the effect of step width on iliotibial band strain

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The effect of step width on iliotibial band strain

by

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABSTRACT</td>
<td>iii</td>
</tr>
<tr>
<td>CHAPTER I. Introduction</td>
<td>1</td>
</tr>
<tr>
<td>Thesis Organization</td>
<td>6</td>
</tr>
<tr>
<td>CHAPTER II. Literature Review</td>
<td>7</td>
</tr>
<tr>
<td>CHAPTER III. The Effect of Step Width on Iliotibial Band Strain</td>
<td>14</td>
</tr>
<tr>
<td>Introduction</td>
<td>14</td>
</tr>
<tr>
<td>Methods</td>
<td>18</td>
</tr>
<tr>
<td>Experimental Setup</td>
<td>18</td>
</tr>
<tr>
<td>Protocol</td>
<td>19</td>
</tr>
<tr>
<td>Data Analysis</td>
<td>20</td>
</tr>
<tr>
<td>Statistical Analysis</td>
<td>21</td>
</tr>
<tr>
<td>Results</td>
<td>21</td>
</tr>
<tr>
<td>Discussion</td>
<td>26</td>
</tr>
<tr>
<td>References</td>
<td>30</td>
</tr>
<tr>
<td>CHAPTER IV. General Conclusions</td>
<td>32</td>
</tr>
<tr>
<td>APPENDIX A. Informed Consent</td>
<td>33</td>
</tr>
</tbody>
</table>
ABSTRACT

Iliotibial band (ITB) syndrome is a common running injury that has been the cause of much pain in the active population. The ITB originates on the pelvis, crosses the hip joint, travels along the lateral thigh and inserts on the lateral, proximal tibia and fibula. Irritation and pain occur when there is excessive friction of the ITB as it crosses the lateral femoral condyle in the region of the knee joint. It has been shown that runners that have ITB syndrome tend to run with a narrower step width. This narrower step width would presumably stretch the ITB to a greater extent and increase the potential for ITB syndrome. This study was designed to test the hypothesis that strain and rate of strain development in the ITB would increase as the step width becomes narrower.

Fifteen recreational or competitive runners ran at their preferred 5k running pace. Each subject ran at their preferred step width, their preferred step width +5% of their leg length and their preferred step width -5% of their leg length.

Results showed that there was a significant difference in strain across all conditions (p < .0001). There was an increase in strain rate across all conditions with the highest strain rate in the narrow running condition and the lowest strain rate in the wide running condition but only the narrow and wide (p = .003) and wide and normal (p = .016) comparisons were significant.

There was a relationship between a runner’s step width and the strain on the ITB. Results indicated that there may be a benefit to widening the step width in runners prone to ITB syndrome. Further analysis should be conducted to insure that this suggested running style does not cause abnormal stresses or anatomical alignments that could induce injury.
Future research should examine step width and strain while running during conditions known to be harmful to the ITB such as downhill running.
CHAPTER I

Introduction

The iliotibial band (ITB) is a band of connective tissue that originates at the iliac crest, crosses the hip joint, travels down the lateral portion of the thigh and inserts at Gerdy’s Tubercle on the proximal tibia. It also inserts on the patella, the linea aspera and the lateral femoral condyle. There are also several muscle insertions on the ITB. At the hip, three quarters of the gluteus maximus, portions of the gluteus medius and all of the tensor fascia lata insert onto the ITB. These proximal attachments of the ITB at the hip also help it to serve as a lateral hip stabilizer and resist adduction (Fredericson et al. 2000). The ITB itself is a thickening of the femoral fascia, and because of its insertions at the knee, may serve as a lateral stabilizer between the femoral condyle and the tibia. The ITB is attached to the lateral intermuscular septum and muscle fascia of the quadriceps at the distal end of the femoral segment. This attachment prevents excessive anterior-posterior movement of the ITB during flexion and extension of the knee (Orava 1978; Kaplan 1958).

Iliotibial band syndrome is an overuse injury that is common in sports and occurs at the lateral portion of the knee. It can be described as an inflammatory condition caused by the friction of the iliotibial band (ITB) rubbing across the lateral femoral condyle (Sangkaew 2007). The injury can also occur at the hip. Literature searches have not named ITB syndrome specifically, but have named conditions such as external snapping hip syndrome and greater trochanteric bursitis in which the loosening of a tight ITB can be a key factor in treating the condition (Craig et al. 2007; Ilizaliturri et al. 2006)
Figure 1. Anatomy of the Iliotibial band and tract, as well as local muscles that attach to the Iliotibial Band.

It is believed that ITB syndrome may be caused by weak hip abductor muscles as well as an inflexible ITB (Nobel et al. 1980; Fredricson et al. 2000). Weak hip abductor muscles such as the gluteus medius, minimus and tensor fascia lata could cause a runner to not have the strength to keep the pelvis aligned properly. This would cause a pelvic tilt that could cause increased strain in the ITB. This may also be the reason why the side lying leg lifts, single leg balance, step downs and pelvic drop exercises described by Fredericson et al. (2005) seem to be successful in helping with the recovery process.

Iliotibial band syndrome is commonly diagnosed in individuals who are actively involved in running or cycling, as well as military personnel just starting boot camp and is
rarely seen in individuals who are inactive. ITB syndrome accounts for 12% of all overuse injuries in running (Fredricson et al. 2005) and 15% of all overuse injuries in cycling (Holmes et al. 1993). It typically occurs when an individual has made a significant increase in their weekly running mileage. This is the case for the military personnel that typically go from running little or no miles to dramatically increasing activity during boot camp. During running or cycling the ITB enters what is called the impingement zone. This zone is described as when the knee is flexed between 0 and 30 degrees, with the greatest friction occurring at or around 30 degrees of knee flexion. In this range the ITB and lateral femoral condyle contact and rub across each other which causes the friction (Orchard et al. 1996; Farrell et al. 2003). Downhill running as well as continuous running on a banked track in one direction can contribute to the development of ITB syndrome. Running downhill forces individuals to land with the knee less flexed which increases the amount of pain suffered by ITB syndrome (Orchard et al. 1996). Because of this, more flexion while running would seem better for the ITB. Therefore sprinting would seem to have less of a negative impact on ITB pain because of the increased knee flexion.

ITB syndrome can be treated with conservative means, a decrease or cessation of running, surgery or corticosteroid injection at the site of femoral epicondyle impingement (Gunter et al. 2004; Fredricson et al. 2005). There are several phases of ITB syndrome treatment and rehabilitation (Fredericson and Wolf 2005). Phase 1 is the acute phase. In this phase, treatment typically begins with reducing the swelling at the ITB and lateral femoral condyle friction point. This can be accomplished using several methods which include phonophoresis (the use of ultrasound to enhance delivery of medicines applied topically to an inflamed area), ice massages, oral non-steroidal anti-inflammatory medications and
iontophoresis (the use of electric charge to deliver medicine through the skin). During this time, running activity must be altered (cessation of downhill running or running in single direction on a track) and activities which cause the repetitive friction must cease all together. If, after these treatments, the pain and swelling do not diminish, a corticosteroid injection may be administered at the site of inflammation. Phase 2 is the subacute phase. After the swelling has gone away stretches are begun to not only lengthen the tight ITB but also stretch the lateral muscles and shortened muscle groups. Phase 3 is the strengthening phase. It begins once the issues with ITB and lateral muscle tightness have been resolved through the stretching in phase 2. Some exercises that are helpful in increasing strength in the problematic area include concentric exercises such as leg lifts, balance exercises and pelvic drop exercises (Fredericson et al. 2000, Fredericson et al. 2000). Exercises that work muscles eccentically, triplanar motions and integrated movement patterns have also been included in strengthening programs. Phase 4 is the return to running phase. This phase begins only after strengthening exercises can be completed with no pain. Running should begin with short sprints several times a week on level ground and gradually increase. Running downhill and on uneven surfaces should be avoided. Phase 5 is the surgical management phase. This phase is completed only if the conservative modalities and strengthening methods are not effective. There are several surgical methods used. These methods include z-lengthening, another procedure where a triangular piece of the ITB over the lateral femoral condyle is removed when the knee is flexed at 30 degrees and the mesh technique developed by Sangkaew (2007). With this technique the knee is flexed at 30˚ and a 3cm incision is made over the lateral femoral condyle down to the ITB. Numerous 2mm incisions are then made on the ITB perpendicular to the direction of the ITB fibers and covering the lateral
femoral condyle. These incisions are then spread by the tension in the ITB and create a mesh appearance that decreases the tension in the ITB.

Current research has studied treatments and causes of ITB syndrome. Running kinematics and knee flexion angles have also been studied thoroughly, but not much research has been done studying the effect of adduction of the hip and step width on ITB syndrome. Hip adduction angle during running may play an important role in the development of ITB syndrome, with more adduction causing increased strain. Noehren et al. (2007) found that runners with a history of ITB syndrome ran with increased adduction at the hip and greater internal rotation at the knee. Increased knee internal rotation may have the added effect of further tightening an already tight ITB over the lateral femoral condyle. Hamill et al. (2008) suggested that this increased adduction and internal rotation may cause an increase in strain rate and ITB strain but could only make assumptions. Adduction of the hip and step width are related because as the amount of adduction increases, the runner’s step width will decrease. On the other hand, when adduction decreases the runner’s step width will increase. A narrower step width may force the ITB to lengthen while running and may increase the strain on the ITB while a wider step width may cause the ITB to be more relaxed and thus reduce the strain developed while running. A lack of research on step width and hip adduction during running has prevented the determination of the role that these variables may play in the development of ITB syndrome. The purpose of this research was to study how step width affects the strain and rate of strain development in the ITB. It was hypothesized that both of these variables would increase as the step width decreases.
Thesis Organization

This thesis is organized into Introduction, Review of the Literature, Manuscript and General Conclusions chapters. The manuscript is formatted according to Medicine and Science in Sports & Exercise specifications. References are included in the manuscript, with a full bibliography included at the end of the thesis. The informed consent documentation, the medical history questionnaire and running habits questionnaire have been appended. Extended methods, extended results, and calibration table sections are also included as appendices.
CHAPTER II

Literature Review

Iliotibial band syndrome has been established as an overuse injury which may be caused by several different factors. There has been research done that investigates these factors as well as different methods to alleviate the pain caused by the condition. Of the many factors that have been reviewed and researched, none examine the effect of step width on the conditions causes. Because of the lack of research done on this subject, it was chosen as the topic for further research. In the selection of literature for review, papers were chosen that studied not only biomechanical factors that contribute to ITB syndrome, but also some anatomical factors that may contribute, as well as some that reviewed different methods of treating the condition.

As previously stated, there are several factors that may contribute to the development of ITB syndrome. Individuals who suffer from the condition tend to have a tighter ITB than those who do not suffer from it (Khaund et al. 2005). Hamill et al. (2008) also found that runners with ITB syndrome showed an increase in levels of strain in the affected limb when compared to the unaffected limb and controls. It was also noted that strain rate may play more of a role in ITB syndrome than peak strain because strain rate is more indicative of possible injury to tissue (Hamill et al. 2008). People who suffer from ITB syndrome also tend to have a higher total of weekly running mileage than those who do not suffer from the condition (Noble 1980). Increased mileage, coupled with a tight ITB may cause more friction between the ITB and the lateral femoral condyle during flexion and extension of the knee by increasing the strain and strain rate on the ITB.
A second factor that may contribute to the development of ITB syndrome is the fact that those who suffer from the condition tend to have increased amounts of knee flexion during heel strike when fatigue begins to set in (Miller et al. 2007). Typically it is reported that increased knee flexion during heel strike is actually better for ITB syndrome. This is the knee flexion that comes with faster paced running or sprints. Faster paced running usually has knee flexion angles at heel strike greater than the 30° known to impinge the ITB (Orchard et al. 1996). The increase in knee flexion showed by Miller et al. (2007) puts the knee closer to that 30° zone known to cause femoral condyle rubbing with the ITB more often. Miller et al. (2007) also noted that patients with ITB syndrome seem to have a higher incidence of strain in the ITB due to kinematic factors similar to what was found by Hamill et al. (2008).

Other factors that may contribute to the development of ITB syndrome are the amount of hip adduction and knee internal rotation that is present while running. Those individuals who suffer from ITB syndrome have greater amounts of adduction at the hip and increased amounts of internal rotation at the knee (Noehren et al. 2007). Greater internal rotation at the knee has been found to press the ITB against the femoral condyle (Fairclough et al. 2006). These factors may cause the ITB to be stretched tightly across the femoral condyle, as well as pressed against it. This will cause an increase in strain of the ITB which will lead to the irritation that is associated with the condition. This increased adduction may be attributed to the weakness of the hip abductor muscles (Noehren et al. 2007). It has been found that runners who suffer from ITB syndrome tend to have weaker hip abductor muscles.

A study done by Pohl et al. (2005) researched lower limb kinematics of runners. Runners ran under three different conditions. They were normal step width, crossover step with, and wide step width. During the crossover condition, runners had more rearfoot
eversion; however, this was not accompanied by a significant difference in internal rotation of the shank which has been believed to be associated with ITB syndrome (Noerhen et al. 2007).

The causes of ITB syndrome have been reviewed. How can the condition be treated? The first thing that must be done before actual treatment begins is a clinical diagnosis of ITB syndrome. One method of testing for ITB tightness is the use of Ober’s Test. To conduct this test the doctor would have the patient lie down on the unaffected side of the body and bend both the hip and knee to 90°. On the affected side the knee is bent to 90°. The patient is then asked to adduct the hip. If the ITB is too tight, the patient will have trouble adducting past the midline and may experience pain on the lateral portion of the knee at the femoral condyle site (Khand et al. 2005). Another test done is the Noble compression test (Noble 1980). This test is set up similar to Ober’s test but measures pain. The clinician will have the patient lying on the unaffected side with the affected bent at 90°. The clinician will then apply pressure on the ITB over the lateral femoral condyle. The leg is then straightened out and the patient usually begins to feel pain at about 30° knee flexion which is when the most ITB femoral friction occurs.

Once ITB syndrome has been diagnosed, there are several steps to treating the condition. The first step in actual treatment of the condition is to modify the level of activity. Certain activities like running on a track or hills have to be greatly reduced if not ceased altogether to reduce the repetitive stress associated with ITB syndrome (Khand et al. 2005; Fredericson et al. 2005). The next step is to reduce the swelling at the ITB and femoral condyle point. This may be achieved by using massage techniques, iontophoresis, phonophoresis and icing. Anti-inflammatory medications may also be taken at this time as
long as they are non-steroidal in nature. A corticosteroid injection at the site of the ITB irritation may also be used in some cases. The injection of a corticosteroid coupled with rest will reduce the pain and inflammation caused by ITB syndrome when it is recent onset (Gunter et al. 2004). This method is used when rest, ice and massage are not enough to alleviate the pain caused by the condition.

After the swelling has gone down, an individual would then begin to do stretching exercises. This would help to reduce the compression of the ITB against the femoral condyle that was found to occur by Fairclough et al. (2006) Stretching will also help to reduce the friction of the ITB as it rubs across the femoral condyle during flexion and extension of the knee (Khaund et al. 2005). Stretching exercises would be aimed at lengthening the tensor fascia lata and ITB together and usually consist of a sub maximal muscle contraction held for 7s followed by a stretch held for 15s (Fredericson et al. 2005). An example of an ITB stretch would be the patient standing upright with the affected leg extended and adducted across the unaffected leg. The patient then laterally flexes the trunk toward the direction the affected leg is adducted. The stretch should be felt on the side of the hip (Fredericson et al. 2005)

A person who suffers from ITB syndrome would also need to increase the strength of their hip abductors. Weak hip abductors have been associated with increased hip adduction during running (Fredericson et al. 2005). Increased hip adduction has been found in those with ITB syndrome (Noehren et al. 2007). An increase in the strength of the hip abductors may also factor in to the step width of an individual during running. Increasing the step width may, in turn, decrease the internal rotation of the knee as well as hip adduction and ITB strain. There are several exercises that can be done to strengthen the muscles important for hip abduction. The main focus should be increasing the strength of the gluteus medius
muscle (Fredericson et al. 2000). Important strengthening exercises include a pelvic drop exercise where the patient stands on a platform on one leg and lets the other hang off the side. The patient then contracts the gluteus medius to raise the hips to a level position and relaxes it to lower them (Khand et al. 2005; Fredericson et al. 2000). Other exercises include concentric exercises such as side lying leg lifts, single leg balance and single step down exercises.

Fredericson et al. (2005) also developed a series of exercises that work the hip abductor muscles eccentrically. These exercises are the modified matrix, wall bangers, frontal plane lunges, an exercise that develops the supinators of the loading leg and an exercise that works the pronators of the loading leg. The modified matrix is done by having the patient stand upright with the left foot pointed towards 12 o’clock and the right pointed towards 3 o’clock. The right arm is abducted and externally rotated. The patient then rotates the hips toward the left leg, shifts his weight to the left leg and reaches with the right arm over the left leg. Wall bangers are an exercise where the patient stands upright with the right side of their body 15-30 cm away from a wall. The patient then reaches to the left and rotates their hips toward the left foot, flexes their knees and bangs their right hip against the wall, making sure to not hold the position, then returns to the standing position. Frontal plane lunges are performed with the feet shoulder width apart. The patient steps out laterally until tension is felt in the gluteals and lower extremities. The loading leg supinator exercise is performed by doing the frontal plane lunge with an added contralateral reach. The loading leg pronator exercise is performed by doing the frontal plane lunge with an added medial reach. When all non invasive methods are unsuccessful, surgery may be recommended. There are several surgical methods of ITB tension release. One method of surgery is known
as the mesh technique. The knee is set at 30 degrees of flexion. This is where there is the most impingement of the ITB on the femoral condyle (Farrell et al. 2003). A 3cm incision is made over the lateral femoral condyle. Several 2mm slits are made in the ITB directly over the femoral condyle. Because of the ITB tension, the small slits spread out and give the appearance of a meshed material. This will cause the ITB to not be as tight and will alleviate the pain caused by ITB syndrome (Sangkaew 2007). In a 2nd surgical technique, the knee is flexed at 30° and a triangular piece of the ITB that is over the femoral condyle is surgically removed (Martens et al 1989). A 3rd technique is known as z-lengthening where a z-shaped incision is made with the middle line of the z in the direction of greatest tension.

The last step in the treatment of ITB syndrome is the returning to running. This is done only after the patient is able to perform the exercises and stretches pain free. Patients should start off performing light sprints every other day and avoid hills for the 1st couple of weeks. Sprinting is less harmful to the ITB because the knee is flexed beyond the zone of impingement at heel strike. Patients can gradually increase the frequency and duration of running after the initial 2 week period has passed (Fredericson et al. 2005).

From reviewing the literature on ITB syndrome, the condition is caused by several biomechanical and anatomical factors that influence the strain of the ITB. There is disagreement on what affects the condition the most. Several methods of treating the symptoms of the condition are available. There are also criticisms as to whether there is one method that works best in treating ITB syndrome. The research I am proposing is to find what the impact of step width is on ITB syndrome. If it is found that a slightly increased step width can reduce the prevalence of ITB syndrome by reducing the strain on the ITB and the
amount of friction, there may be steps that can be taken to help prevent the condition from occurring in runners.
CHAPTER III

The Effect of Step Width on Iliotibial Band Strain
Samuel Campbell and Timothy R. Derrick

Introduction

The iliotibial band (ITB) is a band of connective tissue that originates at the iliac crest, crosses the hip joint, travels down the lateral portion of the thigh and inserts at Gerdy’s Tubercle on the proximal tibia. It also inserts on the patella, the linea aspera and the lateral femoral condyle. There are also several muscle insertions on the ITB. At the hip, three quarters of the gluteus maximus, portions of the gluteus medius and all of the tensor fascia lata insert onto the ITB. These proximal attachments of the ITB at the hip also help it to serve as a lateral hip stabilizer and resist adduction (Fredericson et al. 2000). The ITB itself is a thickening of the femoral fascia, and because of its insertions at the knee, may serve as a lateral stabilizer between the femoral condyle and the tibia. The ITB is attached to the lateral intermuscular septum and muscle fascia of the quadriceps at the distal end of the femoral segment. This attachment prevents excessive anterior-posterior movement of the ITB during flexion and extension of the knee (Orava 1978; Kaplan 1958).

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It is believed that ITB syndrome may be caused by weak hip abductor muscles as well as an inflexible ITB (Nobel et al. 1980; Fredricson et al. 2000). Weak hip abductor muscles such as the gluteus medius, minimus and tensor fascia lata could cause a runner to not have the strength to keep the pelvis aligned properly. This would cause a pelvic tilt that could cause increased strain in the ITB. This may also be the reason why the side lying leg lifts, single leg balance, step downs and pelvic drop exercises described by Fredericson et al. (2005) seem to be successful in helping with the recovery process.

Iliotibial band syndrome is commonly diagnosed in individuals who are actively involved in running or cycling, as well as military personnel just starting boot camp and is rarely seen in individuals who are inactive. ITB syndrome accounts for 12% of all overuse injuries in running (Fredricson et al. 2005) and 15% of all overuse injuries in cycling (Holmes et al. 1993). It typically occurs when an individual has made a significant increase in their weekly running mileage. This is the case for the military personnel that typically go from running little or no miles to dramatically increasing activity during boot camp. During running or cycling the ITB enters what is called the impingement zone. This zone is described as when the knee is flexed between 0 and 30 degrees, with the greatest friction occurring at or around 30 degrees of knee flexion. In this range the ITB and lateral femoral condyle contact and rub across each other which causes the friction (Orchard et al. 1996; Farrell et al. 2003). Downhill running as well as continuous running on a banked track in one direction can contribute to the development of ITB syndrome. Running downhill forces individuals to land with the knee less flexed which increases the amount of pain suffered by
ITB syndrome (Orchard et al. 1996). Because of this, more flexion while running would seem better for the ITB. Therefore sprinting would seem to have less of a negative impact on ITB pain because of the increased knee flexion.

ITB syndrome can be treated with conservative means, a decrease or cessation of running, surgery or corticosteroid injection at the site of femoral epicondyle impingement (Gunter et al. 2004; Fredricson et al. 2005). There are several phases of ITB syndrome treatment and rehabilitation (Fredericson and Wolf 2005). Phase 1 is the acute phase. In this phase, treatment typically begins with reducing the swelling at the ITB and lateral femoral condyle friction point. This can be accomplished using several methods which include phonophoresis (the use of ultrasound to enhance delivery of medicines applied topically to an inflamed area), ice massages, oral non-steroidal anti-inflammatory medications and iontophoresis (the use of electric charge to deliver medicine through the skin). During this time, running activity must be altered (cessation of downhill running or running in single direction on a track) and activities which cause the repetitive friction must cease all together. If, after these treatments, the pain and swelling do not diminish, a corticosteroid injection may be administered at the site of inflammation. Phase 2 is the subacute phase. After the swelling has gone away stretches are begun to not only lengthen the tight ITB but also stretch the lateral muscles and shortened muscle groups. Phase 3 is the strengthening phase. It begins once the issues with ITB and lateral muscle tightness have been resolved through the stretching in phase 2. Some exercises that are helpful in increasing strength in the problematic area include concentric exercises such as leg lifts, balance exercises and pelvic drop exercises (Fredricson et al. 2000, Fredericson et al. 2000). Exercises that work muscles eccentrically, triplanar motions and integrated movement patterns have also been
included in strengthening programs. Phase 4 is the return to running phase. This phase begins only after strengthening exercises can be completed with no pain. Running should begin with short sprints several times a week on level ground and gradually increase. Running downhill and on uneven surfaces should be avoided. Phase 5 is the surgical management phase. This phase is completed only if the conservative modalities and strengthening methods are not effective. There are several surgical methods used. These methods include z-lengthening, another procedure where a triangular piece of the ITB over the lateral femoral condyle is removed when the knee is flexed at 30 degrees and the mesh technique developed by Sangkaew (2007). With this technique the knee is flexed at 30° and a 3cm incision is made over the lateral femoral condyle down to the ITB. Numerous 2mm incisions are then made on the ITB perpendicular to the direction of the ITB fibers and covering the lateral femoral condyle. These incisions are then spread by the tension in the ITB and create a mesh appearance that decreases the tension in the ITB.

Current research has studied treatments and causes of ITB syndrome. Running kinematics and knee flexion angles have also been studied thoroughly, but not much research has been done studying the effect of adduction of the hip and step width on ITB syndrome. Hip adduction angle during running may play an important role in the development of ITB syndrome, with more adduction causing increased strain. Noehren et al. (2007) found that runners with a history of ITB syndrome ran with increased adduction at the hip and greater internal rotation at the knee. Increased knee internal rotation may have the added effect of further tightening an already tight ITB over the lateral femoral condyle. Hamill et al. (2008) suggested that this increased adduction and internal rotation may cause an increase in strain rate and ITB strain but could only make assumptions. Adduction of the hip and step width
are related because as the amount of adduction increases, the runner’s step width will decrease. On the other hand, when adduction decreases the runner’s step width will increase. A narrower step width may force the ITB to lengthen while running and may increase the strain on the ITB while a wider step width may cause the ITB to be more relaxed and thus reduce the strain developed while running. A lack of research on step width and hip adduction during running has prevented the determination of the role that these variables may play in the development of ITB syndrome. The purpose of this research was to study how step width affects the strain and rate of strain development in the ITB. It was hypothesized that both of these variables would increase as the step width decreases.

Methods

Subjects

Eight male and seven female experienced runners (age: 23.7 ± 5.36 years; height: 174.0 ± 7.5 cm; mass: 70.3 ± 9.19 kg) were asked to participate in this study. Each subject signed an informed consent agreement and filled out a physical activity questionnaire prior to participation in the study. No subject suffered from any lower extremity injury while participating in the study.

Experimental Setup

An AMTI (OR6 model) force platform was used to capture the ground reaction forces at a rate of 1600 Hz. Kinematic data were collected using eight infrared cameras (Vicon MX40) with a frame rate of 160 Hz. These cameras were connected to the same computer as the force platform so that the kinematic and GRF data could be collected simultaneously using the Nexus software. The cameras were attached to an octagon connected to the ceiling in the Iowa State University biomechanics laboratory.
**Protocol**

Anthropometric data were recorded for each subject before data collection began. These variables include body mass, height, thigh length, mid thigh circumference, calf length, calf circumference, foot length, foot breadth, malleolus height and malleous width. A total of twenty-eight reflective markers were placed on the pelvis and lower extremities of each subject. These locations were the dorsifoot, lateral foot, heel of foot, medial and lateral maleoli, proximal and distal tibia, back of leg slightly below the gastrocnemius, lateral and medial femoral condyles, anterior thigh, lateral thigh, hip and ASIS of both sides of the body as well as the sacrum. The subjects first stood on the force platform while static data were recorded. The medial knee and ankle markers were then removed for the running trials. Subjects ran at a self-selected 5k pace so their preferred stance width and running velocity could be recorded. Stance-width was calculated as the distance between the right and left heel markers during the respective stance phases. A minimum of 2 steps had to be captured in succession with the infrared cameras in order to calculate step width. A positive step width value indicated that the heel markers did not cross the midline of the body while the subject ran. A step width of 0cm indicated that the subject ran landing with each step directly on the midline of the body. A negative step width indicated that the subject ran with each step crossing the midline (a step with the right leg landed on the left side of the midline and a step with the left landed right of the midline). Each subject ran ten successful trials at their preferred velocity and stance width until 10 successful trials were recorded. The average running velocity and step width during the normal condition was calculated from these 10 trials and used to verify the success of a trial during the wide and narrow conditions. During the wide condition a stance width of at least 5% of leg length wider than preferred
was required. During the narrow condition a stance width of at least -5% of leg length narrower than preferred was required. If the subject’s stance width was not wide enough or narrow enough, or the velocity did not fall within the allowed range (+5% or -5% from the preferred), that trial was recaptured. The order of presentation of the wide and narrow conditions was alternated between subjects but each subject began with the normal running condition.

Data Analysis

Kinematic data were low-pass filtered at 8Hz. Center of mass locations and segment masses were calculated using Vaughan’s regression equations (Vaughan et al., 1992) using the anthropometric data that were collected before data collection began. All kinematic data were imported into a scaled SIMM model and a spherical wrapping object was created to represent the lateral condyle. The mediolateral protrusion of the wrapping object was adjusted for each subject so that impingement of the ITB on the lateral femoral condyle occurred at 25-30° of knee flexion as suggested by the literature (Orchard et al., 1996; Farrell et al. 2003). Length of the ITB was calculated by summing the individual segments of the SIMM musculotendinous unit for each frame of data. ITB strain and rate of strain development were calculated, following the methods of Hamill et al. (2008) using the equations:

\[
\text{Strain} = \frac{L_i - L}{L} = \frac{\Delta L}{L} \times 100 \quad \text{and} \quad \text{Rate of Strain} = \frac{\Delta \text{Strain}}{\Delta \text{Time}}
\]

where \(L_i\) is equal to the length of the ITB during time \(i\) of the stance portion of the run and \(L\) is equal to the resting ITB length calculated during the standing calibration trial.
**Statistical Analysis**

A repeated measure ANOVA with one factor and three levels was used for statistical analysis with alpha level set at .05. Tukey comparisons were used when needed. Effect sizes (ES) were also calculated. Effect size quantifies the magnitude of the effect relative the pooled standard deviation (Cohen, 1992). Cohen (1992) proposed that ES values of 0.2-0.5 indicate small differences, 0.5-0.8 indicate moderate differences, and greater than 0.8 indicate large differences. Variable abbreviations include knee angle (KA), time (t), abduction (ab), internal rotation (int), hip angle (HA), flexion (flex) and hip moment (HM).

**Results**

There were no significant differences seen in running velocity across conditions (Table 1). The running velocities for the narrow, normal and wide running conditions all averaged 4.0 m/s with standard deviations ranging from ±0.57 to 0.58 m/s. There were also no significant differences found in heel strike index between the normal and wide ($p = .264; ES = 0.16$), normal and narrow ($p = .326; ES = 0.03$) and the narrow and wide conditions ($p = .326; ES = 0.18$) with heel strike values of 31.2% of stance for the normal condition, 27.4% of stance for the narrow condition and 27.8% of stance for the wide condition. There were significant differences between step widths with the wide condition having the largest step width (10.2±0.04 cm) and the narrow step width having the smallest (-6.3±0.05 cm). The normal step width was 2.6±0.04 cm. All differences were significant with the p-values all less than .000 and large effect sizes ranging from 1.77 to 3.89 (Table 1).
Table 1: Comparison of narrow, normal and wide step widths with corresponding running velocities.

Iliotibial band strain increased as the step width became narrower (Figure 2). Significant differences were found in ITB peak strain across conditions with the narrow step width condition having the greatest level of strain (3.7±0.50%) compared to normal running (3.1±0.52%) (p < .0001; ES = 1.03). The wide step width strain (2.7±0.50%) was significantly less than the normal condition (p < .0001; ES = 0.75).
Figure 2. Peak strain level during each step width condition. Bars are standard deviation. Normal running is the subjects regular running pattern. Narrow running is running with a step width that is less than the normal running step width. Wide running is running with a step width that is greater than the normal running step width. The numbers 1, 2 and 3 indicate the step width is significantly different from narrow, normal or wide respectively.

Strain rates tended to increase with the narrowing step width but not all comparisons were statistically significant (Figure 3). There were no significant differences found in strain rate between the normal and narrow step widths (ES = 0.19; p = .221). However there were significant differences found between the normal and wide step widths (ES = 0.33; p = .016) and the wide and narrow step widths (ES = .52; p = .003). ITB strain rate during the normal step width was 10.8 ± 10.32%/s. ITB strain rate during the narrow condition was 12.8 ± 8.42%/s. ITB strain rate during the wide condition was 7.4 ± 8.99%/s.
Figure 3. Strain rate during each running condition. Strain rate is an important factor in the development of injury to tissue. The higher the rate of strain the more likely the tissue will sustain injury. Bars are standard deviations. The numbers 1, 2 and 3 indicate the step width is significantly different from narrow, normal or wide respectively.

ITB impingement occurs at approximately 30 degrees of knee flexion. We observed greater tension in the ITB during this critical point in the gait cycle with narrower step widths (Figure 4). When the knee was flexed at 30 degrees, ITB strain was significantly different across conditions \( p < .0001 \). The greatest strain at 30 degrees of knee flexion was seen during the narrow step width with a value of \( 2.9 \pm .53\% \ (ES = 1.89) \). The least strain at 30 degrees of knee flexion was seen during the wide step width with a value of \( 2.4 \pm .68\% \ (ES = 0.94) \). Normal step width running had a value of \( 2.9 \pm .53\% \ (ES = 0.94) \).
Figure 4. The values for strain when the knee is flexed at 30 degrees. Bars are standard deviations. These values occur about 10% earlier in the stance phase compared to the peak strain values reported earlier. The numbers 1, 2 and 3 indicate the step width is significantly different from narrow, normal or wide respectively.

Other observed variables included time to maximum strain, time to 30° knee flexion, knee angle abduction at 30° knee flexion, knee internal rotation at 30° knee flexion, heel strike index (where on the foot the subject landed, ie: heel vs. midfoot vs. forefoot measured as a percent of stance), hip angle abduction at 30° knee flexion, hip angle internal rotation at 30° knee flexion, hip angle flexion at 30° knee flexion and hip abduction moment at 30° knee flexion (Table 1). Significant differences were found between each step width condition in the time it took to reach a knee angle of 30° and hip angle abduction at 30° knee flexion. The variables knee angle abduction at 30° and hip flexion angle at 30° each showed significant differences between the normal and wide step widths and the narrow and wide step widths. Significant differences were also seen between the normal and narrow step widths, as well as the narrow and wide step widths in hip internal rotation angle at 30° knee flexion. Hip
abduction moment at 30° knee flexion showed a significant difference between the normal and narrow step widths. No significant differences were seen in time to max strain, knee internal rotation at 30° knee flexion or heel strike index.

<table>
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<tr>
<th>Variable</th>
<th>Condition</th>
<th>Mean</th>
<th>StDev</th>
<th>Effect Size</th>
<th>p-Value</th>
<th>Comparison</th>
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<td>3.1</td>
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<td>0.087</td>
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<tr>
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</table>

Table 2: Comparisons of narrow, normal and wide step width running conditions for each variable. Condition 1 is narrow, condition 2 is normal and condition 3 is wide running. KA is knee angle, HA is hip angle, and HM is hip moment, ab is abduction, ad is adduction and int is internal rotation. Angles and moments are all at 30 degrees of knee flexion.

Discussion

The purpose of this research was to study how step width affects the strain and rate of strain development in the ITB. It was hypothesized that both of these variables would
increase as the step width decreases. The results obtained in this study largely supported these hypotheses. There was significantly increased strain on the ITB as the step width narrowed. These findings support the hypotheses. Results also showed that there was a significantly increased rate of strain development between the normal and wide step widths and between the narrow and wide step widths. The comparison between normal and narrow step widths was not significant. According to Hamill et al. (2008), rate of strain development is a key factor in the development of ITB syndrome because of the physical properties of the ITB. This information suggests that the lower rate of strain development seen in the wide running condition may be preventative in the development of ITB syndrome. This also means that the increase (although not significant) in the rate of strain development seen during the narrow condition may have a negative impact on the development of ITB syndrome.

Another factor considered to be important in the development of ITB syndrome is knee internal rotation. Noehren et al. (2007) found that runners who developed ITB syndrome had greater internal rotation at the knee compared to healthy subjects. This study found that when examined at a knee flexion angle of 30°, the amount of internal rotation at the knee did not differ going from a normal, to a narrow and finally to a wide step width. The fact that there was no difference in internal rotation of the knee as described by Noehren et al. (2007) may have occurred because runners were asked to run at a step width that is uncharacteristic of how they normally run. Noehren et al. (2007) had subjects run at their normal step width and then examine differences in kinematics between injured and non injured subjects. In the current study, subjects may have compensated for the change in step width by increasing or decreasing motion at another location.
The reported values from this study for time to maximum strain were 27.47% of stance for the normal running step width, 29.07% of stance for the narrow running step width and 29.27% of stance for the wide running step width conditions. These are slightly greater than the values reported for the time to knee angle of 30°. The times to reach a knee flexion angle of 30° were 19.5% of stance during the normal step width running condition, 20.3% of stance during the narrow step width running condition and 18.8% of stance during the wide step width running conditions. The literature states that maximum ITB impingement occurs at 30° of knee flexion (Orchard et al. 1996; Farrell et al. 2003). This means that peak strain should occur at about the same period of the stance phase as 30° of knee flexion. This study found that the peak strain occurred slightly after the knee was flexed at 30° or around 30% of the stance phase. These values are slightly lower than those reported by Hamill et al. 2008 who found peak strain values to be at around 35-40% of stance phase. Hamill et al. 2008 also reported somewhat higher peak strain values. These differences in results may be due to differences in the way the actual ITB was modeled and the attachment points used.

The hip abduction angle at 30° knee flexion was 8.4° for the normal step width running condition, 10.2° for the narrow step width running condition and 5.3° for the wide step width running condition. These values were expected and are likely the main explanation for the increased strain during narrower step widths. As the step width is decreased you would expect greater hip adduction and these results confirm this. Hip adduction increases the length of the ITB and thus the passive tension. Noehren et al. (2007) noted that individuals with ITB syndrome ran with greater hip adduction than those who did not have ITB syndrome. The results from this study showed that external rotation of the hip increased from a narrow to a wide step width, similar to what the literature states. The ITB
attachment at the lateral femoral condyle is what may cause the increase in strain seen as the step width is decreased when the runner increases adduction and externally rotates the hip. It is also expected that there be a change in abduction moment between conditions with more of an abduction moment during the wide step width running condition and more of an adduction moment during the narrow step width running condition.

Passive tension caused by stretching the ITB is not the only means of tightening this structure. The insertions of the hip abductor muscles onto the ITB indicate that any increase in the activation of these muscles will increase the tension of the ITB. The hip abductor moment increased by 35% (a small effect size) from the wide step width to the narrow step width. This indicates that there may be increased active as well as passive tension in the ITB during narrower step widths.

The current study shows that there is an inverse relationship between step width and ITB strain. As the step width is decreased the strain increases and as the step width increases ITB strain decreases. The decrease in strain seen with the wider step width indicates that widening a runner’s step may be used as a preventative measure along with gait retraining. It also may help alleviate some of the pain in those already diagnosed with ITB syndrome. Further analysis should be conducted to insure that this suggested running style does not cause abnormal stresses or anatomical alignments that could induce injury. One limitation of this study is the fact that each model was adjusted so that impingement occurred around 30° of knee flexion rather than having a default model for everyone and viewing the differences between the individuals running pattern. However this allowed for a different set of data to be collected and manipulated in a different way to look at key variables at a certain point during the gait cycle. An assumption of this study was that the most critical point for ITB...
syndrome was when the knee was in 30 degrees of flexion. This has been shown to be an average value for when the ITB crosses the lateral femoral condyle but it does not allow for individual differences in the anatomical structures. Future studies may look at methods for determining this point for individual runners.

References


CHAPTER IV

General Conclusions

Step width may be an important factor in the development of ITB syndrome. Not because of the step width itself, but because of the effect the step width has on other anatomical structures. The results of this study suggest that as a runner narrows their step width, the ITB strain and strain rate increase. The evidence also suggests that the muscles that are attached to the ITB generate more force as the step width narrows. This would produce additional tension in the ITB independent of the geometrical, passive tension caused by the stretching of the ITB. It is not known which of these mechanisms play the more significant role in ITB syndrome.

Due to the complexity of the ITB, its origin, insertions and its muscular attachment points, altering step width may have complex ramifications. Is the narrow step width adopted by some ITB syndrome runners the result of anatomic abnormalities or muscular deficits or a combination of both? It is possible that altering step width may not be the best solution for all runners. There is also a question of performance. Widening the step width does indeed decrease ITB strain, but if performance suffers, runners will not willingly adopt a new style of running.

The findings of this study suggest future treatment and preventative measures taken to decrease the prevalence of ITB syndrome may include some form of gait retraining to widen an individual’s step width coupled with the current stretching and hip abductor strengthening treatments, but the effect of step width on other aspects of running must be researched thoroughly before implementation of such retraining.
APPENDIX A

Informed Consent

Title of Study: Examination of Lower Body Running Biomechanics during Different Step Widths

Investigators: Samuel Campbell, Stacey Meardon, Timothy Derrick

This is a research study. Please take your time in deciding if you would like to participate. Please feel free to ask questions at any time.

INTRODUCTION

The purpose of this study is to determine the effects of stride width (distance between your feet while you run) on two types of running injury. The potential for IT band syndrome (pain on the outside portion of the knee) and stress fracture will be evaluated. You are being invited to participate in this study because you have been identified as a recreational or competitive runner.

DESCRIPTION OF PROCEDURES

If you agree to participate in this study, your participation will last for approximately 1.5 hrs and will involve one visit to the department. During the study you may expect the following study procedures to be followed: You will arrive and sign a consent form as well as fill out a survey. You will change into provided clothes and we will take the following measurements: thigh length, mid-thigh circumference, calf length, calf circumference, foot length, foot breadth, ankle height, ankle width, body mass, and height. Twenty-five ¾ inch reflective markers will be attached to your right leg using double-sided tape. You will rotate your right leg while the position of each marker is recorded. Next, you will run down a 25 meter runway at your preferred 5k running pace and your right foot will land on a 1-meter, marked region on the floor. Data will also be collected during this run. Ten successful runs will be collected in each of three conditions (normal stride width, wide stride width and narrow stride width). Successful trials will be within 5% of the your normal running speed and at the proper stride width and with the proper foot landing in the marked region on the floor. You will be given as much time as you need between runs.

Data from this study will be added to ISU's biomechanics running database.

BENEFITS

If you decide to participate in this study there will be no direct benefit to you. It is hoped that the information gained in this study will benefit society by helping to prevent injuries of the lower body that can occur in runners.
RISKS
Potential risks include muscle and/or tendon strain from running and skin irritation due to adhesive markers used to apply retro-reflective markers to the skin. Muscle and tendon strain will be minimized by having participants run at their preferred running speed. Skin irritation from adhesive markers is expected to be minimal.

COSTS AND COMPENSATION
You will not have any costs from participating in this study. You will not be compensated for participating in this study.

PARTICIPANT RIGHTS
Your participation in this study is completely voluntary and you may refuse to participate or leave the study at any time. If you decide to not participate in the study or leave the study early, it will not result in any penalty or loss of benefits to which you are otherwise entitled.

CONFIDENTIALITY
Records identifying participants will be kept confidential to the extent permitted by applicable laws and regulations and will not be made publicly available. However, federal government regulatory agencies, auditing departments of Iowa State University, and the Institutional Review Board (a committee that reviews and approves human subject research studies) may inspect and/or copy your records for quality assurance and data analysis. These records may contain private information.

To ensure confidentiality to the extent permitted by law, the following measures will be taken: You will be assigned a unique code and letter which will be used on data forms instead of your name. Study records will be kept in a locked filing cabinet or password protected computer files. Data will be retained indefinitely. If the results are published, your identity will remain confidential.

QUESTIONS OR PROBLEMS
You are encouraged to ask questions at any time during this study.

For further information about the study contact:
  Samuel Campbell – 103B Forker Building (515)294-3100, samcamp@iastate.edu
  Stacey Meardon – 283 Forker Building (515)294-2953, smeardon@iastate.edu
  Timothy Derrick – 249 Forker Building, tderrick@iastate.edu

If you have any questions about the rights of research subjects or research-related injury, please contact the IRB Administrator, (515) 294-4566, IRB@iastate.edu, or Director, (515) 294-3115, Office of Research Assurances, Iowa State University, Ames, Iowa 50011.

**********************************************************************************************************************

PARTICIPANT SIGNATURE
Your signature indicates that you voluntarily agree to participate in this study, that the study has been explained to you, that you have been given the time to read the document and that your questions have been satisfactorily answered. You will receive a copy of the written informed consent prior to your participation in the study.

Participant’s Name (printed)

(Participant’s Signature)  (Date)

INVESTIGATOR STATEMENT

I certify that the participant has been given adequate time to read and learn about the study and all of their questions have been answered. It is my opinion that the participant understands the purpose, risks, benefits and the procedures that will be followed in this study and has voluntarily agreed to participate.

(Signature of person obtaining informed consent)  (Date)