

The Effect of Gluteus Medius Training on Hip Kinematics in a Runner with Iliotibial Band Syndrome

ABSTRACT: Iliotibial band syndrome (ITBS) is a common clinical presentation in runners. There are several hypotheses to explain this condition including faulty control of the hip joint in the frontal plane during the stance phase of running. It is postulated that improving activity in the gluteus medius muscle may assist in producing more appropriate stabilization and therefore reduce the stress on the Iliotibial band (ITB). This single case study provides an interesting clinical scenario where a single-subject with ITBS was measured for hip kinematics during running, before and after a trial period of classic gluteus medius exercises. The biomechanical data show an initial (pre-intervention) increase in adduction position during the stance phase of running on the affected side (in contrast to the unaffected side). This was measured using a MOVEN motion analysis suit. After the trial intervention period, the relative position of the affected hip had reduced in adduction at both heel strike and at 30° knee flexion. This study provides support for the theory that hip control in the frontal plane may be a contributing factor in ITBS. Clinicians are encouraged to monitor hip control as well as ITBS symptoms when they utilise this gluteus medius protocol. Further research to establish whether change in pelvic control results in decrease in ITBS symptoms is warranted.

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BACKGROUND

Iliotibial band syndrome (ITBS) is the second leading cause of knee pain and the primary cause of lateral knee pain in runners (Noehren et al 2007). ITBS makes up 12% of all overuse injuries in running and 22% of all lower extremity running injuries (Fredericson and Weir 2006, Grau et al 2008, Taunton et al 2002). Due to the increased awareness of aerobic exercise to maintain a healthy lifestyle, jogging and running have become more popular. This is mirrored by an increase in acute and chronic running injuries (Dugan and Bhat 2005). ITBS is common among cyclists, football players, hockey players, downhill skiers, weight lifters and long distance runners (Gunter and Schweltnus 2004).

In long-distance running, repetitive flexion and extension of the knee joint leads to excessive rubbing of the distal iliotibial band across the lateral femoral condyle (Grau et al 2008). The pain usually increases over the duration of the run due to cumulative effects of

the repetitive knee flexion/ extension movements and consequently leads to an inflammatory process (Franco et al 1997, Fredericson and Wolf 2006, Khaund and Flynn 2005). In severe cases, the runner may not be able to continue running and needs to seek medical attention (Noehren et al 2007). ITBS in runners is thus a significant problem, as the intensity of the pain can lead to attrition from running (Miller et al 2007).

Pain develops after heel strike in the initial standing phase, while the knee joint angle is in less than 30 degrees of flexion (Fredericson and Wolf 2005). This may be the maximal zone of impingement during running (Fredericson and Weir 2006). A relative smaller knee flexion angle at heel strike predisposes a runner to ITBS, since more time is then spent in the impingement arc of knee flexion (Fredericson and Wolf 2005). The relatively smaller knee flexion angle has been suggested to be due to hip muscle weakness of the gluteus medius (Fredericson et al 2000). However it is not entirely clear

why distance runners may be prone to this weakness. Fredericson et al (2000) proposed that running is mainly a sagittal plane activity which requires less hip control in the frontal plane.

Biomechanical analysis can unlock explanations to presentations such as ITBS, but there is a dearth of biomechanical research into understanding the relationship between hip control and ITBS in runners (Fairclough et al 2007). In healthy runners, the gluteus medius, especially the posterior part, is primarily a global stabilizer which initiates external rotation of the hip. In addition, the gluteus medius muscle should contract eccentrically at heel strike and then concentrically during the stance

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phase to control frontal plane hip movements (Fredericson et al 2000). Although the role of the gluteus medius during the running cycle in healthy individuals has been established, the role of this muscle in ITBS remains vague.

A recent ITBS biomechanical theory is that the degree of frontal plane hip angles may influence an individual's risk of developing ITBS (Miller et al 2008). During running, increased hip adduction and internal rotation angles during the stance phase may increase strain on the ITB (Fredericson and Wolf 2005, Noehren et al 2007). Miller et al (2008) further reported that runners who were prone to develop ITBS demonstrated coupled hip adduction/abduction and tibia internal/external rotation movements. These coupled knee patterns may increase tension on the ITB, with ensuing micro-trauma of the tissue (Fredericson et al 2000). These coupled movements may therefore be an effect or cause of ITBS (Noehren et al 2007).

Gluteus medius muscle weakness may be related to impaired hip frontal plane control (Fredericson et al 2000). Weakness of this muscle may lead to relatively increased hip adduction and internal rotation and an increased valgus vector at the knee (Fredericson et al 2000, Niemuth et al 2005). This finding is in agreement with researchers who postulate that impaired gluteus medius control is a predisposing factor for ITBS (Fairclough et al 2007). Grau et al (2008) reported no difference in hip abduction muscle strength between runners with and without ITBS, but a shortcoming was that functional biomechanical analyses of hip control during running was not conducted. The importance of the hip musculature in the prevention and treatment of ITBS thus remains controversial. The aim of this study was thus to ascertain the effect of a gluteus medius strengthening program on hip control during the stance phase of running in a runner with ITBS.

METHODOLOGY

This study was approved by the Human Research Ethics Committee of the Faculty of Health Sciences, Stellenbosch University (N08/09/245) and the subject

provided signed consent. Permission to conduct the study was obtained from the Performance Institute of Stellenbosch University (SUSPI) where the study was conducted.

Participant recruitment and eligibility criteria

The participant was recruited from the physiotherapy clinic of SUSPI. The inclusion criteria were: an amateur, male or female runner that ran on average between 80 and 100 km per week and competed in races without financial incentives. The participant was recruited being positive for the following criteria: Older than 18 years with complaints of lateral knee pain during or after running and which increased with downhill running; positive testing with the Ober, Noble and hop tests as well as on palpation of the ITB over the lateral condyle of the femur; wearing neutral running shoes without orthotics; good general health, no associated musculoskeletal injuries, and should not have been receiving any other form of medical or alternative treatment. An objective inclusion criterion was relative weakness of the gluteus medius muscle on the affected side compared with the unaffected side as measured by a hand-held dynamometer. Relative weakness was defined as at least 20% less strength compared to the unaffected side (Maffiuletti 2010). The exclusion criteria were previous lower limb injuries or any soft tissue treatment received for current ITBS.

Study design

A single-subject, ABA –design study (where A represents the baseline phases and B the treatment phase) was conducted over eight weeks. The study timeline consisted of the following three phases:

Baseline phase (A1): Baseline assessments were conducted one week after the inclusive criteria were met and the participant had been diagnosed with ITBS. The assessments included biomechanical analyses of the hip joint angles in the frontal plane (hip adduction/abduction) on three alternate days in the same week (Monday, Wednesday and Friday). Hip angles were analysed using

the MOVEN motion analysis system. Pain was monitored using the Visual Analogue Scale (VAS) on all three days when the biomechanical analyses were done.

Intervention phase (B): During this phase, the six-week gluteus medius strengthening program was implemented.

The *follow-up phase (A2):* Biomechanical analyses were of the frontal hip joint angles were repeated on three alternate days during the eighth week of the study. Pain was monitored using the VAS.

Intervention

The intervention was a six-week, daily gluteus medius strengthening program which was aimed at increasing muscle control and local muscle endurance on the affected leg. The mode of delivery was a combination of supervised and home-based sessions. Three supervised sessions which lasted about 40 minutes were conducted at SUSPI throughout the eight weeks intervention phase. The principle researcher supervised all sessions. In addition, the participant received a printed copy of the program at the beginning of the intervention program to continue the exercises at home, bar the days when attending sessions at SUSPI. The home-based exercises were followed up telephonically.

Description of exercises:

The program consisted of the exercises described in figures 1, 2 and 3. The rationale of including transverse abdominal muscle exercises is that function of this stabilizer is a prerequisite to any form of strength training as it ensures load balance within the kinetic chain (Akuthota et al 2008). Core stability is imperative for initiation of functional limb movements (Akuthota et al 2008). In this case, the activation of transverse abdominals was important to keep the spine in the neutral position during execution of the hip exercises. Electromyographic studies have illustrated that the exercises in figures 2 and 3 are optimal for improving strength control of the gluteus medius (Distefano et al 2009).



Figure 1: Transverse Abdominal activation. Hold the position and do 8 breaths 10 times (Hodges and Richardson 1996)



Figure 2 A

B

Figure 2 A and B: A) Clam – Beginner phase, transverse abdominals activated, hold the position and lift the knee. Repeat 8 times, three sets. B) Straight leg raise in side lying (progression of Clam). Side lying with transverse abdominal activated. Repeat 8 times four sets (Fredericson et al 2000).



Figure 3 AB

Figure 3 A and B: A) Single Leg Hitch of Step - Spine in neutral with transverse abdominus activated. The gluteus medius of the affected side slowly pulls the unaffected pelvis upwards to neutral spine. Repeat 8 times, three sets. (Fredericson and Weir 2006, Fredericson et al 2000). B) Sideways step up (Progression of Single Leg Hitch). Side step up with transverse abdominal activated. Repeat 8 times, four sets (Fredericson and Wolf 2005, Khaund and Flynn, 2005).

Verbal feedback during exercise execution

The exercises were monitored and corrected as necessary by the principle researcher. If pain was experienced in the knee, the exercise technique was corrected by verbal feedback. Pain may be an indication that strain is imposed on the ITB that may lead to increased hip internal rotation and consequent irritation over the distal part of ITB.

Exercise progression

Exercises were progressed by increasing the number of repetitions, when the participant demonstrated good technique (neutral spine and appropriate hip ROM) without fatigue. This was ensured during the supervised training sessions at SUSPI.

Study Procedures

Clinical evaluation

• ITBS diagnostic tests

At the first appointment (day one), a subjective and physical examination was conducted using clinical diagnostic tests including the Noble test, the Hop Test, the Ober test and palpation over the distal ITB area (Barber and Sutker 1992, Franco et al 1997, Fredericson and Weir 2006, Khaund and Flynn 2005). The participant was diagnosed with ITBS because both the Noble and Hop tests and the palpation were positive, and subjectively reported lateral knee pain while or after running (Fredericson and Weir 2006).

• Gluteus medius muscle strength test

In side-lying, the participant produced an isometric action of hip abduction for three to five seconds in approximately 30° of hip abduction and 5° of hip extension with the hip in neutral rotation (Fredericson et al, 2000). Maximum resistance was applied by the researcher using a hand-held dynamometer proximal to the lateral malleolus (Fredericson et al, 2000). During the testing, continuous monitoring of movement was done to ensure appropriate stabilisation and that no hip flexion was allowed and rest periods were given between testing. During the test procedures of the gluteus medius strength, no pain was produced at any stage. Three measurements were taken and the average score was used for the final score.

The muscle strength test using the hand-held dynamometer has demonstrated good test-retest reliability and the validity assessments have been compared to isokinetic testing of shoulder and hamstrings (Hyde et al, 1983, Bohannon et al, 1986). We need to acknowledge that with the strength test of gluteus medius the tensor fascia latae and gluteus minimus could have been recruited due to both being hip abductors (Hollingshead et al 1982).

• Pain assessment

The principal researcher administered a uni-dimensional Visual Analogue scale (VAS) for resting pain as well as pain with walking and running (Collins et al, 1997).

Motion analysis of hip angles during running

The biomechanical measurement of hip motion in the frontal plane was done using the MOVEN motion analysis system (developed by Xsens Technology B.V, Netherlands, inertial motion system). The MOVEN motion analysis system consists of Lycra strips with sixteen attached inertial sensors which are placed over the joints. Each sensor is comprised of a 3D gyroscope, 3D accelerometers and 3D magnetometers. These motion trackers give the total orientation estimate of the hip. This was used to calculate the 3D linear acceleration, giving the translation estimate of the joint. All the sensors were positioned to ensure accurate orientation of the suit, although only hip angles were analysed. Validity and reliability of the MOVEN, compared to the Vicon motion analysis system have been previously established by Scheffer and Cloete (2008).

The biomechanical analysis was conducted in the Stellenbosch University Gymnasium Sports Hall. The participant started with a two-minute, warm-up cycle before running. No pain was present before any biomechanical testing was conducted or during the running trails. The participant was then instructed to run at a speed of 9-10km/hour, which is

reportedly the participant’s average running speed when training. The speed was monitored with the MOVEN’s detachable speedometer.

One running trial of ten minutes was captured on each of the three alternate test days during the baseline and follow-up phases. The last two minutes of the ten-minute run were captured, however the participant was blinded as to the length of the run and to when the data were recorded, hence he altered his style. The biomechanical data of the last three steps of the tenth minute during the run was analysed for each of the three trials (one trial on three alternate days) Therefore, the hip biomechanics of a total of nine steps were analysed for the baseline and the follow-up phases. Reliability and repeatability for the biomechanical assessment was conducted on the same day before the trails were performed.

The data were transferred wirelessly to a laptop to process the hip kinematics. The motion capture’s software converts acceleration and orientation measurements (obtain from motion capture sensors) to translation (three Cartesian components) and rotation (quaternion vector) measurements. The orientation of each segment is calculated by means of quaternion multiplication (Baker 2009). This enables the calculation of each joint’s flexion angle by subtracting the orientation measures of the joint’s inner and outer segment. Each joint’s translation in 3-D space and its rotation angles are therefore available for export, in this case, an excel spreadsheet. The

point of heel strike and 30° was visually estimated by the engineer. The data were then accurately documented and organised in columns which included the day, step number, time frame and abduction in an Excel spreadsheet for each leg.

Data Analysis

Descriptive statistical techniques were used to analyse the hip adduction data. The measurement closest to heel strike and to 30° of knee flexion of each of the three steps in the trial was documented and plotted in an MSExcel spread sheet. The definition of direction of movement was stipulated by the engineer and the MOVEN analysis system. The abduction movement in the affected (right) leg was negative and adduction was positive. In the unaffected leg (left) it was the reverse i.e. adduction was negative and abduction was positive.

RESULTS

Subject description

The participant was a 21 year-old male, who had no history of any injury to his affected leg which was his right (and dominant) leg. His running program consisted of 15 to 20 km per day on the road during the week and 30 km’s on a Saturday. Sundays were rest days. He consistently ran on the same surfaces, and did not change any of his training intensity or running shoes. His shoes were deemed to be in good condition and appropriate for the study. Mean gluteus medius strength of the affected leg was 12.5kg (SD: 1.95) and the unaffected

Table 1: Means (sd) of pre- and post-test scores for the position of the affected and unaffected hips at two points in the running cycle, measured in degrees.

	Affected leg at heel strike	Unaffected leg at heel strike	Affected leg at 30° knee flexion	Unaffected leg at 30° knee flexion
Pre- intervention Mean(sd)	+3.27 (2.76) add	+0.58 (6.43) abd	+12.4 (2.68) add	-5.64(4.00) add
Post- intervention Mean(sd)	-0.20 (4.14) abd	-3.7 (4.29) add	+9.8 (3.37) add	-12.1 (2.4) add
Change score Mean (sd)	-3.47 (5.74)	-0.78 (7.22)	-2.63 (3.86)	-6.46 (6.15)

NB – affected leg abduction values = -ve, adduction values = +ve; non-affected abduction values = +ve, adduction values = -ve.

leg was 20kg (SD: 2.59). Thus the affected side was 37.5% weaker than the unaffected side.

The pre-intervention biomechanical data showed an increase in hip adduction of the affected leg (M: 3.27°, SD: 2.76) compared to the unaffected side at heel strike (M: 0.58° SD 6.43) and at 30° knee flexion (affected M: 12.4° adduction, SD: 2.68 versus unaffected M: 5.64°, SD: 4.00) (see Table 1).

After the intervention phase, the affected leg had a mean decrease in hip adduction at the affected leg at heel strike (M: 0.20° abduction, SD: 4.14) and at 30° knee flexion (M: 9.80° adduction, SD: 3.37) (see table 1). After the intervention phase there was an increase in adduction of the unaffected leg at heel strike and at 30° of knee flexion.

Pain VAS assessment

The participant reported a 5/10 VAS pain score with walking and jogging and no pain at rest at the first day of assessment. A week later, the participant reported a VAS of '0' with walking or any activities, indicated that no pain was experienced before the study was conducted. All subsequent pain measures were 0/10 VAS during the running trails of this study.

DISCUSSION

The main objective of this study was to investigate the biomechanical effect of gluteus medius training (which focused on the control and endurance in the frontal plane of hip kinematics) during the stance phase of running in a patient with ITBS.

Gluteus medius strengthening has been part of a wide range of treatment plans for athletes with ITBS. Other interventions previously reported for ITBS include stretching, soft tissue mobilization, dry needling and biomechanical correction of the footwear (Fredericson and Weir 2005).

The biomechanical test results of this study during the pre-intervention phase reported increased hip adduction in the affected leg, with the gluteus medius weakness compared to the unaffected leg. This confirmed that the participant in this study presented with a similar

clinical presentation to those described in the biomechanical study of Noehren et al (2007). This adds further support that a relationship exists between the hip muscle weakness and an injury pattern in runners suffering from ITBS.

With the use of the MOVEN system, measurements after the intervention stage reported a reduction of adduction at heel strike and 30° knee flexion of the affected side during running (mean change 3.47° and 2.63° respectively). According to Scheffer and Cloete (2008) any change result of two degrees or less indicates an inaccurate measurement or no change. Therefore we have evidence to suggest that there was a true change in hip abduction control during the study period. These changes in kinematics observed might have been clinically relevant even bearing in mind the large standard deviations indicate quite large variance. Given the study design we cannot say with certainty that the change was as a result of the intervention.

The uninvolved leg was also measured and monitored by the MOVEN system before and after the intervention. Before the intervention, the unaffected leg with a 37.5% stronger gluteus medius strength reported an increased in hip abduction compared to the affected hip. The intervention phase was only conducted on the gluteus medius of the affected side. Although at the end of the post-intervention phase the unaffected leg reported a decrease in abduction of the hip. This could be due to compensatory strategies of the pelvis for stability after only training a specific muscle group. Currently, no published evidence could be found to support this.

There were many limitations to this study. Although the MOVEN system showed reliability according to Scheffer and Cloete (2008), the sensitivity of the system at heel strike point was questionable due to the subjective time-point estimate of the engineer. Furthermore, limited conclusions can be made from a single-case design. A larger sample size will be of more value to confirm this study's preliminary findings. Measuring post-intervention strength of gluteus medius would have indicated that a six-week program of the above-

mentioned exercises was either adequate or inadequate for an athlete to increase in strength and endurance. The participant did continue with cycling for 30 minutes, on alternative days, to keep fit. He was cycling at the same intensity before the study, so this probably did not affect the end result of the study. The participant complied with all required exercises and stayed within the parameters of the study.

A longer trial period may be needed to measure gluteus medius strength/control because it is a global stabilizer that may need more than a six-week strength training program (Hodges and Richardson 1996). The exercises could have also been progressed with adding resistance to increase the level of muscle activation and potentially improve the strengthening effects. It must be remembered, though, that it is not necessarily strength that improves functional ability, but rather motor coordination parameters such as timing, sequencing or grading of force production.

CONCLUSION

The high incidence numbers of ITBS among long-distance runners demonstrates the importance of more biomechanical research in athletes with ITBS (Noehren et al 2007). The use of the gluteus medius strengthening program which focuses on endurance and control demonstrated changes in the abduction/adduction hip angles during the stance phase of running. Clinicians should continue to trial this intervention with clear outcome measures to monitor individual responses in ITBS symptoms. In future studies, larger numbers should be included to further our understanding of the faulty kinematics in ITBS during running.

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