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Assessment of Strength, Flexibility, and Running Mechanics in Males with Iliotibial Band Syndrome

Brian Noehren, PT, PhD[1], **Anne Schmitz, PhD**[1], **Ross Hempel, BS**[1], **Carolyn Westlake, MS**[1], and **William Black, MD**[2]

[1]Division of Physical Therapy, University of Kentucky, Lexington, KY, USA

[2]Department of Sports Medicine, University of Kentucky, Lexington, KY, USA

Abstract

Study Design—Cross-sectional laboratory study.

Objectives—To assess differences in hip strength, iliotibial band length, and hip and knee mechanics during running between male runners with iliotibial band syndrome and healthy controls.

Background—Flexibility, strength, and running mechanics are commonly assessed in patients with iliotibial band syndrome (ITBS). However, these variables have not been evaluated concurrently in this population.

Methods—Thirty-four males participated (17 healthy, 17 ITBS). Hip strength was measured with a hand held dynamometer and iliotibial band flexibility was assessed using an inclinometer while performing the Ober's test. Kinetic and three-dimensional kinematic data were obtained during running. Kinematic variables of interest included frontal and transverse plane hip and knee joint angles at the time of early stance. Independent sample t-tests as well as effect sizes were used to assess group differences.

Results—Compared to the control group, persons with ITBS had a significantly lower Ober's measurement (1.2°), weaker hip external rotators (1.2 Nm/kg), greater hip internal rotation (3.7°), and greater knee adduction (3.6°). However, only hip internal rotation and knee adduction exceeded the minimal detectable change score.

Conclusions—Our results suggest that intervention strategies that target neuromuscular control of the hip and knee may be indicated for males with iliotibial band syndrome.

Key Terms

hip and knee mechanics; hip strength; Ober's test; running

Address correspondence to Brian Noehren, 204D Wethington Building, 900 South Limestone Street, Lexington, KY 40536. b.noehren@uky.edu.

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Iliotibial band syndrome (ITBS) occurs in 5–14% of runners and is the leading cause of lateral knee pain and the second leading cause of overall knee pain in this population.[32] Despite its high prevalence, little is known about the etiology of this condition. Development of ITBS is thought to include extrinsic factors (e.g. training volume, shoe wear) as well as intrinsic factors (e.g. flexibility, strength, running mechanics, etc.).[1,30,32]

Physical therapy programs typically focus on addressing the intrinsic factors that contribute to ITBS. While there have been limited reports on the role of these intrinsic factors individually, there has been no comprehensive analysis of these factors within the same group. Moreover, previous studies have consisted of males and females, or females only. Considering males with ITBS as a separate group may be important as previous research has shown that men and women have different muscular strength and running mechanics, and thus, may have different intrinsic factors that contribute to this injury.[8,11,35] In addition, establishing an injury profile in men with ITBS is important since males comprise 50 to 81% of those suffering from ITBS.[32]

Hip strength and iliotibial band (ITB) flexibility are commonly assessed as part of the evaluation of an injured runner with ITBS. For example, hip abductor weakness has been demonstrated in track athletes with ITBS.[12] However, this is in contrast to more recent research in which no differences in hip abductor strength in persons with ITBS were reported.[14] The conflicting results between previous studies could be the result of different testing procedures (isometric versus isokinetic assessment of muscle strength) and group demographics (high level athletes versus recreational runners).[12,14]

While there have been a limited number of reports on hip abductor strength in runners with ITBS, there have been no studies evaluating hip external rotation strength in this population. Hip external rotation strength plays an important role in providing rotary control of the hip and weakness of the external rotators may contribute to greater strain on the ITB.[1] Lastly, while the Ober's test is typically used as an indicator of ITB flexibility, the authors are not aware of any published reports highlighting whether runners with symptomatic ITBS exhibit diminished ITB length.[1,30,32]

Abnormal running kinematics, specifically excessive motions of the hip and knee in the frontal and transverse planes, are often cited as important contributing factors with respect to the development of ITBS.[10,13,23,32] The attachment sites of the ITB make this structure particularly vulnerable to altered secondary plane running mechanics. Proximally, the ITB is attached to the pelvis through both the tensor fascia latae and gluteal muscles.[3,22] Distally, its insertion includes the lateral femoral epicondyle and Gerdy's tubercle.[3,22] Therefore, greater hip and knee adduction, as well as greater hip and knee rotation may increase the tensile strain in the ITB.

Hamill et al. have confirmed that runners with symptoms do experience greater ITB strain rates during the early stance phase of running.[15] However, previous investigations evaluating the kinematic variables that may contribute to the development of ITBS have been mixed. For instance, one study of women with ITBS found greater peak hip adduction and knee internal rotation whereas another study using a mixed sample of males and female

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runners with ITBS found no differences in hip or knee kinematics.[13,23] The lack of consensus among studies suggests that males with ITBS may have a different kinematic profile when compared to females.

The purpose of the current study was to assess differences in hip abduction and external rotation strength, ITB length (Ober's test), as well as frontal and transverse plane kinematics at the hip and knee in males with ITBS. Based on what is known about the intrinsic factors that may contribute to ITBS, it was hypothesized that male runners with ITBS would have significantly weaker hip abductor and external rotators, diminished length of the ITB, increased hip and knee adduction, and increased hip internal and knee external rotation angles compared to a control group.

METHODS

A total of 34 male runners between the ages of 18–45 participated in this study (17 with ITBS and 17 pain-free controls). The control and ITBS groups were similar in terms of age, distance run per week, mass, and height (Table 1). The number of subjects was chosen to detect a moderate effect size (Cohen's d of 0.5) with reasonable statistical power (β=0.8).

The study was approved by the Institutional Review Board of the University of Kentucky. Subjects were recruited from local races, posted flyers, and physician offices. Prior to participation, all subjects provided written informed consent. To be considered for the study, subjects in both the ITBS and control groups had to report running at least 16 kilometers per week. In addition, persons with ITBS had to report being free from any other lower extremity injury other than ITBS for the past 6 months. Similarly, the control group had to be injury free for the past 6 months.

Individuals with ITBS were evaluated by a licensed physical therapist to determine if they qualified for the study. Runners in the ITBS group had to report an insidious onset lateral knee pain while running for at least the past 2 months. Participants were included in the ITBS group if they had reported pain of at least 3 out of 10 on the numeric rating scale during running. The repeatability and validity of this scale previously has been reported (ICC 0.93–0.95).[1,17] During the evaluation, potential subjects had to report pain with direct palpation of the distal attachments of the ITB at either Gerdy's tubercle or the lateral femoral epicondyle, or report pain during the Noble compression test which has been reported to have acceptable inter-rater reliability.[6] As part of the evaluation, possible ligamentous (varus stress test) and meniscus injuries (McMurray test) were ruled out.[18]

Each subject's hip strength was measured with a hand held dynamometer (Lafayette Instruments, Lafayette, IN) using previously reported procedures that have been shown to be reliable.[4,16,17] To measure hip abduction strength of the involved leg, the subject was positioned in sidelying (non-involved side) and pushed into the dynamometer using the involved leg. The dynamometer was secured 5 cm proximal to the tibiofemoral joint line with a stabilization strap around the dynamometer and the testing table. Hip external rotation strength was subsequently measured in a seated position, with the dynamometer placed on the inside of the involved leg 5 cm superior to the ankle joint and held in place with a

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stabilization strap.[16] For both strength tests, the participants were instructed to gradually increase how much they pushed over 3 seconds and then to hold their maximum effort for the next 2 seconds.

All individuals performed 2 practice trials followed by 3 testing trials. The maximum efforts attained during the 3 testing trials were then averaged for each subject. The raw force values were multiplied by femur length to give a torque value, normalized by mass to account for body size, and then multiplied by 100. Femur length was measured as the distance from the greater trochanter to the medial tibiofemoral joint line. A post-hoc analysis demonstrated that the normalized torque values were not correlated with mass or height, demonstrating the effectiveness of the normalization strategy to minimize the influence of subject size.[2]

The length of the ITB was assessed using the Ober's test using previously established procedures.[25,27] The individual was placed in sidelying with the examiner standing posteriorly. The investigator's knee was placed on the subject's back for stabilization and to prevent the spine from rolling backwards during the evaluation. While maintaining the knee in a slightly flexed position (10–15°), the subject's upper thigh was then brought into hip extension and adduction until the pelvis started to tilt or when there was no additional hip adduction movement. This technique has been previously shown to be reliable (ICC 0.90).[27] In addition, an electric inclinometer (Craftsman, Model 320.48295, accuracy of 0.1°) was placed with the end at a marker 5 cm from the distal lateral femoral epicondyle, giving a measure of degrees from the horizontal.

Following strength and flexibility testing, individuals completed an instrumented gait analysis. Retroreflective markers were placed on the skin at the L4-5 junction, bilateral iliac crests, anterior superior iliac spines, greater trochanters, medial and lateral femoral epicondyles, tibial plateaus, malleoli, as well as the first and fifth metatarsal heads. Rigid shells with clusters of four markers were placed bilaterally on the thigh and shank. Additional tracking markers were placed on the posterior aspect of the shoes. To control for the influence of footwear, all subjects wore New Balance WR662 running shoes (New Balance, Brighton, MA, USA). A standing calibration was then collected, followed by a hip motion trial to establish the hip joint center.[28]

After a warm-up consisting of walking for 5 minutes, subjects ran at 3.3 m/s on an instrumented treadmill (Bertec Corp, Columbus, Ohio). This speed was chosen to be consistent with previous studies[29,34] and to provide acceptable repeatability.[26] The marker trajectories were recorded at 200Hz with a 15 camera motion analysis system (Motion Analysis Corp, Santa Rosa, USA). Force data was collected at 1200 Hz.

Visual 3D software (C-motion, Germantown, MD, USA) was used to filter the data, identify the functional hip joint center, and calculate joint angles for 5 running cycles. Marker trajectory data was filtered at 8 Hz and force data was filtered at 35 Hz using a 4th order Butterworth low pass filter with zero lag. The cutoff frequencies were selected using the results of a residual analysis of the data.[36] Heel strike and toe off for a running cycle occurred when the vertical ground reaction force was 30 N.

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Joint coordinate systems were defined in the Visual 3D software using previously published procedures.[24] The pelvis coordinate system was placed at the midpoint of the line connecting the iliac crests, Z-axis oriented along the line connecting the midpoint of the iliac crests and the midpoint of the greater trochanters, and the XZ-plane established through a plane best fit to the iliac crests and greater trochanters via least-squares. A segment fixed coordinate system for the femur was placed at the functional hip joint center[28] with the Z-axis defined as oriented along a line connecting the hip joint center and the midpoint of the femoral epicondyles and the XZ-plane established by the epicondyles and greater trochanter. The shank coordinate system was positioned at the midpoint of the tibial plateaus, the Z-axis was oriented along a line connecting the origin and midpoint of the malleoli, and the XZ-plane established by minimizing the sum of squares distance between epicondyles, malleoli, and a plane. For all segments, the Y-axis was oriented forward and perpendicular to the frontal (XZ) plane and the X-axis as the cross-product of the Z and Y-axes.

Joint angles were determined using a Cardan rotation sequence of flexion, adduction, and internal rotation, referencing the distal segment to the proximal segment. Custom Labview code (National instruments, Austin, Texas) was used to extract frontal and transverse plane hip and knee joint angles at the time of the initial impact peak for each trial. Values were then averaged across the 5 trials for each subject. Joint angles were obtained during early stance since ITBS symptoms have been reported to occur during this period of time.[1,30]

Means and standard deviations of the following variables of interest were calculated for each group: hip strength, ITB length, and frontal and transverse plane hip and knee joint angles at the time of the impact peak. To assess group differences between these variables, independent t-tests were performed using SPSS version 18.0 (IBM SPSS, Chicago, Illinois). The injured limb in the ITBS subject was compared to the same limb in the matched control participant. Differences were considered significant if $p<0.05$.

If a variable was shown to be statistically significant, clinical relevance was established using the effect size and MDC. Effect sizes were calculated in G*Power.[7] The minimal detectable change (MDC) was quantified according to Wilken[33] where the intra-class correlation coefficients were assumed to be 0.9 for the Ober's test [27], 0.9 for the isometric strength tests,[17] and 0.98 for joint angles.[9] We considered statistically significant findings to be clinically meaningful if the effect size was greater than 0.5[5] and the difference between groups was greater than the MDC.

RESULTS

Compared to the control group, males with ITBS exhibited significantly greater hip internal rotation and knee adduction angles during the early stance phase of running, weaker hip external rotators, and decreased ITB length (Table 2). No group differences were noted in hip abduction strength or hip adduction angle.

DISCUSSION

ITBS is a leading source of knee pain in male runners.[32] Previous studies relating intrinsic factors to the development of ITBS have examined only a single factor in isolation as

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opposed to assessing multiple factors concurrently. In the current study, we compared hip strength, hip and knee kinematics, and ITB length between males with ITBS and matched controls with the intent of developing a more comprehensive injury profile for this population.

On average, male runners with ITBS had diminished ITB length, altered hip and knee kinematics, and diminished hip strength. Specifically, males with ITBS exhibited significantly greater knee adduction, hip internal rotation, and weaker hip external rotators compared to the control group. Although the strength difference in the hip external rotators did not exceed the MDC, there was a relatively large effect size. As such, the observed increase in hip internal rotation could have been the result from a shorter ITB, weakness of the hip external rotators, or altered neuromuscular control.

Contrary to our hypothesis, males with ITBS had neither greater hip adduction angles nor weaker hip abductor muscles when compared to the control group. As those in the injured group currently had ITBS, we cannot rule out the possibility that these individuals may have attempted to control hip adduction as a potential compensatory strategy to reduce pain while running. Even though previous research in females with ITBS suggests runners do not alter their mechanics in the presence of chronic pain,[10,23] it is possible that males and females respond to pain differently.

Our strength findings are in contrast to a study that found both males and females with ITBS had weaker hip abductor muscles.[12] It is possible the difference in testing protocols such as using a stabilizing strap and subject demographics may have contributed to the differences between studies. The stabilizing strap as used in the current study limits the influence of the evaluator's strength in determining force output. However, our results are in agreement with Grau et al. who reported no differences in hip abductor strength between persons with ITBS and pain-free controls.[14]

The Ober's test is a common clinical measure used to assess the length of the ITB. In the current study, the ITBS group exhibited decreased ITB length compared to the control group. While statistically significant however, the observed difference between groups was only 1.2 degrees. Considering that the differences between groups neither exceeded the MDC score nor were associated with at least a moderate effect size, caution should be used in interpreting the clinical significance of this result. Our finding is in agreement with the work of Miller et al. who reported no differences in Ober's test results when evaluating a non-symptomatic retrospective group of patients with a history of ITBS.[21]

Due to the multiple attachments of the distal ITB to both the femur and tibia, excessive frontal and transverse plane knee motion may increase ITB strain. Persons in the ITBS group were significantly more adducted at the knee, which is in agreement with previous studies that have shown persons with ITBS to have greater static varus alignment.[20,31] While not statistically different, runners with ITBS did exhibit greater knee external rotation (4.7°) during early stance compared to the control group. While this difference is relatively large, there was considerable variability among subjects. With the femur as the shared segment between the hip and knee, it is likely that changes in knee kinematics may in part be a reflection of altered hip kinematics. Since the hip was more internally rotated in the ITBS group, it is reasonable that this motion could have contributed to observed knee rotation.

This study is not without limitations. The study design was cross-section in nature, thus limiting our ability to explicitly establish cause-and-effect relationships. Also, measurement of isometric strength in a non-weight bearing position does not necessarily reflect muscle function during a dynamic task. However, isometric strength testing is commonly used in the literature and in the clinic.[16,25] Lastly, it is well documented that there are limitations in motion capture due to skin movement artifact, particularly in the frontal and transverse planes of motion.[19] However, marker clusters were used to minimize this effect, and any artifact due to skin movement would have been consistent between the groups.[19]

CONCLUSION

Collectively, we found that male runners with ITBS exhibited significantly greater hip internal rotation and knee adduction angles during running, less hip external rotation strength, and diminished length of the ITB. While statistically different, the magnitude of difference for ITB length and hip external rotation strength did not exceed the MDC score, suggesting other factors such as neuromuscular control may play a larger role in contributing to altered hip and knee kinematics in this population.

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KEY POINTS

FINDINGS

Males with ITBS exhibited greater hip internal rotation and knee adduction angles during the early stance phase of running. While statistically significant, group differences in hip external rotator strength and ITB length were not considered clinically relevant.

IMPLICATIONS

Our data suggest that intervention strategies that target neuromuscular control of the hip may be indicated for males with iliotibial band syndrome.

CAUTION

The study design was cross-sectional. Therefore, these results cannot be used to establish explicit cause-and-effect relationships.

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TABLE 1

Subject Demographics

Subject Group	Number of Subjects	Age (yrs)	Distance Run per Week (km)	Mass (kg)	Height (m)	Pain
Control	17	28.1 ± 5.7	30.8 ± 17.9	69.9 ± 8.7	1.80 ± 0.07	0.0
Iliotibial Band Syndrome	17	33.5 ±6.6	31.4 ± 21.7	76.7 ± 5.7	1.79 ± 0.06	4.9 ± 1.6
p-value	-	0.628	0.362	0.626	0.638	-

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TABLE 2

Group Differences in Strength, Flexibility, and Kinematics

Test	Controls	ITBS	Average Difference between Groups	Minimal Detectable Change	Statistical Significance	Effect Size
Hip						
Ober's Test (°)	18.8 ± 4.0	17.6 ± 4.7	1.2	3.8	p=0.03	0.275
Hip Abduction Strength (Nm/kg)	17.8 ± 3.6	17.7 ± 4.1	0.1	3.4	p=0.14	0.026
Hip Adduction (°)	8.6 ± 4.1	7.9 ± 2.6	0.7	1.3	p=0.59	0.204
Hip External Rotation Strength (Nm/kg)	7.8 ± 1.2	6.6 ± 2.2	1.2	1.6	p=0.03	0.677
Hip Internal Rotation (°)	9.6 ± 5.2	13.3 ± 6.6	***−3.7***	2.3	p=0.03	0.623
Knee						
Knee Adduction (°)	3.7 ± 3.6	7.3 ± 2.8	***−3.6***	1.3	p=0.001	1.117
Knee External Rotation (°)	7.5 ± 7.4	12.2 ± 7.8	***−4.7***	3.0	p=0.11	0.618