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Iliotibial band syndrome: an examination of the evidence behind a number of treatment options

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Iliotibial band (ITB) syndrome (ITBS) is a common cause of distal lateral thigh pain in athletes. Treatment often focuses on stretching the ITB and treating local inflammation at the lateral femoral condyle (LFC). We examine the area's anatomical and biomechanical properties. Anatomical studies of the ITB of 20 embalmed cadavers. The strain generated in the ITB by three typical stretching maneuvers (Ober test; Hip flexion, adduction and external rotation, with added knee flexion and straight leg raise to 30°) was measured in five unembalmed cadavers using strain gauges. Displacement of the Tensae Fasciae Latae (TFL)/ITB junction was measured on 20 subjects during isometric hip abduction. The ITB was uniformly a lateral thickening of the circumferential fascia lata, firmly attached along the linea aspera (femur) from greater trochanter up to and including the LFC. The microstrain values [median (IQR)] for the OBER [15.4(5.1–23.3)me], HIP [21.1(15.6–44.6)me] and SLR [9.4(5.1–10.7)me] showed marked disparity in the optimal inter-limb stretching protocol. HIP stretch invoked significantly ($Z = 2.10$, $P = 0.036$) greater strain than the SLR. TFL/ITB junction displacement was 2.0 ± 1.6 mm and mean ITB lengthening was $<0.5\%$ (effect size = 0.04). Our results challenge the reasoning behind a number of accepted means of treating ITBS. Future research must focus on stretching and lengthening the muscular component of the ITB/TFL complex.

Iliotibial band (ITB) syndrome (ITBS) is the most common cause of lateral knee pain in athletes, occurring with a reported incidence as high as 12% in runners and up to 22% in military recruits (Jordaan & Schwellnus, 1994; Akuthota et al., 2002; Beynnon et al., 2003; Fredericson & Wolf, 2005; Fairclough et al., 2006; Ellis et al., 2007). ITBS also presents in athletes who participate in running, cycling, dancing, volleyball, tennis, football, skiing, weight lifting, and aerobics (Holmes et al., 1993; Messier et al., 1995; Orchard et al., 1996; Fredericson & Wolf, 2005; Fairclough et al., 2006; Ellis et al., 2007; Winston et al., 2007). It is also a common presentation in exercising adults, occurring in up to 15% in women and 7% of men (Segal et al., 2007).

The ITB as described in classical textbooks is a structure "over the lateral femoral aspect [where] fascia lata is compacted into a strong iliotibial tract . . ." (Gray, 1995). More current thinking however, focuses on the ITB as a discrete entity, passing from the iliac crest to the lateral (Gerdy's) tubercle of the tibia.

Patients with ITBS complain of pain along the lateral aspect of the knee, specifically at the lateral femoral condyle (LFC) (Ekman et al., 1994). It is often assumed that ITBS results from inflammation secondary to friction of the band across the lateral femoral epicondyle in flexion and extension (Orchard et al., 1996; Fredericson & Wolf, 2005; Pedowitz, 2005). Pain is most acute at 30° flexion, particularly affecting the more posterior fibers (Nishimura et al., 1997), and an accompanying bursitis is also described. The gross pathology and histopathology of ITBS has been described in tissue obtained at surgery (Noble, 1980). Features of chronic inflammation characterize the macroscopic appearance of tissue between the distal ITB and the LFC, but a true bursa does not appear to be characteristic of the pathology (Noble, 1980; Orava et al., 1991; Muhle et al., 1999). These findings have been supported by reports of magnetic resonance imaging findings in patients with ITBS (Ekman et al., 1994; Nishimura et al., 1997).

More recently a prospective study performed in a healthy athletic population found that a greater strain rate was seen in the ITB of those athletes who developed ITBS when compared with those who did not (Hamill et al., 2008). Numerous biomechanical risk factors have been proposed (e.g. genus varus, abnormal lower limb alignment, foot biomechanics, and body type, etc.) but well-conducted scientific studies to link these factors in a causal relation to the development of ITBS in runners are limited (Gunter & Schwellnus, 2004; Fredericson & Wolf, 2005; Fairclough et al., 2006; Ellis et al., 2007; Noehren et al., 2007).

A number of treatment modalities have been suggested for the management of ITBS. These include rest, pool running, reducing the amount and intensity of running, ice, stretching and strengthening of hip abductors, podiatric assessment, massage, and oral non-steroidal anti-inflammatory drugs (Noble, 1979; McKenzie et al., 1985; Kirk et al., 2000; Fredericson & Wolf, 2005; Fredericson & Weir, 2006; Ellis et al., 2007; Fairclough et al., 2007). There are only two published randomized controlled trials regarding appropriate treatment which suggest a role for injected corticosteroid ITBS (Gunter & Schwellnus, 2004) and a combination of an anti-inflammatory/analgesic together with physiotherapy (Schwellnus et al., 1991) in early (<2 week duration) ITBS. A consensus of opinion regarding best practice in the treatment of ITBS has however not been reached.

Given the ambiguity surrounding etiological factors for ITBS, the authors noted the relative lack of evidence-based treatment of ITBS. We have undertaken a novel cadaver-based study coupled with an *in vivo* biomechanical analysis of ITB strain during movement to investigate both the mechanism of proposed etiological factors, and examine the anatomical principles upon which a number of the traditional treatments of ITBS are based. Our hypothesis is that a number of the traditional treatments aimed at local inflammation and stretching the ITB derive from an incorrect understanding of the relevant anatomy and pathology.

Materials and methods

This investigation was composed of three independent sub-experiments in an attempt to answer the proposed questions via a natural progression of research. The initial study consisted of mapping the anatomical landmarks and structure of the ITB. Based on these observations, the second experiment determined the location for a mechanical strain sensor and incorporated an assessment of three different proposed ITB stretches. These two experiments were performed using cadavers. The final *in vivo* study examined strain in the ITB during tensioning in professional athletes.

Study 1: Cadaveric anatomical studies of ITB

Cadaveric specimens

Twenty adult, formalin-fixed cadavers were examined (age: 79 ± 12year, height: 1.66 ± 0.14 m, body mass: 69.4 ± 14.9 kg). Cadavers were preserved with standard formalin embalming fluid under routine process. The Department of Anatomy and Cell Biology, University Melbourne supplied all material. Information on age, gender, and cause of death was provided in accordance with the University of Melbourne Human Ethics Committee approval of applied and clinical investigations utilising cadaver tissues. Information regarding occupational history or previous physical activity levels was not available.

Cadaveric manipulation

Limb alignment was assessed by measuring Q angle with an angle of $<13^\circ$ (male) and $<18^\circ$ (female) confirming a normal configuration (Peeler et al., 2005). All limbs were fully flexed at hip and knee before positioning in extended, supine anatomical position. Dissection was performed initially in prone then supine positions, to allow removal of all skin and subcutaneous fat from the lower limb. Superficial attachments of the fascia lata and ITB were noted and recorded.

Outcomes

Deep dissection was then performed to investigate:

1. Origin of the ITB and the relationship to Tensae Fasciae Latae (TFL),
2. Location of the insertion of Gluteus Maximus into the ITB,
3. Location of the longitudinal attachment of ITB to the linea aspera,
4. Site of attachment of ITB to the LFC.

Study 2: Cadaveric ITB strain

Subjects

Five unembalmed fresh-frozen cadavers (age: 76 ± 10year, height: 1.74 ± 0.08 m, body mass: 73.4 ± 18.6 kg) were supplied by Department of Anatomy and Cell Biology, University of Melbourne provided in accordance with the University of Melbourne Human Ethics Committee approval of applied and clinical investigation using cadaver tissues. All cadavers were thawed for 24–36 h at 4 °C before testing to ensure complete thawing.

Cadaveric manipulation

The cadaver was positioned supine in the anatomical position on a metal dissection table. The three tests performed are shown in Fig. 1:

1. Control Variable – Straight leg raise to 30° [SLR (Charnley, 1951)],
2. Experimental Variable 1 – Modified Ober test (Ober, 1936) (OBER), and
3. Experimental Variable 2 – Hip flexion, adduction and external rotation, with added knee flexion (HIP).

The hip was maintained in the anatomical position by applying load superior to the greater trochanter on the contralateral limb. External loading was applied to the knee by the examiner to force hip adduction, and this was set at 100 N using a manual muscle tester controlled by the examiner. All stretches were held in position for 30 s, separated by a one-minute interval. All tests were performed on both limbs of each cadaver. Detached fascia specimens subjected to controlled loading showed little evidence of plastic deformation given the rest intervals (1 min) employed. Pre-stretching of all

Fig. 1. Each of the three testing positions. (a) Straight leg raise to 30° (SLR): The patient has their leg raised with the knee extended. (b) Modified Ober test (OBER): The patient lies on their side, the thigh next to the bed is flexed to obliterate any lumbar lordosis. The upper leg is flexed at the knee, the hip is stabilized and the leg is widely abducted and extended at the knee. If there is an abduction contracture the leg will remain passively abducted. (c) Flexed knee hip flexion and adduction, with the examiner controlling for external loading (HIP).

tested limbs was performed in an attempt to ensure that this deformity was minimized. Randomization of stretching was precluded due to the technicalities of strain gauge placement protection during dynamic maneuvers. Accordingly the SLR and OBER were performed first and last as the least and most perturbing stretches.

The SLR test, which replicates the joint angles occurring during heel contact in human locomotion, was included as a control variable. This allowed for the determination of strain occurring during the two experimental tests, which were ITB specific stretching exercises, which does not occur during typical human locomotion.

Strain assessment

Insulated, 10 mm, 120 Ω foil-type microstrain gauges (BCM Sensor Technologies, Antwerp, Belgium) were attached to the external surface of the ITB using a gauge specific cyanoacrylate adhesive (TML, Tokyo, Japan) before the performance of the ITB stretches. Data were acquired at 50 Hz via a USB-based CompactDAQ system, and was normalized and calibrated using a combination of Signal Express 2.0 and Labview 8.5 software (National Instruments, Austin, Texas, USA). This strain acquisition protocol has been found in a separate study performed in our laboratory to produce a high ($r > 0.90$) correlation with gold standard force/displacement measures of tissue, and to have a satisfactory level of repeatability (ICC: $R = 0.76$).

The sensor was placed 8 cm proximal to the lateral femoral epicondyle, ensuring it was undisturbed during maneuvers, and assessed the longitudinal strain on the superficial surface of the ITB. The peak strain value during each test, which consistently occurred immediately after the testing position was assumed, was then determined using a custom written Labview analysis program (National Instruments, Austin, Texas, USA). The data obtained from the gauges in this study do not provide the actual magnitude of strain in percentage terms, as they have not been calibrated for the tissue that they are joined to. However, the results do provide a relative measure of strain in each of the three stretching protocols, allowing for an accurate comparison of the relative stretch occurring in the ITB during each of the tests. Previous studies have implanted buckle (Barker et al., 2004) or linear displacement gauges (Kogler et al., 1999; Coppieters et al., 2006; Alshami et al., 2007) into the fascia. While these sensors provide many benefits, including pre-calibrated displacement and ease of use, their limited ability in detecting dual-axis strain (in this case longitudinal and bending) restricts their application in situations where the transfer of strain may not be uni-axial. In addition, because the stretches incorporated in this study consist of complex, non-linear movements, the minute thickness of foil-type strain gauges securely and non-invasively attached to the fascia provide the benefits of reduced potential for tissue deformity and the consequent measurement error during the trials. It is important to note that the microstrain (me) results reported in this study are based on the manufacturers calibration factors, performed on rigid metal during mechanical testing. Therefore, our reported data does not provide a definitive true strain value, however, as this study was of a within-subject test–retest design the values recorded from the strain gauge allowed for a direct comparison of the results for each stretching intervention.

Data analysis

Statistical analyses were performed comparing each testing procedure. Multiple Wilcoxon signed-rank tests at a significance threshold of $P < 0.05$ were performed for each combination of the testing protocols (SPSS, Chicago, Illinois, USA).

Study 3: *In vivo* measurement of ITB displacement

Subjects

Nineteen professional rugby league players (mean age: 19.00 ± 0.5 years, mean height: 1.83 ± 0.07 m, mean body mass: 90.7 ± 8.8 kg) volunteered to participate in this study. The University of Melbourne Human Ethics Committee granted ethical approval.

Testing protocol

In an attempt to assess whether stretching does occur in the ITB, ultrasound assessment of the TFL/ITB aponeurosis interface was performed during a functional task designed to induce strain in the ITB. This task was a maximal voluntary contraction (MVC) of the TFL, which when stretching occurs, should invoke a shortening of the muscle and consequent lengthening of the ITB. This would produce a proximal shift in the TFL/ITB interface, which would be evident visually during the ultrasound assessment of the task. This protocol has been used extensively in assessment of muscle/tendon interfaces, particularly of the gastrocnemius/Achilles tendon (Magnusson et al., 2003; Arampatzis et al., 2007).

The subject was instructed to lie on their right side on a plinth, with their hips at 180° extension. The subjects then abducted their left leg to a position horizontal with the ground. A manual muscle tester was used to weigh the limb in this position, providing the force level necessary to resist gravity. A custom-made leg cuff and rigid chain were then used to secure the subjects limb to a load cell mounted on the floor, which allowed for an isometric hip abduction with the limb parallel to the ground to be performed. During this test the subjects were required to maintain contact of their heel with a vertical guidepost, in an attempt to isolate the contraction primarily to the TFL. The movement consisted of the subjects lifting their limb to the horizontal position, deemed the baseline level, holding the limb in this position for three seconds and then performing a three second MVC. During the test a 10 MHz, 38 mm linear ultrasound probe (Mindray DP-6600, Shenzhen, China) was fixed to the skin directly superior to the TFL/ITB insertional junction. The excursion of this junction was recorded throughout the entire test, providing an indirect measure of the elasticity of the ITB. The displacement of the junction from the baseline position to the position of peak force was measured using an image analysis program (ImageJ v. 1.36b, National Institute of Health, Bethesda, MD, USA). This method replicates previous anatomical junction studies performed in our laboratory (Bryant et al., 2008). Three MVC tests of the left limb of each subject were performed, separated by a 30 s rest interval.

Data analysis

The one-tailed nature of the experimental protocol meant that even minor shifts in the anatomical landmark would create positive results for ITB displacement. Therefore data analysis was limited to assessments of the magnitude of the effect size using the Cohen's d equation with the initial resting length as the measure of standard deviation. An estimation of the strain occurring in the ITB was performed by measuring the length of the ITB using callipers, based on the mapping performed in Study 1, which thus designated the initial length of the ITB. The displacement of the junction was then added to this initial ITB length to create a measure of ITB length at MVC. The effect size of the percentage difference in length, deemed the ITB strain, was then calculated. The strain occurring in the ITB was then determined using the equation:

$$\text{ITB strain}(\%) = ((L_{\text{MVC}}/L_{\text{i}}) - 1) \times 100$$

where L_{MVC} = ITB length at MVC and L_{i} = ITB length at rest.

Results

Study 1: Cadaveric anatomical studies of ITB

Our anatomical findings confirmed that the ITB is in fact a thickening of the facia lata, which completely envelopes the leg. In all cases it was connected to the femur along the linea aspera from the greater tronchanter (by the intermuscular septum) to, and including, the lateral epicondyle of the femur by coarse fibrous bands. We failed to demonstrate a bursa interposed between the ITB and distal lateral femur on a single cadaver. The TFL muscle was completely enveloped in fascia, its origin formed by fascia lata arising from the iliac crest. TFL inserted directly into ITB, the latter structure behaving as an elongated tendon insertion of TFL. A substantial portion of Gluteus Maximus inserted directly into ITB, independently of the portion of muscle that inserts into the greater trochanter. These findings are shown in cadaveric form in Fig. 2 and schematically in Fig. 3.

Study 2: Cadaveric ITB strain

The microstrain (me) values [median (IQR)] for the OBER [15.4(5.1–23.3)me], HIP [21.1(15.6–44.6)me]

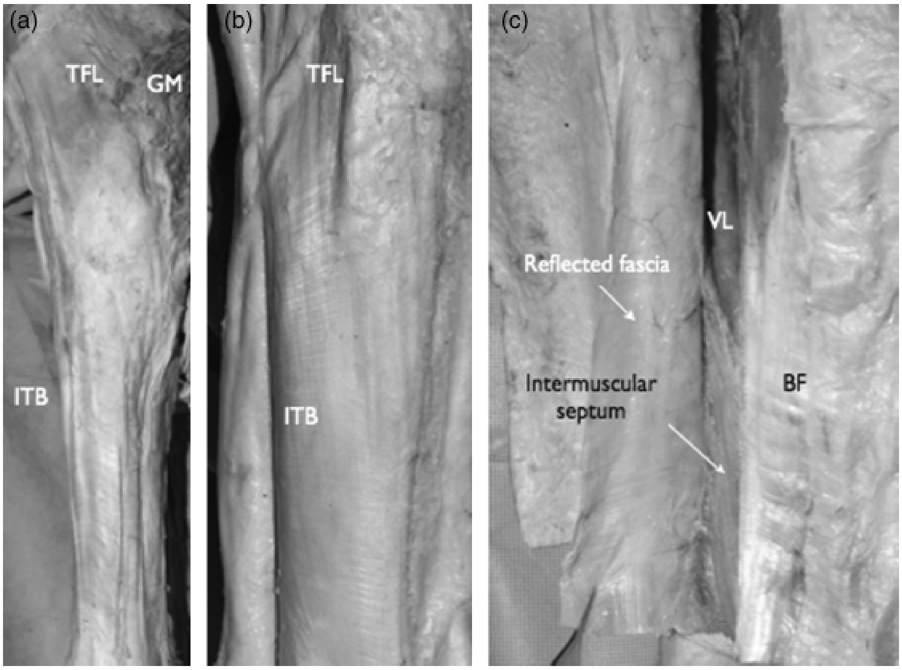

Fig. 2. Dissected specimens of the iliotibial band on the left leg viewed posteriorly. (a) The circumferential nature of the fascia lata is demonstrated, the position of iliotibial band (ITB) is shown. Tensae fasiae latae (TFL) is completely enveloped in fascia, the fascial insertion of Gluteus Maximus is also highlighted. (b) The iliotibial band (ITB) as a lateral thickening of the fascia lata rather than a distinct entity. (c) The fascia lata dissected to reveal the intermuscular septum attaching the iliotibial band to the femur, separating vastus lateralis (VL) from biceps femoris (BF).

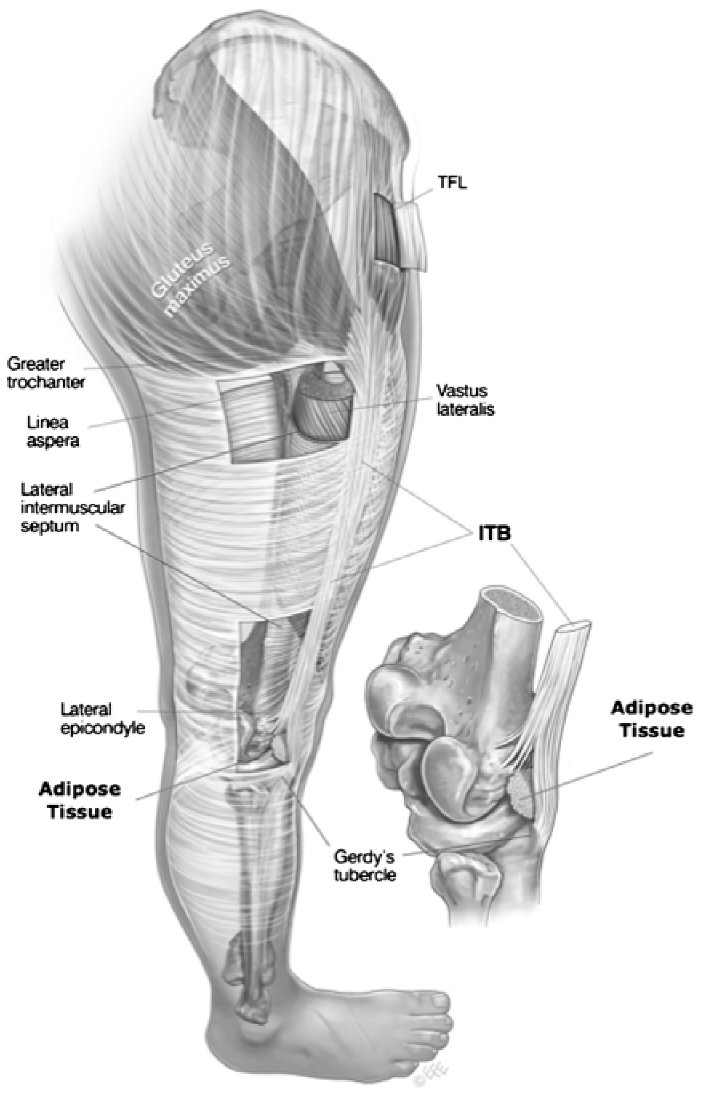

Fig. 3. A schematic representation of the anatomy of the iliotibial band (ITB). TFL, tensae fasciae latae; ITB, iliotibial band.

and SLR [9.4(5.1–10.7)me] showed a marked disparity in the optimal inter-limb stretching protocol. These peak intra-limb strain values occurred during the OBER, HIP or SLR test in three, four and two of the limbs respectively. Statistical analysis revealed that the HIP stretch invoked significantly ($Z = 2.10$, $P = 0.036$) greater strain than the SLR trial. No other significant differences were observed. These results are provided in Fig. 4.

Study 3: *In vivo* measurement of ITB displacement

The TFL/ITB junction displacement during the MVC was 2.0 ± 1.6 mm. The mean ITB length was 87.7 ± 4.6 cm. This resulted in a mean strain of 0.23 ± 0.18% strain. This negligible change in length occurred despite a mean hip abduction force of 235.6 ± 58.3 N.

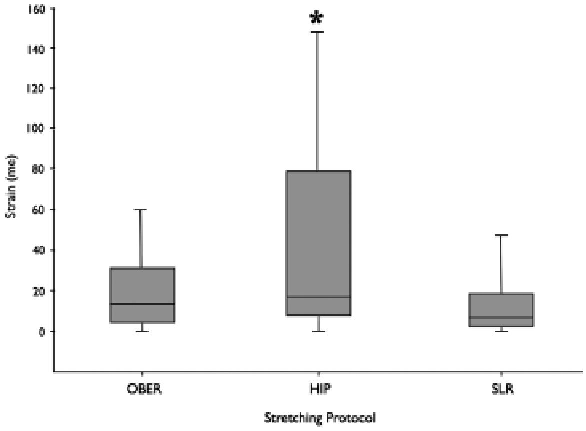

Fig. 4. Strain measured in the iliotibial band (ITB) during three different testing protocols. *Significant ($P < 0.05$) increase in strain during the HIP stretch in comparison with the SLR. OBER, Ober's test; HIP, hip flexion, adduction and external rotation; SLR, straight leg raise.

Discussion

Many of the traditional treatments for ITBS are based on the presence of a bursa between the ITB and the LFC, an ability to stretch the ITB, and the development of friction between the ITB and the LFC due to transverse motion. Our findings challenge these anatomical and pathological principles. Two of the common treatments of ITBS focus on treating local inflammation of the distal ITB and putative "bursa" and stretching the ITB (Noble, 1980; Barber & Sutker, 1992; Fredericson & Weir, 2006). The effectiveness of these two modalities should be questioned given the lack of support for the presence of a lateral bursa and the low magnitude and disparate strain occurring during stretching and MVC found in this study.

In regard to treatment of the "bursa" this routinely utilizes non-steroidal anti-inflammatory drugs or corticosteroid injection in the belief that a bursitis or local inflammation is the basis of the condition (Barber & Sutker, 1992). Our gross anatomical studies failed to demonstrate a bursa interposed between the ITB and distal lateral femur on a single cadaver. These findings correlate closely with the works of Fairclough et al. (2006, 2007), who have suggested that a richly innervated and vascularised loose connective tissue (containing pressure-sensing pacinian corpuscles), represents the pain generating structure in the area. This is also suggested by the surgical specimens and imaging findings previously discussed (Orava et al., 1991; Nishimura et al., 1997). Local inflammation in the area may be related to compression of this connective tissue (Fairclough et al., 2006).

Physiological fibrous bands were found to extend from the ITB to the LFC confirming the findings of Evans (1979) and Fairclough et al. (2007). These bands, and the fact that the ITB is a lateral thickening of the circumferential fascia lata prevent lateral movement over the condyle, result in the "friction" usually reported unlikely from an anatomical standpoint.

While reducing the inflammatory response may be useful in controlling acute symptoms, addressing the underlying biomechanical basis is more likely to result in long-term benefit. Current recommended strategies aimed at stretching the ITB have been tested in this study (McAtee & Charland, 2007).

Our anatomical studies also highlighted some important structural characteristics central to understanding the difficulties in stretching the ITB. The longitudinal and firm attachment (0.3 mm average thickness) of the ITB to the full length of the femur means that the potential for physiological lengthening is limited. This would appear at odds with a number of authors, which have stretched (Yinen, 1997; Fredericson et al., 2002), and even quantified, the lengthening of the ITB (Fredericson et al., 2002). This is likely to represent an apparent, rather than true lengthening, related to the lengthening of TFL rather than the ITB itself.

Results from our ultrasound measurements provide *in vivo* proof that the ITB in fact stretches minimally during isometric contraction of TFL. The average length of ITB in subjects is 88 cm with the average measured movement representing a 0.2% increase in length during a MVC. In addition, ITB strain measurements during three ITB stretching maneuvers demonstrated that in the absence of muscle tone (in cadaveric subjects) the stretches exert a different strain on the ITB. Though of small magnitude, the strain generated by the HIP test [a cadaveric simulation of some of the more dynamic stretches such as Fredericson's "modified matrix exercise" (Fredericson & Wolf, 2005)] was significantly higher than the control test. These findings highlight the tensioning role of gluteus maximus (working synergistically with TFL) in ITBS, concurring with other studies noting the substantial contribution of gluteus maximus to the ITB (Fairclough et al., 2006, 2007).

There are a number of potential limitations in this study. The cadaveric work included here was performed on a much older age group, unlikely to partake in regular exercise. Information regarding occupational history or previous physical activity levels was not available. Given the age profile of the cadavers muscle bulk was not equivalent to fit healthy athletes. The measurement reliability of the Q angle in the supine position is only moderate (Olerud & Berg, 1984). In acknowledging these limitations we must point out that we studied the ITB in the absence of muscle tone, which allows us to comment on the ITB free of muscular influence. Study 3, which did require muscular involvement, was performed on elite rugby players, in whom the TFL muscle was a considerable structure. We also recognize that TFL contraction alone could not be assured in this test, the relative role of gluteus medius in abducting the hip between individuals was not measured. However, for the purpose of this study movement, or lack of movement of the ITB/TFL junction was measured accurately.

The findings reported in this study highlight the limited role lengthening of the fascial component (ITB) has in any lengthening of the ITB/TFL complex, which may instead result from a decrease in stiffness in the muscular components (TFL, gluteus maximus) of the system. The anatomical evidence for the current treatment regimens discussed previously appears insufficient. While local treatment measures may have role in temporarily easing symptoms, they appear to treat symptoms rather than cause. Given that it appears that the muscular component of the complex plays an important role in tensioning of the

ITB, treatment should be directed at TFL and gluteus maximus. Soft tissue therapy such as massage therapy or dry needling of myofascial trigger points may be more valid as these interventions are supported by this construct, however, well-designed randomized controlled studies on current, and proposed, management strategies in a pathological population are needed before any conclusion may be made.

Perspectives

This work revisits the anatomy of the iliotibial tract, combining gross anatomy with modern techniques for measuring strain and stretch in order to evaluate the evidence base for traditional treatment regimens. Our results suggest that measures aimed at treating local inflammation and stretching the ITB (Kirk et al., 2000; Fredericson & Wolf, 2005; Fredericson & Weir, 2006; Ellis et al., 2007) are based on an incorrect understanding of the relevant anatomy and pathology. Future studies must focus on the efficacy of treatment of the muscular component of the ITB/TFL complex. Soft tissue measures such as massage and dry needling may be utilized to decrease muscular stiffness and effect a functional lengthening of the complex.

Key words: Iliotibial band syndrome, treatment, anatomy, sports injury.

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