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Examining Biomechanical and Anthropometrical Factors as Contributors to Iliotibial Band Friction Syndrome

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This study was conducted in an attempt to determine if the biomechanical parameters thought to predict iliotibial band injury could accurately differentiate between iliotibial band (IT band) injured and healthy runners. 20 injured and 20 healthy runners were tested. Injured subjects were randomly assigned into groups of ten (INJ-1 or INJ-2). Ten healthy runners acted as controls (CON) and ten healthy (EXP) subjects trained for 1 week with a 1.27 cm felt heal pad in the shoe of their longer leg. All subjects completed a runner's questionnaire, and 13 lower extremity anatomical measurements, four clinical lower extremity assessments, and 2D kinematics from the sagittal and frontal planes during treadmill running were recorded. Comparison of kinematic values between INJ-1 vs. CON and INJ-2 vs. EXP indicated the INJ-1 group had a greater knee flexion angle than the CON group. No other direct comparisons revealed statistically significant differences between groups, nor did a discriminant function based on nine anatomical measurements or analysis of the running questionnaire responses. It was not possible to clearly distinguish between the healthy and injured runners of this study based on the biomechanical factors most commonly thought to predispose individuals to iliotibial band injury.

Keywords: Iliotibial band friction syndrome, functional leg length discrepancy, anthropometer, knee flexion angle, internal tibial rotation

Introduction

Iliotibial band friction syndrome (ITBFS) has been noted as one of the 10 most common medically treated running injuries (James, Bates, & Osternig, 1978; Taunton, Ryan, Clement, McKenzie, Lloyd-Smith, & Zumbo, 2002). The iliotibial band (IT band) is a longitudinal thickening of the lateral distal deep fascia latae and the superficial one quarter of the fibers of the gluteus maximus (James, Bates, & Osternig, 1978). It goes from the anterior superior iliac spine and inserts into Gerdy's tubercle on the lateral tibia, acting as a lateral knee stabilizer. One thought is that at complete knee extension the iliotibial band lies anterior to the lateral femoral epicondyle, as the knee flexes to 30° the gluteus maximus pulls the band posterior to rest atop the lateral femoral epicondyle (Anderson, 1991). During a running cycle as the knee flexes and extends, the IT band continually moves from an anterior to posterior position with respect to the epicondyle (Anderson, 1991). Pain at the injury site occurs when the friction from the band rubbing over the bony prominence causes an inflammatory response in the IT band, periosteum of the underlying bone, and/or bursa between the bony prominence and the fascia (Lindenberg, Pinshaw, & Noakes, 1984; Noble, Hajek & Porter, 1982). Fairclough et al. (2006) suggest in their study that IT Band injury arises because of increased compression of highly innervated fat tissue deep to the band yet superficial to the epicondyle. Their MRI scans indicate at 30° of knee flexion the band moves medially towards the epicondyle (Fairclough et al., 2006).

Researchers have investigated healthy and IT band injured runners for anatomical and lower extremity running kinematics differences in clinical and research settings (Anderson, 1991; Grady, O'Connor, & Bender, 1986; McNicol, Taunton, & Clement, 1981; Messier & Pittala, 1988; Messier, et al., 1995; Noble C., 1980; Orava, 1978; Orchard, Fricker, Abud, & Mason, 1996; Renne, 1975; Sutker, Barber, Jackson, & Pagliano, 1985). Anatomical factors included knee, forefoot and rearfoot alignments, Q-angle, IT band tightness, and size of the lateral femoral epicondyle. (Anderson, 1991; Grady et al., 1986; McNicol et al., 1981; Messier & Pittala, 1988; Messier et al., 1995; Noble C., 1980; Orava, 1978; Orchard et al., 1996; Renne, 1975; Sutker et al., 1985). Studies involving the leg length discrepancy (LLD) measurement have opposing views of its contribution to IT Band pain: (a) the LLD did not contribute to a person's IT band pain, and (b) 6 of 52 IT band cases experienced pain in the longer leg (Grady et al., 1986; Lindenberg et al., 1984; McNicol et al., 1981). Rearfoot motion and knee flexion angle of IT band injured legs have been compared to uninjured legs; but again the studies have opposing views, thus posing a challenge when determining whether kinematic differences between the healthy and injured leg motion was a causative factor of ITBFS (Messier, et al., 1995; Orchard et al., 1996). Investigators further purported that hill running increases IT band pain, yet no known research has evaluated the running kinematics during graded running for runners with IT band injury (Orchard et al., 1996).

The goal of the current study is to collect descriptive, anthropometric, and kinematic data on injured and healthy runners since running injuries are usually multifactorial (James, Bates, & Osternig, 1978). If current treatments of IT band syndrome are based on clinical findings, then determining the extent to which the clinical factors (i.e. leg length discrepancy) affect the injured runner's kinematics would be important for future clinical treatments. In the current study, it was hypothesized that the IT injured runners would have a larger LLD value than the healthy runners would and the pain would occur in their longer leg. Moreover, the LLD would cause the IT injured runners to have different running kinematics (i.e., decreased knee flexion angle and increased internal tibial rotation values) when compared to their healthy running counterparts. The decreased knee flexion angle would cause the band to stay in a position over the lateral femoral epicondyle thereby increasing the stretch of the band. Also, the increased internal tibial rotation would cause an increased stretch on the IT band since the tibia is the distal insertion site. This increased tension of the band across the lateral epicondyle would result in a greater normal force at the site therefore increasing the friction present between the IT band and the bone. Hamill, Miller, Noehren, and Davis (2008) found that IT band injured runners had a greater strain rate of the IT band on their affected leg compared to the non-affected leg for healthy age and training matched controls. If these results were found then or thoses, specific strength training or range of motion training protocol treatments could be used in the treatment of IT band runners with the goal of having them return to running with less time away from the sport.

Method

Participants. Forty participants volunteered for the study, 20 people with IT band injury (INJ: 12 females and 8 males) and 20 people without IT band injury (HEA: 9 females and 11 males), who had run 13 kilometers per week for at least one consecutive year. All subjects were between 18-55 years old from a local running community whose characteristics are presented in Table 1. The INJ and HEA groups were matched for age, height, weight, years running, self-reported training pace, and weekly running mileage.

All INJ runners had a positive Noble Compression test on their injured leg (Noble C., 1980; Noble, Hajek, & Porter, 1982). The HEA participants had no previous history of medical or orthopedic conditions in the last year causing a reduction in training mileage or that contraindicated volunteering for the study. The 20 HEA runners were randomized into two groups of 10 participants, a control group (CON) and an experimental group (EXP).

Procedure. Prior to participation, all individuals read and signed a university Institutional Review Board approved informed consent. All participants completed a training questionnaire. After completing study paperwork, researchers recorded anthropometric measurements and the running kinematics of the volunteers.

Lower Extremity Anatomical Measurements. An anthropometer (Seritex Inc., New York, NY) was used to measure height, functional leg length, iliocristale height, trochanteric height, tibial height, midpatellar height, medial malleolus height, lateral malleolus height, bimalleolar breadth, epicondyle breadth, bispinous breath, hip breadth (within 0.1-cm) as defined by previous researchers (Gordon, Churchill, Clauser, & Bradtmiller, 1989). Important to the hypothesis and the kinematics comparisons was the functional leg length defined as a straight line from the plane on the bottom of the foot passing across the greater trochanter of the extended leg to the back of the seated subject (Gordon et al., 1989). The functional leg length measure included the limb's entire length particularly as it functions during running. During the measurements subjects were seated and instructed to keep their feet shoulder width apart with their weight equally distributed on both feet. Weight was measured using a digital scale to the nearest 0.1-kg. An extended arm goniometer was used to measure Q-angle to the nearest 1.0°. One investigator performed all the anatomical measurements using the goniometer, anthropometer, and scale for each subject.

Kinematic Data Collection. Participants were fitted with light reflecting markers over the greater trochanter, lateral joint line of the knee, and lateral malleolus. An orthogonal set of markers was attached to the tibial tuberosity of the same leg to measure transverse tibial rotation according to the procedures of previous researchers (Cornwall & McPoil, 1995). The INJ group had all markers placed on the injured leg, while CON and EXP groups had the set placed on the longer leg. However, if no LLD was present for the CON or EXP subjects, then markers were placed on a randomly assigned leg. Subjects wore their own running shoes; a procedure similar to that used in previous research measuring ITBFS running kinematics (Messier & Pittala, 1988; Messier, et al., 1995; Orchard et al., 1996).

A Pacer R-9 treadmill (Pacer Industries, Inc., Dallas, TX) was used during kinematic data collection sessions with speed and elevation calibrated prior to the start of testing. Each subject was allowed 10 minutes to warm-up and to adjust to treadmill running, during which the test training pace was established (HEA = 2.75 + 0.36 m/s and INJ = 2.67 + 0.28 m/s; $p = 0.43$). After the warm-up period, the subjects ran at the established pace for 3 minutes in each treadmill condition: uphill graded 5°, downhill graded 5°, and level ground 0°.

The order in which the subjects ran was randomized to control for order effects. During each treadmill condition, three ground contacts for the testing leg were collected, analyzed, and averaged to calculate representative kinematic results for each subject.

An LLD was imposed on the EXP subject using a 1.27-cm thick wool felt heel lift (Hapad INC., Bethel Park, PA, Figure 1) worn in the shoe of their longer leg. The longer leg was determined by functional leg length measures. The EXP subjects were instructed to wear the heel pad only when training for one week. After the week of training, each subject returned for a second visit to undergo video data collection with the heel lift. The EXP subjects reported no injuries while using the heel lift.

Sagittal Plane Kinematic Measurements and Analysis. The knee flexion angle was defined as the angle between the shank segment and the extrapolated thigh segment (Milliron, 1990). The knee angle at foot contact was recorded using an RCA-VHA (30 Hz) camcorder (Thomson Consumer Electric, INC., Indianapolis, IN) in the sagittal plane and perpendicular to the level treadmill condition. The left versus right side camera to treadmill distances were different since room configuration was limited. The video camera was placed 2.9 meters from the treadmill on the left side and 1.2 meters on the right side (Figure 2). Video data were analyzed using Hu-M-An ver. 1 (HMA Technologies, Inc., King City, ON).

Transverse Plane Kinematic Measurements. Transverse tibial motion was measured at 250 Hz using the recordings of the orthogonal marker set with a high speed Kodak® Motion Corder Analyzer (SR 500, Eastman Kodak Corporation, San Diego, CA) positioned 2.7 meters in front of the participants. The camera was perpendicular to the level treadmill condition. PEAK ver. 5.1.1 (Peak Information Technologies, Englewood, CO) analog and digital motion analysis software was used to digitize the high-speed video data. Algebra and trigonometry were applied to coordinates of each ball on the marker set to evaluate the deceleration phase of tibial rotation and the maximum tibial rotation (Cornwall & McPoil, 1995). Deceleration phase of tibial rotation is the difference between the rotation value at initial contact and the value at 22% of the stance phase (Hamill, Bates, & Knutzen, 1984; Hamill, Bates, Knutzen, & Sawhill, 1983). Maximum internal tibial rotation is the difference between the rotation value at initial contact and the value at the greatest degree of internal tibial rotation during stance.

Results

Runner's Questionnaire. INJ and HEA subjects self-reported asphalt, concrete, grass, track, and trails as their preferred choices for running surface. Both groups' training runs involved hills, intervals, and treadmill running. Some HEA and INJ subjects incorporated cycling, weight lifting, swimming, elliptical trainers, stairmasters, and running stadium steps into their training program. Responses to "When a subject decided to change running shoes," included every 4-12 months, every 200-600 miles, shoes feel or look worn out, and increased pain with an old pair of shoes.

Lower Extremity Anatomical Measurements. When comparing the LLD between the HEA (0.08 mm) and INJ (0.47 mm) groups there was no difference ($t(38) = 1.46$, $p = 0.14$). The means indicated that the left leg was longer for each group.

To determine the combined effects of all the anatomical measurements, a discriminant function analysis was performed. This analysis classified the 40 runners as either HEA or INJ based on the nine anatomical differences used to calculate the discriminant function. The values in Table 2 are a summary of the discriminant function and descriptive statistics for the lower extremity anatomical measurements. Sixty-five percent of the subjects were correctly classified, but the discriminant function was not at the level of significance ($p = 0.60$; Wilk's Lambda $\lambda = 0.80$). The structure matrix coefficients define the amount of influence a given factor has on the discriminant function.

Three injured individuals had inflammation on the lateral side of the affected knee causing the appearance of an enlarged lateral femoral epicondyle compared to the unaffected leg. A pre-post assessment of the EXP participants indicated that mild discomfort occurred in 6 of 10 runners, but IT band injury did not result following the one week of heel lift usage during training.

Running Kinematics. A separate 3 X 3 (group x treadmill running condition) analysis of variance (ANOVA) was performed for the knee flexion angle, deceleration phase of tibial rotation in stance, and maximum tibial rotation in stance. The SAS version 8.2 (The SAS Institute, Cary, NC) accounted for the unbalanced design of different sample sizes in each group.

Knee Flexion Angle. Knee flexion angle means and standard deviations are presented in Table 3. There was no group by treadmill running condition interaction ($F(2,37) = 0.36$, $p = 0.83$). There were differences in knee flexion angle among the three treadmill running conditions. Comparisons of means for each of the pair-wise group comparison using a Bonferroni ($\alpha = 0.05$) adjusted comparison provided evidence that the EXP group had a decreased knee flexion angle when compared to the CON group ($F(2,37) = 3.79$, $p = 0.03$).

Tibial Rotation. Deceleration phase of tibial rotation statistics are presented in Table 4. There was no group by treadmill running condition interaction ($F(2,37) = 0.55$, $p = 0.69$). There were no differences for this tibial rotation value among the three treadmill running conditions. There were no differences among the three groups ($F(2,37) = 0.67$, $p = 0.51$).

Maximum tibial rotation statistics are presented in Table 5. There was no group by treadmill running condition interaction ($F(2,37) = 1.48$, $p = 0.21$). There were differences in maximum tibial rotation among the three treadmill running conditions. There were no differences among the groups for maximum tibial rotation ($F(2, 37) = 0.48$, $p = 0.62$).

Discussion

The results of this study indicate that IT band injured runners and healthy runners, with or without an imposed LLD, having similar training regimen variables do not have differences in knee flexion angle at initial contact, tibial rotation in stance deceleration, or maximum tibial rotation in stance. Having no difference for the LLD value in this study agrees with the reports of the authors that had 56% of patients with a longer leg not experience IT band in the longer leg (Lindenberg et al., 1984). However, the current research information disagrees with others who reported that some patients do develop pain in the longer leg (McNicol et al., 1981).

The lower extremity anatomical measurements were measured using an anthropometer to determine if any of these descriptive variables, mainly differences between the right and left leg, would provide more information to differentiate between the HEA and INJ groups. Previous researchers have collected similar data on thousands of subjects to develop percentile ratings for numerous anthropometric measurements (Gordon et al., 1989). None of the lower extremity anatomical measurements used in this study provided clear information that would categorize a runner to be healthy or injured.

Researchers who have investigated knee flexion angle found that it increased for some IT band injured runners and decreased for other injured runners with the use of heel lifts (Jones & James, 1987; Orchard et al., 1996). Additionally, Miller, Lowry, Meardon, and Gillette (2007) found difference in knee flexion angle at initial contact during an exhaustive run between IT band injured and healthy runners. The intention of the current study was to investigate the knee flexion angle at initial contact during different treadmill running conditions and to determine if an injured runner or a healthy runner with an imposed longer leg would have decreased knee flexion angle specifically in the downhill running condition. The heel lift appeared to have caused this difference when comparing the CON to the EXP group, but there was no difference between the INJ and the CON group or the EXP group. Finding no decreased knee flexion angle in the INJ group may indicate that the band is not resting over the lateral femoral epicondyle to produce an increased stretch for a longer period of time when compared to the CON group. The decreased knee flexion angle of the imposed longer leg disagrees with the researchers who investigated imposed LLD during walking and found increased knee flexion angles with an imposed LLD (Sutker et al., 1985). This decreased knee flexion angle may be explained by the difference between running kinematics and walking kinematics at initial contact.

Internal tibial rotation was measured in the current study since the tibia is the site of distal insertion of the IT band. Noehren, Davis, and Hamill (2007) found internal tibial rotation to be greater in IT band injured runners compared to a healthy age-matched control group during level ground running. If the tibia were to internally rotate more in an injured runner than a healthy runner, it may be concluded that the internal tibial rotation was causing a stretch on the IT band that causes pain to develop from increased compression. The current study's results do not support differences in internal tibial rotation for level, uphill or downhill running conditions. This discrepancy may have resulted from the current study's lack of 3D kinematics for the entire lower extremity, therefore the measures are not sensitive enough to detect the changes found by Noehren et al., (2007). However, there is still a need to measure 3D kinematics, kinetics, and muscle activities of ITBFS injured and control runners during uphill and downhill running conditions to have a clear picture of the running variable differences between the injured and healthy groups. This thought is further indicated by Hamill et al., (2008) who found that the strain rate is greater in IT band injured female runners when compared to healthy matched runners, which represented the same subject group measured by Noehren et al., (2007).

It was intended in the current study that the treadmill running conditions would simulate over ground running. Nigg et al., (1995) found that runners would alter their landing to be more flatfooted to maintain balance on the treadmill. Three INJ runners and 4 CON and EXP runners landed in more of a flatfooted position. Therefore, if any subjects changed their running form between over ground to treadmill running conditions, it may not have been detectable among the three groups of runners.

Although the functional leg length measurement differences were not significant in the current study, other researchers commented that LLD might result from a weakness of pelvic region muscles (Fredericson et al., 2000). If an LLD were present in an IT band injured subject, it may cause a lateral tilt of the pelvis as hypothesized by Anderson (1991); thus investigating kinematic and kinetic variables of pelvic motion would be informative for providing treatment to these injured runners. The role of the pelvic anatomy in this injury is supported by the work of Fredericson et al., (2000) who found that the hip abductor torque was less for injured subjects than healthy subjects but improved as part of the rehabilitation process to support symptom-free running. In a follow up study, Fredricson and Wolf (2005) outlined a complete treatment and rehabilitation process for those with ITBFS incorporating exercises that use a biomechanical approach. The approach could be used for athletes with or without a LLD as a means to promote pelvic alignment during the running gait.

The lack of significant differences between INJ and CON or EXP groups is important since the current study examined factors that have previously been cited as etiological factors of IT band syndrome. Examining the contribution of other IT band syndrome potential factors may provide useful information for clinicians in terms of what they should focus on when treating the IT band injured runner or athlete. The ultimate goal is to determine what type of clinical solution can be implemented or developed to alleviate the pain associated with ITBFS. It appears that the combination of hip abductor muscle weakness, strain rate of the IT band during stance, and degree of internal tibial rotation during stance can be used prospectively or retrospectively to help determine the degree each contributes to an individual's IT band pain development in the case of an injury. Having the biomechanical, training, and anatomical data of a runner will ensure a medical team develops the best strengthening and flexibility programs for those who are injured so runners can return to sport with as little away time as possible.

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Table 1. Subject Characteristics by Group

	Group	
Variable	Healthy (n=20)	Injured (n=20)
Height (cm)	172.3 ± 8.8	169.1 ± 8.2
Weight (kg)	69.5 ± 12.2	64.9 ± 11.7
Age (years)	31.5 ± 13.5	31.9 ± 10.1
Yrs. Running (years)	8.3 ± 8.8	7.8 ± 6.9
Training Pace (m/s)	3.13 ± .46	3.04 ± .49
Training Pace (min/km)	5:16 ± 0:37	5:25 ± 0:38
Weekly Mileage (km/week)	36.3 ± 17.0	36.3 ± 17.5
Heel Strikers (runners)	16	17
Mid-foot Strikers (runners)	4	3

Table 2. A Summary of the Discriminant Function Analysis Distinguishing Between Injured and Healthy Runners.

	Wilks Lambda	Chi Square	df	Sign.
Function 1	0.803	7.35	9	0.6045
Structure	Standardized Matrix	Group Coefficients	(means: - sign indicates	
Measure Difference	HEA (n = 20)	INJ (n = 20)		
Funcitional Leg Length (cm)	0.494	0.656	-0.08	-0.47
Iliocristale Height (cm)	-0.256	-0.298	-0.19	0.01
Trochanteric Height (cm)	0.473	0.533	0.53	0.05
Epicondyle Breadth (cm)	-0.130	-0.026	0.14	0.18
Knee Height (cm)	0.301	0.248	0.44	0.24
Tibial Height (cm)	-0.154	-0.047	-0.06	0.03
Bimalleolar Breadth (cm)	-0.431	-0.406	0.08	0.16
Lateral Malleolar (cm) Height	-0.081	-0.116	0.08	0.05
Medial Malleolar (cm) Height	0.221	0.351	0.01	-0.06

Table 3. Knee Flexion Angle Means (SDs) in Three Treadmill Running Condition

	n	Level (deg)	Downhill (deg)	Uphill(deg)
Control Group	10	18 (5)	14 (4)	26 (5)
Injured Group	20	15 (4)	12 (5)	23 (5)
Experimental Group	10	13 (5)	11 (4)	22 (5)

Table 4. Deceleration Phase of Tibial RotationMeans (SDs) in Three Treadmill Running Condition

	n	Level (deg)	Downhill (deg)	Uphill(deg)
Control Group	10	6 (3)	5 (2)	7 (3)
Injured Group	20	6 (2)	6 (4)	6 (3)
Experimental Group	10	6 (2)	7 (4)	8 (3)

Table 5. Maximal Tibial RotationMeans (SDs) in Three Treadmill Running Condition

	n	Level (deg)	Downhill (deg)	Uphill(deg)
Control Group	10	15 (4)	13 (5)	14 (5)
Injured Group	20	14 (4)	12 (6)	16 (4)
Experimental Group	10	13 (2)	11 (3)	17 (3)

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Lara M. DUKE is currently a college instructor at Douglas College, New Westminster, British Columbia Canada and teaches Biomechanics, Motor Learning, and Conditioning classes. Her specialties in the sport field are anatomy of running injuries, sport biomechanics applications, and teaching video analysis preparation to coaching and PE specialist students. Lara strives to improve teaching of biomechanics concepts by encouraging students to explore the applicability of its concepts to sport and daily life activities.