekly through out the study period.

- Take baseline measurements for the muscles on the side of the hip using a handheld dynamometer, a hand-held device used to measure muscle strength. These measurements will be measured bi-weekly through out the study period.

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Please note that you do not have to answer any questions on the questionnaire that cause distress.

Jenny Biegler, licensed physiotherapist will:

- Take baseline measurement for the Y-balance and single-limb mini squat. These tests will measure quality of movement and will be done 3 times over the 8-weeks.
- The Y-balance test is a dynamic test that requires strength, balance and flexibility. The Y Balance Test Kit™ consists of a stance platform to which three pieces of PVC pipe are attached in the front, side and backwards directions. The participants will stand on one leg on the center foot plate with the front of the running shoe at the starting line. While maintaining single leg stance, the participant will be asked to reach with the free limb in the three directions listed above. A final measurement will be taken at the end of each direction.
- The single-limb mini squat will be used to assess quality of movement. Participants will be instructed to do a partial squat on each leg while being evaluated by a physiotherapist.

Following all your routine tests and questionnaires you will be sent home with a package that includes 7 copies of the NPS and 2 copies of the LEFS questionnaire. The NPS should be completed at the end of each week and the LEFS completed at the end of each bi-weekly period.

Week 0-8: Exercises Intervention

All participants will be randomized into 3 exercises interventions. If you are in group B or C, each week you will be required to have one in-clinic visit, 20 min each and two homecare session. At the end of your 1st in-clinic visit you will be given your program to do at home for the 2nd and 3rd session. Over the 8-weeks, a program will be given to you if your exercises intervention progresses. Group A, B and C will check in bi-weekly to complete hip strength test and hand in the numeric pain scale and re-test hip strength.

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Evaluation of Outcomes in Assessment of Iliotibial Band Syndrome Rehabilitation Programs
Consent to Take Part in Health Research

Evelyn Lajoie, licensed physiotherapist will:

- Supervise and instruct each exercise program. They will be available to answer any questions about the exercises technique and will be able to provide you with appropriate progressions or regressions if the exercise intensity is not suitable. Each exercises will be progressed each week.

Possible risks and discomforts:

There is always a risk when individuals are asked to perform exercises. Some of the risks include muscle soreness, sprains/strains. All testing and exercises will be performed under the supervision and instruction of a certified strength and conditioning specialist, chiropractor and physiotherapist in order to reduce the chance of injury.

Benefits

Benefits can include increased core strength, reduction of pain, increased flexibility and faster return to pain-free running.

Liability statement

By Signing this form, you do not give up any legal rights and you do not release the study doctor, participating institutions, or anyone else from their legal and professional duties.

Study withdrawal

You may withdraw from this study at any time without giving any reason. If you choose to enter the study and then decide to withdraw at a later time, you can choose to have your data removed from analysis.

Confidentiality

Your confidentiality will be respected. However, research records and health or other source records indentifying you may be inspected in the presence of the investigator or his designate representative, Dr. Janine McKay and the clinical research ethics board for the purpose of

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monitoring research. No information or records that disclose your identity will be published without your consent, nor will any information or records that disclose your identity be removed or released without your consent unless required by law.

You will be assigned a unique study number as a participant in the study. This number will not include any personal information that could identify you (e.g., if will not include your Personal Health Number, SIN, or your initials, etc.) Only this number will be used on any research-related information collected about you during the course of this study, so that your identity will be kept confidential. Information that contains your identity will remain only with the Principle Investigator and/or designate. The list that matches your name to the unique study number that is used on your research-related information will not be removed or released without your consent unless required by law.

Your right to privacy are legally by federal and provincial laws that require safeguards to insure that your privacy is respected. You also have the legal right of access to the information you that has been provided for the study, if need be, an opportunity to correct any errors in this information. Further details about these laws are available on request to your study doctor.

Information collected for the health/injury history will be done by Dr. Ryan Gannon. The history will questions related to your running history and questions about your knee pain. Baseline information such as weight, month and year of birth, leg of injury and age will be collected.

When you sign this consent form you give us permission to

- Collect information from you
- Collect information from your health record

Use of records

The research team will collect and use only the information they need for this research study.
This information will include your

- date of birth (month and year ONLY)

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- sex
- injury history/physical exam
- weight
- leg of injury

Information collected and used by the research team will be stored by Dr. Janine McKay. Dr. Janine McKay is the person responsible for keeping it secure.

Your access to records

You may ask the researcher to see the information that has been collected about you.

Reimbursement and Remuneration

You will not incur any costs for participating in this study. Parking costs up to a maximum of $3 will be reimbursed for clinic visits. Parking receipts should be kept and given to the study coordinator (Dr. Janine McKay) for reimbursement. Supplies such as therabands for your exercise program will given to you at the time of your session, however if you loose or misplace your equipment you will be responsible for purchasing another band. Cost for the band ranges from $6-$8. You will not be remunerated for your participation in this study.

Questions

If you have any questions about taking part in this study, you can meet with the investigator who is in charge of the study at this institution. See contact on page 1.

If I have any concerns about your treatment rights as a research subject and/or your experiences while participating in this study, you should contact the Research Participant Complaint Line at the University of British Columbia's Office of Research Services at [redacted], toll-free at [redacted], or by email at [redacted]

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Evaluation of Outcomes in Assessment of Iliotibial Band Syndrome Rehabilitation Programs
Consent to Take Part in Health Research

Signature Page

Name of principal investigator: Dr. Jack Taunton

To be filled out and signed by the participant:

My signature on this consent form means:

- I have read and understood the information in this consent form.
- I have had enough time to think about the information provided. I have read and understood the information in this consent form.
- I have been able to ask for advice if needed.
- I have been able to ask questions and have had satisfactory responses to my questions.
- I understand that all of the information collected will be kept confidential and that the results will only be used for scientific purposes.
- I understand that my participation in this study is voluntary.
- I understand that I am completely free at any time to refuse to participate or to withdraw from this study at any time, and that this will not change the quality of care that I receive.
- I understand that I am not waiving any of my legal rights as a result of signing this consent.
- I understand that there is no guarantee that this study will provide any benefits to me.

I agree to take part in this study. Yes { } No { }

I will receive a signed copy of this consent form for my own records.
I consent to participate in this study.

____

Participant's Signature	Printed name	Date

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Evaluation of Outcomes in Assessment of Iliotibial Band Syndrome Rehabilitation Programs
Consent to Take Part in Health Research

Signature of Person Obtaining Consent	Printed name	Study Role	Date

To be signed by Dr. Janine McKay

I have explained this study to the participant. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

Signature of Person Assisting in the Consent Discussion	Printed Name	Date

Principle Investigators Signature

Principle Investigator Signature	Printed Name	Date

My signature above signifies that the study has been reviewed with the study participant by me and/or by my delegated staff. My signature may have been added at a later date, as I may not have been present at the time the participant's signature was obtained.

Appendix D : Initial Visit ITBS Assessment Sheet

<table>
<tr><td>CHIROPRACTIC INITIAL ASSESSMENT

ITBS Study Inclusion Criteria ITBS</td><td>UI: ________________
Leg Dominance:_______________
DOB:
____
Date: ____
Height:_____________________Weight:_____________</td></tr>
<tr><td>History
Chief Complaint:

Constant/Intermittent
Acute/Sub Acute/Chronic

MOI/Duration

Radiation:

Intensity:

Character/Quality:

Relieving Factors:

Aggravating Factors:

Sensation:

Crepitation/snapping/edema

Observation: Squinting Patella
Genu Varum/Valgum MMS
Swelling Y/N Where?

Leg Length (ASIS- medial malleolus): inches

R
L</td><td>Ortho Tests R L

Nobels Test
McMurrays
Joint line Tenderness
Thessaly’s
Cabot`s manoeuvre
Apley’s compression test
Apley’s distraction test
Valgus/Varus Stress test
Passive patellar compression
Eccentric Step Test

MMT out of 5

Hip extension

Hip flexion

Side-lying abduction

Seated external rotation

Palpation
Popliteus
Gerdy’s Tubercle
LCL
Other:</td></tr>
<tr><td>Running History:
Number of years as a runner:
Km/wk (average last 3 months):
Specialty:

Have there been any recent changes in:
Volume:
Intensity:
Surface:
Hills:
Running shoes:
Fatigue-stress:</td><td>Length Analysis R L

Modified Thomas Test ITB/RF/Psoas ITB/RF/Psoas
SLR (degrees)
Modified Obers (ITB) MMS MMS
Obers (TFL) MMS MMS
Elys +/- +/-
<hr>Past History (List all traumatic or sport-related injuries)
1.
2.
3.
4.
5.</td></tr>
</table>

Foot Orthosis NO/YES, since______________,for______________ Version 3: March 29, 2015	**Dx:** **Inclusion met YES/NO** **If no, why?**

Appendix E : Weekly Training Log

Unique Identification Code: ____________________

Weekly Training Log

WK:1 Daily Run/Workout	Time/Interval	Pain or discomfort 0-10
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

WK 2: Daily Run/Workout	Time/Interval	Pain or discomfort 0-10
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

WK:3 Daily Run/Workout	Time/Interval	Pain or discomfort 0-10
Monday		

Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

WK 4: Daily Run/Workout	Time/Interval	Pain or discomfort 0-10
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

WK 5: Daily Run/Workout	Time/Interval	Pain or discomfort 0-10
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

WK:6 Daily Run/Workout	Time/Interval	Pain or discomfort 0-10
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

WK:6 Daily Run/Workout	Time/Interval	Pain or discomfort 0-10
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

WK 8: Daily Run/Workout	Time/Interval	Pain or discomfort 0-10
Monday		
Tuesday		
Wednesday		
Thursday		
Friday		
Saturday		
Sunday		

Appendix F : Weekly Numeric Rating Scale for Pain

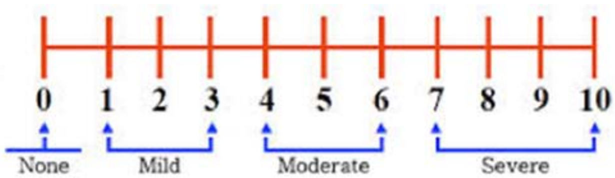
Unique Identification Code: ______________________

Weekly Numeric Rating Scale for Pain

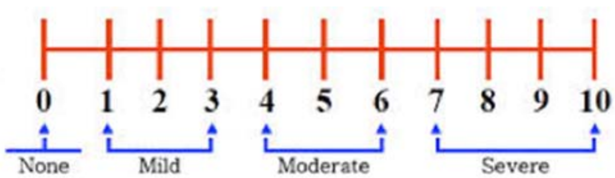
Please fill out the numeric pain rating scale (NPRS) to at the end of each week. This is a numeric scale that will ask you to rate your current pain intensity from 0 ("no pain") to 10 ("worst possible pain"). Week 0 will be completed during your initial visit.

******Please note: As soon as your pain rating is 0/10 you may begin week one of the return to run program. See return-run-program for more details on progressions and regressions.**

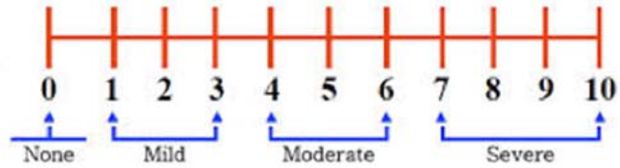
Date: ____________________ Week 0



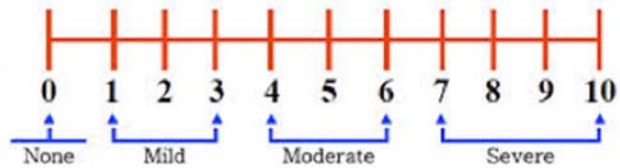
Date: ____________________ Week 1



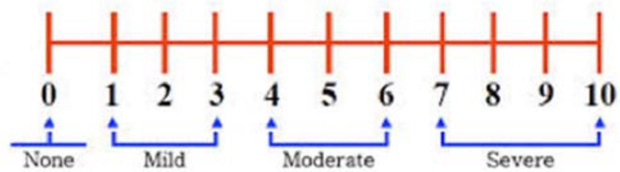
Date: ____________________ Week 2



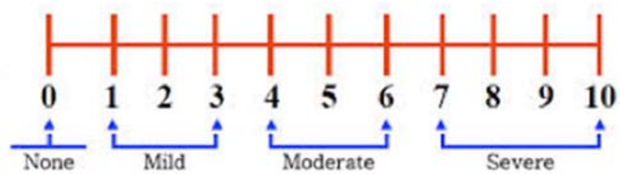
Date: ____________________ Week 3



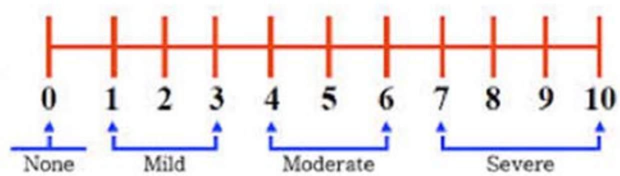
Date: ____________________ Week 4



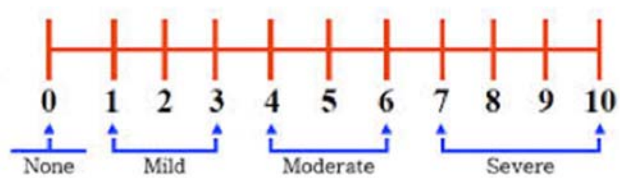
Date: ____________________ Week 5



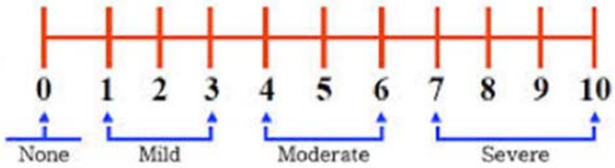
Date: ____________________ Week 6



Date: ____________________ Week 7



Date: ____________________ Week 8



0
1
2
3
4
5
6
7
8
9
10
None
Mild
Moderate
Severe

Appendix G : Lower Extremity Functional Scale

Unique Identification number:______________________ Date: ___________________

THE LOWER EXTREMITY FUNCTIONAL SCALE

We are interested in knowing whether you are having any difficulty at all with the activities listed below because of your lower limb Problem for which you are currently seeking attention. Please provide an answer for **each** activity.

Today, do you or would you have any difficulty at all with:

	Activities	Extreme Difficulty or Unable to Perform Activity	Quite a Bit of Difficulty	Moderate Difficulty	A Little Bit of Difficulty	No Difficulty
1	Any of your usual work, housework, or school activities.	0	1	2	3	4
2	Your usual hobbies, re creational or sporting activities.	0	1	2	3	4
3	Getting into or out of the bath.	0	1	2	3	4
4	Walking between rooms.	0	1	2	3	4
5	Putting on your shoes or socks.	0	1	2	3	4
6	Squatting.	0	1	2	3	4
7	Lifting an object, like a bag of groceries from the floor.	0	1	2	3	4
8	Performing light activities around your home.	0	1	2	3	4
9	Performing heavy activities around your home.	0	1	2	3	4
10	Getting into or out of a car.	0	1	2	3	4
11	Walking 2 blocks.	0	1	2	3	4
12	Walking a mile.	0	1	2	3	4
13	Going up or down 10 stairs (about 1 flight of stairs).	0	1	2	3	4
14	Standing for 1 hour.	0	1	2	3	4
15	Sitting for 1 hour.	0	1	2	3	4
16	Running on even ground.	0	1	2	3	4
17	Running on uneven ground.	0	1	2	3	4
18	Making sharp turns while running fast.	0	1	2	3	4
19	Hopping.	0	1	2	3	4
20	Rolling over in bed.	0	1	2	3	4
	Column Totals:					

Minimum Level of Detectable Change (90% Confidence): 9 points **SCORE: _____/ 80**

Appendix H : Single Limb Mini Squat Score Sheet

UI:________________

Single Limb Mini Squat

Score Sheet

Date: __________________ Week 0

Trial #	Knee-over-foot position	Knee-medial-to-foot position
1		
2		
3		
4		
5		

Date: __________________ Week 8

Trial #	Knee-over-foot position	Knee-medial-to-foot position
1		
2		
3		
4		
5		

Appendix I : Y Balance Score Sheet

Unique Identification Code: ___________________________

6- practice trials: Check the box after each trial has been completed.

Trial	1	2	3	4	5	6

Date: ________________ Week 0

Lower Quarter Y-Balance Test: Right LE Limb Length: _______cm (Distal ASIS to Distal Medial Malleolus)

Direction	Right Trial 1	Right Trial 2	Right Trial 3	Left Trial 1	Left Trial 2	Left Trial 3
Anterior						
Posteromedial						
Posterolateral						

Direction	Greatest. Right	Greatest Left
Anterior		
Posteromedial		
Posterolateral		

Date: ________________ Week 8

Lower Quarter Y-Balance Test: Right LE Limb Length: ________cm (Distal ASIS to Distal Medial Malleolus)

Direction	Right Trial 1	Right Trial 2	Right Trial 3	Left Trial 1	Left Trial 2	Left Trial 3
Anterior						
Posteromedial						
Posterolateral						

Direction	Greatest. Right	Greatest Left
Anterior		
Posteromedial		
Posterolateral		