ORIGINAL RESEARCH

ALTERED SAGITTAL PLANE HIP BIOMECHANICS IN ADOLESCENT MALE DISTANCE RUNNERS WITH A HISTORY OF LOWER EXTREMITY INJURY

Pamela B. Lachniet, MD, PhD^{1,2,3}Jeffery A. Taylor-Haas, PT, DPT, OCS, CSCS⁴Mark V. Paterno, PT, PhD, SCS, ATC⁴Christopher A. DiCesare, MS, CSCS¹Kevin R. Ford, PhD, FACSM⁵

ABSTRACT

Background: Lower extremity overuse injuries, including bone stress injuries (BSI), are common in runners and may result in prolonged recovery and time off from running. Identifying risk factors for running-related overuse injuries may have a clinically relevant role in prevention of these injuries.

Purpose: The purpose of this study was to compare an adolescent and young adult population of male runners known to have a history of BSI with an injury-free cohort and retrospectively assess for kinematic differences that may differentiate the two cohorts

Study Design: Controlled laboratory case control investigation

Level of Evidence: Level 3

Methods: 25 male high school and collegiate cross-country runners were enrolled. Ten self-reported a prior history of BSI consisting of lower extremity stress fracture or shin splints/medial tibial stress syndrome and were categorized as injured (INJ). Fifteen self-reported no prior history of lower extremity injury and were categorized as uninjured (UNINJ). All runners were pain-free at time of testing. Runners ran at a self-selected speed on a treadmill with retro-reflective markers attached to thorax, pelvis, and each lower extremity segment. Three-dimensional kinematic calculations were made during stance phase (initial treadmill heel contact to toe off) and averaged over 20 steps. One-way ANCOVA was used to compare kinematic differences at the hip and knee between the INJ and UNINJ cohort.

Results: Runners in the INJ group demonstrated greater peak hip flexion during stance phase on both the right limb [INJ = $32.5^{\circ} (\pm 3.8^{\circ})$ vs. UNINJ = $26.9^{\circ} (\pm 4.6^{\circ})$; $p < 0.01$] and the left limb [INJ = $31.2^{\circ} (\pm 4.8^{\circ})$ vs. UNINJ = $26.8^{\circ} (\pm 3.1^{\circ})$; $p = 0.01$] when compared to the UNINJ group. No significant difference in step length or step rate between the INJ and UNINJ cohorts was noted when normalized to height and weight ($p = 0.39$ and 0.39).

Conclusions: The results of this study demonstrate increased peak stance phase hip flexion in a population of young adult male runners with a previous history of BSI. This association may represent an important preliminary finding in the development of a clinically relevant tool to identify risk of BSI. Due to the retrospective nature of this study, future prospective investigations are warranted to validate these findings to determine if these alterations are compensatory following an injury or predictive of a future injury.

Keywords: Bone stress injury, kinematics, running

¹ Division of Sports Medicine, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA.

² Division of Emergency Medicine, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA.

³ Anderson Hills Pediatrics, Cincinnati, OH, USA.

⁴ Division of Occupational Therapy & Physical Therapy, Cincinnati Children's Hospital Medical Center, Cincinnati, OH, USA.

⁵ Department of Physical Therapy, School of Health Sciences, High Point University, High Point NC, USA.

Financial Disclosure and Conflict of Interest: We affirm that we have no financial affiliations (including research funding) or involvement with any commercial organization that has a direct financial interest in any matter included in this manuscript.

CORRESPONDING AUTHOR

Jeffery A. Taylor-Haas, PT, DPT, OCS, CSCS

Coordinator, Division of OT/PT-Sports

Medicine and Orthopaedics

Cincinnati Children's Hospital Medical Center

MLC 11033, 3333 Burnet Avenue

Cincinnati, OH 45229

Phone: 513-636-3418

Fax: 513-636-2528

E-mail: Jeffery.Taylor-Haas@cchmc.org

INTRODUCTION

Injuries in the running population are common, with estimates of 17-79% of runners affected.¹ Of particular concern is the high rate of injuries in young athletes, with high school cross-country runners reported to have an annual incidence of injury as high as 17 per 1000 athletic exposures.² Overuse injuries involving bone, often referred to as bone stress injury (BSI), occur along a spectrum of disorders starting with stress reaction and progressing to stress fracture and complete bone fracture as the repetitive loading stresses on the bone exceeds the bone's capacity to repair itself.³ In high school athletes participating in cross-country and/or track and field teams, previous injuries were reported by 68% of female subjects and 59% of male subjects.⁴

While the etiology of such injuries is likely multifactorial and involves both extrinsic and intrinsic factors, the identification of altered kinematics for BSI may have a clinically relevant role in prevention. Given that the micro-damage to the bone in BSI is a product of both frequency of loading as well as the intensity of loading, training errors such as increased training intensity, longer running distance, and rapid increases in mileage, have been cited as consistent contributors to BSI.⁵ A frequently noted stress reaction afflicting distance runners is medial tibial stress syndrome (MTSS) which can progress to a tibial stress fracture if bone stress continues to exceed bone repair and healing. Previous studies have identified specific risk factors that may contribute to MTSS, including prior history of MTSS, female gender, less running experience, use of orthotics, increased BMI, and, in males, increased hip external rotation range of motion (ROM).^{6,7} Various kinematic and kinetic factors implicated in tibial stress fractures in adult females include increased peak hip adduction, absolute free moment, peak rear-foot eversion, and vertical loading rates.^{8,9} It is not known, however, whether these factors are associated with tibial stress fracture risk in adolescent and young adult male long-distance runners.

Longer step lengths have also been linked to an increased probability of developing tibial stress fractures.¹⁰ The vertical impact and loading rates at the tibia are higher with longer step lengths^{11,12,13} which increase the bone strain. In contrast, manipulation

of step rates above preferred rates with a concomitant decrease in step length results in a significant reduction in vertical impact peak, vertical instantaneous loading rate, and vertical average loading rate.¹³ Kinematic changes are observed in the lower extremities of runners who self-select lower step rates, including longer step length, increased peak hip flexion, decreased knee flexion at initial contact (IC), and increased peak knee flexion.¹⁴ These changes place the foot in front of the center of mass at IC in a position of over-striding, decreasing the capacity to absorb and attenuate ground reaction forces, and increasing the risk for BSI.¹⁴

While previous studies of running injuries have mostly focused on adults, females, and military populations,^{15,16} there are relatively few studies specifically comparing the running kinematics of previously injured and uninjured high school and collegiate long-distance runners. The purpose of this study was to compare an adolescent and young adult population of male runners known to have a history of BSI with an injury-free cohort and retrospectively assess for kinematic differences that may differentiate the two cohorts. It was hypothesized that runners with a previous BSI would demonstrate unique sagittal plane running kinematics at the hip and knee, as well as a lower step rate and increased step length, when compared to a previously uninjured cohort.

METHODS

Participants

Twenty-five male high school ($n = 11$) and collegiate ($n = 14$) cross-country runners participated in this study. The age, height, mass, and BMI for the participants are listed in Table 1. Informed written consent was obtained from each subject in accordance with the protocol approved by the Institutional Review Board at Cincinnati Children's Hospital Medical Center. Data were collected immediately prior to the fall cross-country season for each athlete. Athletes met inclusion criteria if they were currently participating on a high school or collegiate cross-country team and free from pain during testing, by self-report. Athletes were excluded from the study if they were currently under medical supervision and had not been fully cleared to participate in a structured running program.

Table 1. Subject Demographics.			
	UNINJURED	INJURED	p-value
	Male (n=15)	Male (n=10)	Males
Age in yrs (SD)	18.3(1.5)	19.8(2.0)	0.05
Height in cm (SD)	175.4(5.6)	180.4(4.6)	0.03*
Weight in kg (SD)	60.4(3.9)	64.8(3.5)	0.008*
BMI in kg/m ² (SD)	19.6(1.0)	19.8(1.2)	0.78
Avg. Weekly Mileage (SD)	64.2(15.0)	72.8(12.8)	0.17
*Indicates significant difference between uninjured and injured cohorts SD=Standard Deviation			

At the start of the study protocol, participants were asked to complete a survey developed by the research team to report their history of previous shin splints (MTSS), exertional compartment syndrome, and lower extremity stress fractures (tibia, fibula, femur, metatarsal, navicular, or pelvis) and weekly mileage (Appendix 1). Study data were collected and managed using REDCap electronic data capture tools hosted at Cincinnati Children's Hospital.¹⁷ Ten runners self-reported a prior history of tibial stress fracture and/or MTSS (INJ group). No prior history of lower extremity injury (UNINJ group) was reported by 15 of the participants.

Kinematic data collection

Lower extremity 3D kinematics during running using a self-selected speed on a custom-built treadmill were calculated as previously described.¹⁸ The average speed was 3.8 (± 0.2) m·sec⁻¹ (UNINJ) and 3.8 (± 0.2) m·sec⁻¹ (INJ) ($p=0.592$), which corresponds to a light training pace of 7.0 min·mile⁻¹. Following an acclimation period of three to five minutes, a one-minute trial was collected. All participants were provided with a standard Adidas neutral running shoe during data collection.

Reflective markers were placed on the thorax (posterior cluster of 3 markers), pelvis (right ASIS, left ASIS, and sacrum), and each lower extremity segment (thigh, shank, foot) with a minimum of three tracking markers on each segment (Figure 1).¹⁹ Specifically, hip and knee angular displacement were calculated based on the distal segment rotating relative to the proximal segment. Three-dimensional marker trajectories were collected using a motion analysis system (Motion Analysis Corporation,

Figure 1. Marker Set-Up and Treadmill Protocol. Reprinted with permission from IJSPT.

Santa Rosa, CA) with 10 digital cameras as previously described.¹⁸

Thirty consecutive steps were recorded, defined as initial contact of the foot with the treadmill to toe-off when the foot left the treadmill (the total of which was the stance phase). Proper stance phase identification in each trial was verified by a frame-by-frame inspection of the identified gait events, i.e., initial contact and toe-off, performed by one reviewer for all participants. This was done by ensuring that, for a given event, the foot was in a reasonable posture (as opposed to mid-swing, for example). Calculations were made during stance phase and averaged over the first 20 recorded steps. One-way analysis of covariance (ANCOVA) was used to compare kinematic differences at the hip and knee between the INJ and UNINJ cohorts while controlling for variables of interest. An exploratory α level of 0.05 was determined *a priori* to indicate statistical significance.

Foot strikes were determined in Visual3D (C-Motion, Inc., Germantown, MD) using a previously described algorithm.²⁰ In order to classify runners as either rear-foot strikers or mid-foot strikers, Cartesian coordinate data were determined at initial contact for each of the markers affixed to the runner's heel and lateral foot at the fifth metatarsal. Runners were classified as rear-foot strikers if the heel marker had smaller vertical displacement than the lateral foot marker at initial contact. Conversely, runners were classified as forefoot strikers if the lateral foot marker had smaller vertical displacement than the heel marker at initial contact. To differentiate between mid-foot and forefoot striking, visual inspection of

the video was performed; this was determined by assessing which of the toe and lateral foot markers had the smaller vertical displacement at initial contact for these runners.

RESULTS

Demographics

One-way ANOVA was used to compare demographic variables of the INJ and UNINJ groups of runners. There was no statistically significant difference in age between the UNINJ (18.3 ± 1.5 years) vs INJ (19.8 ± 2.0 years) cohorts ($p=0.05$). The average heights ($p=0.03$) and weights ($p=0.008$) of the INJ runners were significantly greater than the UNINJ cohort but there was no significant difference in BMI ($p>0.05$) noted (Table 1). There was no significant difference ($p=0.17$) in weekly mileage between the INJ and UNINJ cohorts (Table 1).

Comparison of hip kinematics

Hip kinematics in the sagittal plane were compared between the INJ and UNINJ groups. Peak hip flexion was used as the dependent variable while history of prior injury was the independent variable. Subject height and weight were used as covariates in the in the analysis. Runners in the INJ cohort demonstrated greater peak hip flexion (Table 2) during the stance phase on both the left limb [INJ = $31.2^\circ (\pm 4.8^\circ)$ vs. UNINJ = $26.8^\circ (\pm 3.1^\circ)$; $p=0.003$] (Figure 2) and the right limb [INJ = $32.5^\circ (\pm 3.8^\circ)$ vs. UNINJ = $26.9^\circ (\pm 4.6^\circ)$; $p=0.012$] (Figure 3) when compared to runners in the UNINJ cohort.

The timing for which peak hip flexion occurred during the stance phase was compared to the magnitude of peak hip flexion in both limbs. For the UNINJ cohort, no association was noted between the peak hip flexion angle and the point in the gait cycle at

Table 2. Running Kinematics. Reported in degrees (SD) except when noted.

	Uninjured Male (n=15)	Injured Male (n=10)	p-value
Left Hip Flexion	26.8(3.1)	31.2(4.8)	0.003*
Right Hip Flexion	26.9(4.6)	32.5(3.8)	0.012*
Left Hip Adduction	13.2(2.7)	13.8(3.1)	0.639
Right Hip Adduction	13.0(3.0)	12.7(3.5)	0.391
Left Hip IR	1.0(4.4)	-1.6(6.0)	0.735
Right Hip IR	1.9(3.5)	-0.1(4.2)	0.295
Left Knee Flexion	39.2(6.3)	44.4(6.3)	0.089
Right Knee Flexion	41.5(6.1)	45.8(5.7)	0.073
Left Knee Abduction	0.6(3.2)	0.1(2.6)	0.939
Right Knee Abduction	1.3(2.0)	0.5(1.8)	0.372
Left Knee IR	7.5(4.4)	8.4(5.1)	0.555
Right Knee IR	10.1(5.1)	8.8(3.6)	0.236
Step Length in meters (SD)	1.13(0.06)	1.18(0.06)	0.386 **
Step Rate in steps/min (SD)	171.0(7.9)	168.4(6.1)	0.390 **
Footstrike Type (RF/MF+FF)	14/1	7/3	0.316
*Indicates significant difference between uninjured and injured cohorts			
**Controlled for mass and height			
SD= standard deviation; IR= internal rotation; RF=rearfoot strike, MF=midfoot strike, FF=forefoot strike

Figure 2. Average Peak Hip Flexion of the Left Limb: Prior history of injury vs. No prior history of injury. (CI = confidence interval).

Figure 3. Average Peak Hip Flexion of the Right Limb: Prior history of injury vs. No prior history of injury. (CI = confidence interval).

which this occurred (Figure 4). Conversely, runners in the INJ cohort demonstrated a positive correlation between these variables with higher peak hip flexion angles occurring later in the stance phase of the gait cycle (16-18% of the gait cycle; R^2 linear = 0.252, Figure 5).

Comparison of knee kinematics

Knee kinematics in the sagittal plane were compared between the INJ and UNINJ groups. Peak knee flexion was used as the dependent variable while history of prior injury was the independent variable. Subject height and weight were used as covariates in the

Figure 4. Relationship between peak hip flexion and percent of stance phase at which time peak hip flexion occurs in male runners with no prior history of lower extremity injury.

Figure 5. Relationship between peak hip flexion and percent of stance phase at which time peak hip flexion occurs in male runners with a prior history of lower extremity injury.

analysis. Knee kinematics were compared in the sagittal plane between the INJ and UNINJ groups. Peak knee flexion (Table 2) in both the left and right limbs was not statistically significantly different, although each demonstrated a trend towards significance with greater flexion in the INJ cohort ($p = 0.09$ and 0.07 , respectively).

Foot strike, step length, and step rate

No significant difference in step length or step rate between the INJ and UNINJ cohorts was noted ($p = 0.39$ and 0.39 , respectively; Table 2). Despite

no significant difference in BMI between the two cohorts, the INJ runners were heavier and taller than the UNINJ runners (Table 1). Step length and step rates, therefore, were normalized to height and weight for each cohort. Foot strike patterns were not significantly different between the INJ and UNINJ cohorts (Table 2). Of the 25 males studied, 21 were classified as rear-foot strikers, two as forefoot strikers, and two as mid-foot strikers.

DISCUSSION

It was hypothesized that adolescent and young adult male runners who previously experienced a lower extremity BSI would demonstrate unique sagittal plane running kinematics at the hip and knee, as well as a lower step rate and increased step length when compared to a previously uninjured cohort. This hypothesis was partially supported in that the group of previously injured male runners showed a statistically significant increase in bilateral peak hip flexion during the stance phase with a trend towards significance in increased peak knee flexion. No significant differences were noted in step length or step rate between the two groups.

In this study, the altered kinematics of the previously injured male cohort most closely resembles the running kinematics of runners who self-select a reduced step rate.¹⁴ Although changes in step rate and step length have been theoretically tied to a decreased risk of BSI,¹⁰ to the authors' knowledge the association between increased peak hip flexion and BSI is a novel finding. Since no difference in step rate or length was observed despite the altered kinematics, it is possible that the altered sagittal plane hip kinematics themselves are a risk factor for injury. However, due to the cross-sectional nature of the study, cause and effect cannot be clearly determined. The differences in hip kinematics between groups may be a result of compensatory alterations following a BSI injury.

It was further observed that the timing of peak hip flexion during the stance phase varied between runners. Previously injured runners who attained peak hip flexion later in the stance phase of the gait cycle also exhibited an association with a greater magnitude of hip flexion. No association between the timing and magnitude of peak hip flexion was observed

in the uninjured runners. It is postulated that the runners who had delayed hip flexion may not have been effectively pre-activating their gluteal muscles in anticipation of ground contact. A previous study performed in uninjured runners showed an increase in activity of the gluteus maximus and medius during late swing/pre-activation when step rates were increased by 10% over preferred, effectively reducing over-striding.²¹ As the gluteus maximus eccentrically controls stance hip flexion, delayed hip flexion in the previously injured runners may be indicative of altered gluteal activation. As gluteal activation was not directly measured, further investigations are warranted.

The demographics of the male runners differed in that the INJ cohort was taller, and heavier. Despite the INJ cohort presenting with increased weight and height measurements compared to the UNINJ cohort, the BMI measurements between the two cohorts were not significantly different. Average self-reported weekly mileage between the two cohorts, which can be viewed as a marker for the amount of repetitive bone stress incurred, was also not significantly different.

Limitations

The retrospective design limits the ability to draw cause and effect conclusions between injury and altered kinematics. It is possible that the kinematic differences noted were modifications made by the runners secondary to their previous injuries, rather than the cause of their injuries. All runners, however, were pain-free at the time of testing and had been medically cleared for running. In addition, for convenience all data collection was performed on a treadmill rather than overground running. Previous studies comparing overground vs treadmill running have shown that the kinematic data obtained is similar, particularly for the hip.^{22,23} The differences in knee flexion showed a trend towards significance. It is possible that the current study was underpowered to detect a statistically significant difference. Further, all runners ran in a standard running shoe in an attempt to remove shoe design as a covariate that could impact running mechanics.^{24, 25} While this practice is common,²⁶ running in a novel shoe may have influenced the runners' mechanics.

Additionally, kinetic data was not available for this study which could have assisted in interpreting kinematic results. Finally, this data was collected on a competitive, male cohort and thus these results must be viewed with caution when comparing to other running populations.

Future studies should focus on prospective data collection to determine if runners with increased hip flexion during running gait have a higher incidence of lower extremity BSI and should include a female cohort. This would enable investigation of causality as well as a potential area of intervention for injury prevention. In addition, future studies should consider assessing gluteal muscle activation as an improved means of determining the potential effects of altered stance phase hip mechanics on muscle activation and timing. Finally, as bone stress injuries are influenced by factors such as dietary preferences, bone density, and training habits, future studies should consider additional screening questions at the time of data collection.

CONCLUSION

In conclusion, the results of the current study indicate altered stance phase sagittal plane hip kinematics in a population of young adult male runners with a previous history of bone stress injury. These novel findings warrant future investigative efforts to further delineate associations and potential prospective risks, if any, in this patient population.

REFERENCES

1. van Gent RN, Siem D, van Middelkoop M, et al. Incidence and determinants of lower extremity running injuries in long distance runners: a systematic review. *Br J Sports Med*. 2007;41(8):469-480.
2. Rauh MJ, Koepsell TD, Rivara FP, et al. Epidemiology of musculoskeletal injuries among high school cross-country runners. *Am J Epidemiol*. 2006;163(2):151-159.
3. Warden SJ, Davis IS, Fredericson M. Management and prevention of bone stress injuries in long-distance runners. *J Orthop Sports Phys Ther*. 2014;44(10):749-765.
4. Tenforde AS, Sayres LC, McCurdy ML, et al. *PM R*. 2011;3(2):125-131.
5. Hreljac A, Ferber R. A biomechanical perspective of predicting injury risk in running: review article. *Int SportMed J: Running Injuries*. 2006;7(2):98-108.
6. Hubbard TJ, Carpenter EM, Cordova ML. Contributing factors to medial tibial stress syndrome: a prospective investigation. *Med Sci Sports Exerc*. 2009;41(3):490-496.
7. Newman P, Witchalls J, Waddington G, et al. Risk factors associated with medial tibial stress syndrome in runners: a systematic review and meta-analysis. *Open Access J Sports Med*. 2013;4:229-241.
8. Milner CE, Ferber R, Pollard CD, et al. Biomechanical factors associated with tibial stress fracture in female runners. *Med Sci Sports Exerc*. 2006;38(2):323-328.
9. Pohl MB, Mullineaux DR, Milner CE, et al. Biomechanical predictors of retrospective tibial stress fractures in runners. *J Biomech*. 2008;41(6):1160-1165.
10. Edwards WB, Taylor D, Rudolphi TJ, et al. Effects of stride length and running mileage on a probabilistic stress fracture model. *Med Sci Sports Exerc*. 2009;41(12):2177-2184.
11. Derrick TR, Hamill J, Caldwell GE. Energy absorption of impacts during running at various stride lengths. *Med Sci Sports Exerc*. 1998;30(1):128-135.
12. Hamill J, Derrick TR, Holt KG. Shock Attenuation and Stride Frequency during Running. *Hum Mov Sci*. 1995;14(1):45-60.
13. Hobara H, Sato T, Sakaguchi M, et al. Step frequency and lower extremity loading during running. *Int J Sports Med*. 2012;33(4):310-313.
14. Heiderscheit BC, Chumanov ES, Michalski MP, et al. Effects of step rate manipulation on joint mechanics during running. *Med Sci Sports Exerc*. 2011;43(2):296-302.
15. Rauh MJ, Macera CA, Trone DW, et al. Selected static anatomic measures predict overuse injuries in female recruits. *Mil Med*. 2010;175:329-35.
16. Sharma J, Golby J, Greeves J, et al. Biomechanical and lifestyle risk factors for medial tibial stress syndrome in army recruits: a prospective study. *Gait Posture*. 2011;33(3):361-5.
17. Harris PA, Taylor R, Thielke R, et al. Research electronic data capture (REDCap) – A metadata-driven methodology and workflow process for providing translational research informatics support. *J Biomed Inform*. 2009;42(2):377-81.
18. Ford KR, Taylor-Haas JA, Genthe K, et al. Relationship between Hip Strength and Trunk Motion in College Cross-Country Runners. *Med Sci Sports Exerc*. 2013;45(6):1125-1130.
19. Taylor-Haas JA, Hugentobler JA, DiCesare CA, et al. Reduced hip strength is associated with increased hip motion during running in young adult and

-
- adolescent male long-distance runners. *Int J Sports Phys Ther*. 2014;9(4):456-467.
20. Stanhope SJ, Kepple TM, McGuire DA, et al. Kinematic-based technique for event time determination during gait. *Med Biol Eng Comput*. 1990;28(4):355-360.
21. Chumanov ES, Wille CM, Michalski MP, et al. Changes in muscle activation patterns when running step rate is increased. *Gait Posture*. 2012;36(2):231-235.
22. Fellin RE, Manal K, Davis IS. Comparison of lower extremity kinematic curves during overground and treadmill running. *J Appl Biomech*. 2010;26(4):407-414.
23. Riley PO, Dicharry J, Franz J, et al. A kinematics and kinetic comparison of overground and treadmill running. *Med Sci Sports Exerc*. 2008;40(6):1093-1100.
24. Mullen S, Toby EB. Adolescent runners: the effect of training shoes on running kinematics. *J Pediatr Orthop*. 2013;33(4):453-7.
25. Rose A, Birch I, Kuisma R. Effect of motion control running shoes compared with neutral shoes on tibial rotation during running. *Physiotherapy*. 2011;97(3):250-5.
26. Williams DS, Tierney RN, Butler RJ. Increased medial longitudinal arch mobility, lower extremity kinematics, and ground reaction forces in high-arched runners. *J Athl Train*. 2014;49(3):290-6.

APPENDIX

0331 Previous Running Injury

previous history

First name:

Last name:

Today's date:

Date of birth:

Sex:

- ☐ Male
☐ Female

Select your Ethnicity:

- ☐ Hispanic or Latino
☐ Not Hispanic or Latino

Select your Race:
(you may select more than one)

- ☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Native Hawaiian or Pacific Islander
☐ White

Year in school:
(select upcoming year if in-between grades)

- ☐ 1st
☐ 2nd
☐ 3rd
☐ 4th
☐ 5th
☐ 6th
☐ 7th
☐ 8th
☐ 9th
☐ 10th
☐ 11th
☐ 12th
☐ College (Freshman)
☐ College (Sophomore)
☐ College (Junior)
☐ College (Senior)
☐ College (Graduate School)
☐ Other

Sport and Running Participation

Sports that you have played
(select all sports you have played on an organized team)

- ☐ Baseball/Softball
- ☐ Basketball
- ☐ Cross Country
- ☐ Field Hockey
- ☐ Football
- ☐ Lacrosse
- ☐ Soccer
- ☐ Swimming
- ☐ Tennis
- ☐ Track and Field
- ☐ Volleyball
- ☐ Wrestling
- ☐ Other

You selected 'OTHER' in the previous question, list the other sports and number of years you played them:
(Separate with commas)

Number of years you played BASEBALL/SOFTBALL:

Number of years you played BASKETBALL:

Number of years you ran CROSS COUNTRY:

Number of years you played FIELD HOCKEY:

Number of years you played FOOTBALL:

Number of years you played LACROSSE:

Number of years you played SOCCER:

Number of years you SWAM:

Number of years you played TENNIS:

Number of years you competed in TRACK & FIELD:

Number of years you played VOLLEYBALL:

Number of years you WRESTLED:

Over the PAST 6 months, how many miles did you run per week?

- ☐ None
- ☐ Between 1 and 15 miles
- ☐ Between 16 and 30 miles
- ☐ Between 31 and 45 miles
- ☐ Between 46 and 60 miles
- ☐ Between 61 and 75 miles
- ☐ Greater than 76 miles

Over the PAST 6 months, what was the running surface for the majority of your running?

- ☐ concrete (e.g. sidewalk)
- ☐ asphalt (e.g. road)
- ☐ dirt/grass trail
- ☐ rubber track
- ☐ cinder/crushed rock trail
- ☐ treadmill
- ☐ other

Over the NEXT 6 months, how many miles do you plan to run per week?

- ☐ None
- ☐ Between 1 and 15 miles
- ☐ Between 16 and 30 miles
- ☐ Between 31 and 45 miles
- ☐ Between 46 and 60 miles
- ☐ Between 61 and 75 miles
- ☐ Greater than 76 miles

How often do you typically change your running shoes?

- ☐ Less than 300 miles
- ☐ Between 300 and 500 miles
- ☐ Greater than 500 miles
- ☐ Do not know

What is your foot type?

- ☐ Flat foot, low arch (e.g. pes planus)
- ☐ Normal
- ☐ High arch (e.g. pes cavus)
- ☐ Do not know

What is the brand of your current running shoe?

What is the model of your current running shoe?

What is the style of your current running shoe?

- ☐ Motion control
- ☐ Stability
- ☐ Cushioning
- ☐ Trail
- ☐ Racing
- ☐ Barefoot
- ☐ Do not know

Do you wear foot orthoses?
(e.g. orthotics)

- ☐ No
- ☐ Yes

What type of orthotic device do you wear?

- ☐ Custom
- ☐ Store bought (over the counter)
- ☐ Do not know

Medical History

Have you ever had a menstrual period?

- ☐ Yes
☐ No

How old were you when you had your first menstrual period?

How many periods have you had in the past 12 months?

- ☐ 0
☐ 1-3
☐ 4-6
☐ 7-12
☐ Greater than 12

Have you ever been diagnosed with shin splints (Medial Tibial Stress Syndrome)?

- ☐ Yes
☐ No

Which leg had shin splints?

- ☐ Left
☐ Right
☐ Both
☐ Do not remember

Have you ever been diagnosed with a exertional compartment syndrome ?

- ☐ Yes
☐ No

Which leg had exertional compartment syndrome?

- ☐ Left
☐ Right
☐ Both
☐ Do not remember

Have you ever been diagnosed with a stress fracture?

- ☐ Yes
☐ No

List the location(s) of the stress fracture(s):

- ☐ Left tibia (shin bone)
☐ Right tibia (shin bone)
☐ Left fibula (calf bone)
☐ Right fibula (calf bone)
☐ Left femur (thigh bone)
☐ Right femur (thigh bone)
☐ Left metatarsals (5 long bones in the foot)
☐ Right metatarsals (5 long bones in the foot)
☐ Left tarsal navicular (foot/ankle bones)
☐ Right tarsal navicular (foot/ankle bones)
☐ Pelvis
☐ Other

Other stress fracture location: