BIOMECHANICAL INJURY PREDICTORS FOR MARATHON RUNNERS : STRIDING TOWARDS ILIOTIBIAL BAND SYNDROME INJURY PREVENTION

John M. MacMahon, Ajit M. Chaudhari and Thomas P. Andriacchi
Stanford Biomotion Laboratory, Stanford University, Stanford, California

The purpose of this study was to prospectively analyze a large group of marathon runners (n=20) and test for biomechanical determinants of running injuries. The opportunity to prospectively follow runners of organized marathon training teams allowed for testing of the hypothesis that functional biomechanics may lead to iliotibial band syndrome (ITBS). Each runner was gait tested prior to developing any injuries. Injury predictors were generated by comparing those legs which eventually got ITBS injuries (n=7) with those legs that were injury free (n=33). Higher peak hip adduction moments ($p<0.05$) and higher angular impulses adducting the hip during stance phase ($p<0.005$) were found to be significant predictors of ITBS. With this prognostic test as a benchmark, training and coaching may produce dynamic injury prevention.

KEY WORDS: injury prediction, injury prevention, running injuries, iliotibial band, training techniques

INTRODUCTION: The rigor of the marathon is legendary. In 490 BC, the runner Pheidippides ran from Marathon with news of the Greek victory over the Persians, stood on the steps of the Acropolis in Athens and shouted, "Rejoice, we conquer!" and then dropped dead. Less severe injuries await today's marathoner. Nonetheless, marathon running is growing in popularity around the world. With the global dose of Olympic glory about to be dispensed in Sydney this summer, this trend should be expected to increase.

Many of these running injuries are due to the repetitive nature of training. Iliotibial band syndrome (ITBS), anterior knee pain, shin splints, stress fractures and plantar fasciitis are some of the most common overuse running injuries, with the ITBS injuries accounting for 12-21% of the knee injuries (Ballas, Tytko, & Cookson, 1997, Luter, 1984). Runners with ITBS often present with pain at 30º of knee flexion, the angle at which the iliotibial band is traversing the lateral epicondyle. Efforts to predict injury through anatomical characteristics have not been repeatable (van Mechelen, 1995, Wen, Puffer & Schmarlzried, 1998). Without understanding the biomechanical causes of ITBS the desired goal of injury prevention has little hope of success.

The purpose of this study was test the hypothesis that the biomechanics of running influences the generation of iliotibial band syndrome injuries. In particular, the adduction moment at the hip and its associated angular impulse are expected to be high in runners experiencing the symptoms of iliotibial band syndrome. Such a prognostic tool will help develop training methods that reduce the incidence of injury.

METHODS: All runners (N=20, Age 36.8$\pm$8.5, Wt (kg) 65.1$\pm$7.5) were recruited from organized marathon training teams. All runners were given access to an on-line survey to determine whether they were suitable for the study. Inclusion criteria was as follows:

1. Maximum Number of Marathons Completed: 2
2. Weekly Mileage Just Prior to Joining the Marathon Team: less than 20 miles/week
3. Major Injuries: no lower limb surgeries or significant soft-tissue injuries

The first two criteria isolated runners with two commonly accepted risk factors for injury: limited experience and increasing mileage (from less than 20 up to 40 miles/week in training) (Fredericson, 1998). The third criterion eliminated those who may have adapted gaits.

The runners were recruited from two marathon training programs. Each team engaged in a 5-month training schedule. The teams had similar schedules with respect to total mileage, peak mileage per week (~40 miles/week) and total number of runs. All runners were gait tested before the end of the second month of training (before injury) and less than two weeks before they ran the marathon (after injury). The runners were informed that they would not be given any feedback or allowed to examine the gait data.

Injury determination. All runners who joined the study were requested to maintain an active training log and an on-line log was developed and put at their disposal. The log recorded the date, course, cross-training, time (optional), relative speed, minutes stretched before run, warm down (yes/no), comments about the run, health professional visits (yes/no, if yes, why?), and experiences of pain (yes/no, if yes, describe). Runners were also interviewed verbally during their return gait test. Finally, 6 weeks after their marathon the runners were asked to fill out a questionnaire that directly asked if their training was affected by these common distance runner injuries: ITB (hip), ITB(knee), Achilles tendonitis, anterior knee pain, plantar fasciitis, stress fractures, and posterior tibial syndrome. Injury determination was based on the criteria that 3 consecutive training days had to be affected.
Gait acquisition. Gait tests were performed using a previously described six-marker retro-reflective system (Andriacchi et al., 1997) developed by CFTC using 120Hz Qualisys cameras and a Bertec force plate. The protocol consisted of a one-mile warm-up jog and 3 running trials for each leg.
Analysis methods. The statistical analysis was based on comparing the legs that became injured with those that did not. For each leg one pre-training running trial and one speed-matched post-training trial were chosen for comparison. The runners' legs (n=40) were separated into those that suffered ITBS injuries (n=7, avg. speed = 2.63 m/s) and those that did not (n=33, avg. speed 2.66 m/s). Since the pre-training trials were also pre-injury, these tests could be used to isolate predictors of ITBS injury. The comparison of the kinematics and kinetics of these sets of legs required using two-tailed heteroscedastic t-tests (Figure 1).

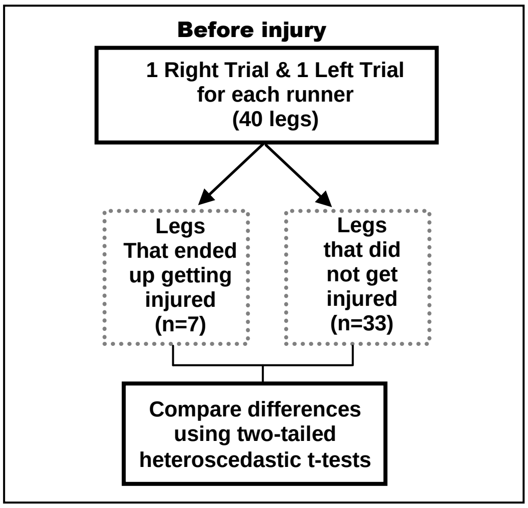

Figure 1 - Experimental design to investigate statistical significant differences between legs destined to get iliotibial band syndrome injuries and those that did not during marathon training.

Due to the role of the iliotibial band as a lateral stabilizer, the normalized peak adduction moments (%WT*HT) about the hip and the normalized angular impulse adducting the hip during stance phase (%WT*HT*(Stance time (s))) were hypothesized as the relevant kinetic measures for this injury. The normalized angular impulse adducting the hip during stance phase is a reflection of the overall load of the lateral structure.

RESULTS: There were dynamic gait differences found between the injured and uninjured legs. Throughout stance phase, the ensemble average hip adduction moments for injured and uninjured populations were remarkably different (Figure 2). The peak adduction moment ($p<0.05$) and the normalized angular impulse adducting the hip during stance phase ($p<0.005$) were both significantly higher in the legs that were bound for injury than those that were not (figure 3A-B~~1~~).

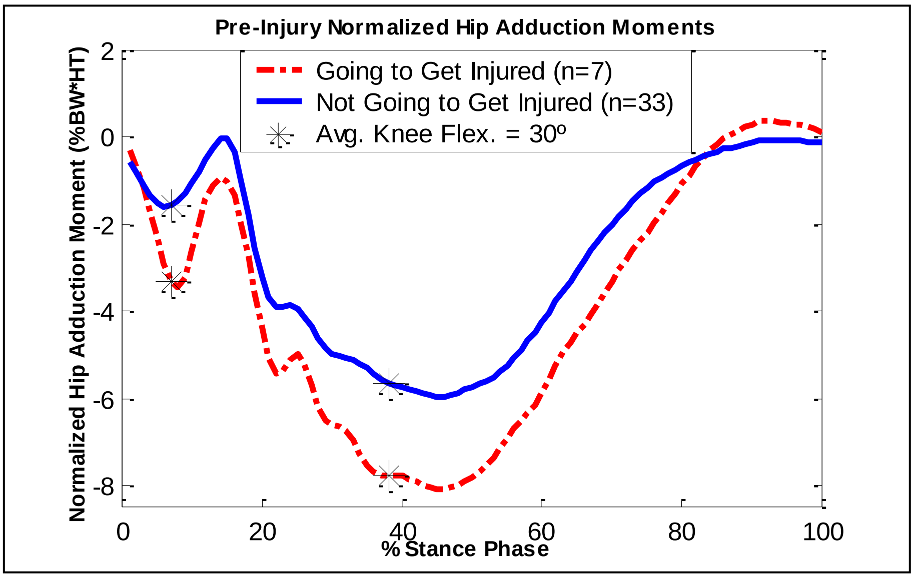

Figure 2 - Ensemble average normalized hip adduction moments for legs bound for IBTS injury (red-dashed: n=7) and those that were injury free (blue-solid: n=33). (Points of interest (✳): ITBS cases present with pain at 30º of knee flexion.)

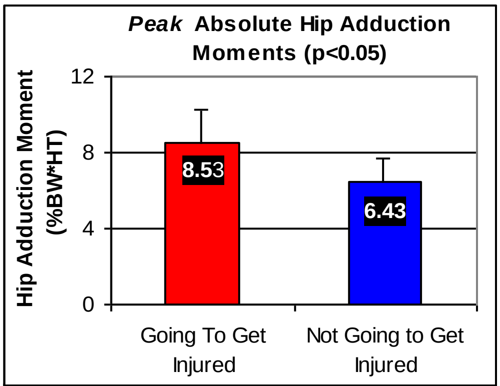

Figure 3A

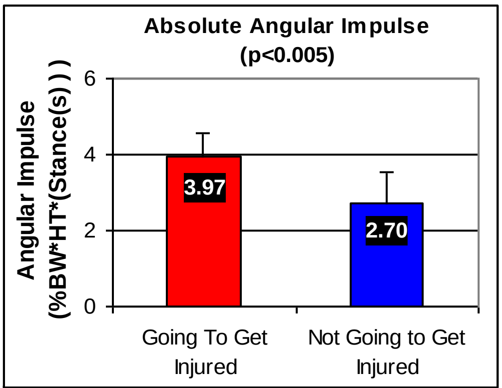

Figure 3B

Figures 3A & 3B - Peak absolute adduction moments (Fig. 3A) and normalized angular impulse during stance, in the direction of adduction of the hip, (Fig. 3B) for legs going to get ITBS injuries (n=7) and those not going to get injured (n=33). Please note the scale change from figure 3A to figure 3B.

DISCUSSION: From this research, biomechanical engineers, coaches and trainers now have a means of identifying those at risk for iliotibial band injuries. More importantly, injury prevention may be within reach. Given this information, it should be possible to identify an effective interventional approach to reduce the adduction moments in runners at risk.

As other researchers focusing on ITBS recovery have implied (Fredericson, 2000), the hip appears extremely important in ITBS injuries. ITBS cases present with tenderness associated with 30º of knee flexion. In this study, the ensemble average emphasizes the differences found near 30º of knee flexion in the hip adduction moment (figure 2).

When the angular impulse is higher in the ITB, the loading of the abduction muscles will subsequently be higher throughout stance. During longer runs, a runner with a larger angular impulse is likely to be more prone to fatigue. If so, the fatigued muscles may exacerbate the problem. One possible outcome of this may be further increased peak adduction moments and higher angular impulses during long runs, creating a positive feedback loop that results in injury.

A similar biomechanical approach may be able to uncover prognostic measures of other running injuries such as anterior knee pain, shin splints, and plantar fasciitis. Although there is nothing we can do for Pheidippides, we believe we are striding towards injury prevention for runners.

REFERENCES:

Andriacchi, T.P., & Mikosz R.P. et al. (1997). Musculoskeletal Dynamics, Locomotion and Clinical Applications, In V.C. Mow & W.C. Hayes (Eds.), *Basic Orthopaedic Biomechanics* (pp. 37-68). New York,:Lippincott-Raven.

Ballas, M.T., Tytko, M.D., & Cookson, A.T.C. (1997). Common overuse running injuries: diagnosis and management. *American Family Physician*, **55**(5), 2473-2480.

Fredericson, M., Guillet, M., & DeBenedictis, L. (2000). Innovative solutions for iliotibial band syndrome myofascial restrictions and hip abductor weakness can contribute to itbs but can be relieved by massage therapy, stretching, and strengthening. *The Physician and Sports Medicine*, **28**(2), 52-68.

Fredericson, M. (1998). *Sports Medicine,* **21**(1), 49-72.

Lutter, L.(1984). Runner's knee injuries. *Instructional Course Lectures,* **33**, 253-268.

Van Mechelen, W. (1995). Can running injuries be effectively prevented? *Sports Medicine*, **19**(3), 161-165.

Wen, D.Y., Puffer, J.C., & Schmalzried, T.P. (1998). Injuries in runners: A prospective study of alignment. *Clinical Journal of Sport Medicine,* **8**(3), 187-194.

Acknowledgements

Stanford Motion and Gait Analysis Lab and Kevin Rennert.