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Hip and Pelvis Biomechanics during Running as Risk Factors for Injury in Collegiate Runners: A Prospective Study

Original Research

Monique Mokha, Dustin Gatens

Nova Southeastern University, Ft. Lauderdale, FL/USA

Abstract

Introduction Running-related injury (RRI) rates are high and reoccurring with most RRIs classified as overuse. Faulty running biomechanics have been linked to RRI risk in adult, recreational runners. The purpose of this study was to determine if hip and pelvis running biomechanics could predict RRI in a group of collegiate runners.

Methods. Eight female and four male healthy, NCAA Division II cross country runners participated in this prospective study. Runners underwent 3D motion analysis of their kinematics [peak hip adduction (HADD), hip internal rotation (HIR), contralateral pelvis drop (CPD)] prior to the season's start. RRI were tracked for an academic year by the teams' certified athletic trainer via an electronic medical record. Pearson Chi-square analyses were used to determine if RRI could be predicted by HADD, HIR, and CPD, $p<.05$.

Results. Nine runners (75.0%) sustained a total of 27 lower extremity RRI. Runners with excessive HADD were more likely to sustain a RRI ($\chi^2(3)=13.496$, $p=.036$). Injured runners had greater HADD peak motion than non-injured, $12.2+4.7^0$ vs $7.4+4.70^0$, respectively. HIR and CPD were not significant predictors of RRI, $p>.05$.

Conclusion. Increased HADD is a risk factor for RRI in collegiate runners. Runners may benefit from pre-season motion analysis to identify pathomechanics.

Key Words: pathomechanics, distance runners, musculoskeletal injury.

Corresponding author: G. Monique Mokha PhD LAT ATC CSCS e-mail: gm588@nova.edu

Introduction

Running is a popular fitness and sports activity that provides substantial overall health benefits. However, running-related injuries (RRI) do occur and are a major barrier to continued participation.[1] RRI occur with an overall yearly incidence rate between 19.4 and 79.3%.[2] These rates vary depending on the type of runners studied. Novice adult runners are at significantly higher risk of injury 17.8 (95 % CI 16.7–19.1) than recreational runners, who sustained 7.7 (95 % CI 6.9–8.7) RRI per 1000 hours of running.[2] High school girls and boys cross country runners have an injury rate of 19.6 and 15.0 per 1000 athlete-exposures (AE), respectively.[3]

The National Collegiate Athletic Association's (NCAA) Injury Surveillance Program captured 216 and 260 injuries from the men's and women's cross-country between the 2009-2010 and 2013-2014 academic years. This accounted for injury rates of 4.66 and 5.85 per 1000 AE for men's and women's cross-country, respectively. Most occur to the lower extremity[4] with 50-75% of all RRI classified as overuse[5] and occurring more often in females than males.[6]

Faulty running biomechanics have been linked to RRI and specifically in runners with iliotibial band syndrome,[7] patellofemoral pain,[8] Achilles tendon pathology,[9] and tibial stress fractures.[10] The runner with faulty running biomechanics, or pathomechanics typically presents with excessive hip adduction [(HADD) thigh angling inwards], excessive hip internal rotation [(HIR) thigh rotating inwards], and the contralateral hip dropping during stance (CPD). See figure 1 for an example of a runner with the aforementioned pathomechanics.

Figure 1. Running pathomechanics.
Note the prominent drop of the contralateral pelvis in addition to excessive HIR, and HADD of the stance leg.

Gait retraining for runners has gained popularity as an intervention to reduce tissue loads while still maintaining level of activity.[11] Faulty mechanics are identified by the researcher or clinician during a running gait evaluation. Then, they are modified through intervention strategies using verbal, visual, or auditory cues and feedback, or functional pattern training. Gait retraining has typically been implemented with injured runners with promising results. Thus, faulty running mechanics appear to be modifiable, and uninjured runners may benefit from their identification as long as the distinction as pathomechanics is evidence-based. Therefore, the purpose of this study was to prospectively determine if hip and pelvis running biomechanics could predict RRI in a group of collegiate runners. Specifically, we assessed HADD, HIR, and CPD male and female NCAA Division II cross-country runners.

Methods

Participants

Eight female and four male (age, 19.8+2.1 yrs; height, 1.66+0.08m; mass, 57.8+7.0kg; 40.2+15.1 miles/wk) healthy, NCAA Division II cross-country runners participated in this prospective cohort study. Nova Southeastern University's Human Subjects Institutional Review Board approved all procedures involving human subjects, and written informed consent was obtained prior to participation.

Protocol

A 10 infrared camera (120 Hz) Vicon motion analysis system (Vicon Peak, Lake Forest, CA, USA) with Vicon Nexus software (version 2.4) captured running mechanics. Anthropometric measures were measured (i.e. height, weight, pelvis breadth, leg length) and 16 ½" retroreflective markers were placed bilaterally on the subject's pelvis, thighs, knees, lower legs, ankles and feet according the specifications of Vicon's Plug-in Gait model. The runners wore sports bra (women), spandex shorts, and running shoes. Runners began the testing session with a warm-up consisting of general dynamic stretching and a 7 min run on a treadmill at a self-selected pace, with an average of 6.55$\pm$0.64 mph. Data were captured for 10 sec beginning at minute 8 on the treadmill. Data from three consecutive steps were evaluated and found to be consistent, data were extracted from a single representative step from the right leg for analysis. Specific kinematic variables of interest were peak values of hip adduction (HADD) and internal rotation (HIR), and contralateral pelvis drop (CPD) during stance. Values for these variables were calculated using Vicon Nexus software, and then were exported to a Microsoft Excel (Redmond, WA, USA) file to identify the peak range of motion values.

RRI for this study was defined as musculoskeletal damage that met the following criteria: (1) the injury occurred as a result of participation in an organized intercollegiate practice or competition setting; (2) the injury required attention or the athlete sought medical care. Injury evaluations were performed by the staff certified athletic trainers responsible for care of the cross-country teams. If necessary, injuries were confirmed through diagnostic imaging and evaluation through the teams' primary care sports medicine physicians. The athletic trainers documented all injury information (i.e., mechanism, body part, diagnosis) using the computer software, SportsWare (Computer Sports Medicine, Inc., Stroughton, MA, USA). Recurrent or ongoing injuries were not used in the data analysis since the initial injury had occurred prior to the running mechanics testing. Injuries were tracked for the academic year 2016-2017.

Statistical Analysis

Data were analyzed using Statistical Package for the Social Sciences ver. 24 (SPSS, Inc., Chicago, IL, USA). Descriptive statistics were calculated for the pelvis and hip biomechanics results, and RRI. Pearson Chi-square analyses were used to determine if RRI could be predicted by HADD, HIR, and CPD, with "injured/uninjured" as the dependent variable, $p<.05$. Receiver operating characteristic (ROC) curves were calculated to determine the optimal cut point of a significant kinematic variable. The optimal point on the curve was realized when the true-positive rate (sensitivity) was maximized, and the false-positive rate (1-specificity) was minimized, equating to the point with the highest positive likelihood ratio.

Results

Nine of 12 runners (75%) sustained a total of 27 RRI. Table 1 presents descriptive statistics for RRI by body region and frequency. Over 92% of RRI were to the lower extremity and included specific diagnoses such as medial tibial stress syndrome, anterior knee pain, and plantar fasciitis.

Table 1. Summary of RRI by body region and frequency.

Region	Frequency	Percent
Upper extremity	0	0.0
Lower extremity	25	92.6
Trunk	2	7.4

Total # RRI	27	100.0

The binary logistic regression model was statistically significant, $\chi^2(3)=13.496$, $p=.036$. The model explained 67.5% (Cox & Snell R^2) of the variance in RRI occurrence and correctly classified 75% of cases. Figure 2 depicts the mean differences in the peak motion values for CPD, HIR and HADD. Runners with increased HADD were more likely to sustain a RRI.

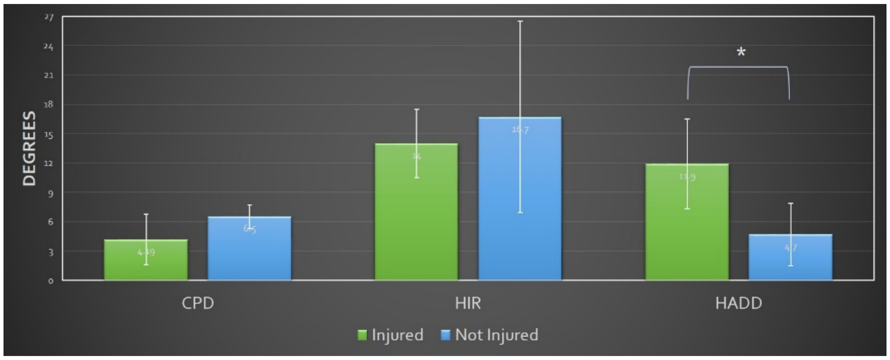

Figure. 2. Peak values of pelvis and hip motion of injured and noninjured runners. Data are expressed as Means ± SD.
*Significant difference between injured and noninjured, $p = 0.036$.

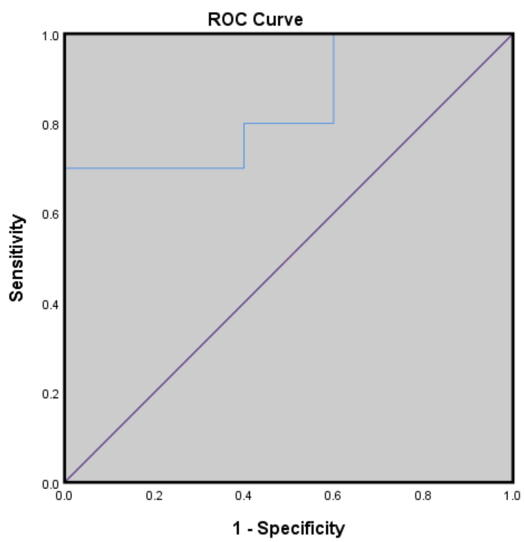

Figure 3. Receiver operating characteristic (ROC) curve for HADD and injuries. The straight line denotes the 50/50 reference line, which is approximated by the receiver operating characteristic curve plotted on sensitivity (true-positive rate) over 1 – specificity (false-positive rate) for each HADD peak value.

Figure 3 depicts the ROC curve for the group of runners. The cut-point value of peak HADD was maximized at 8.9^0.

Discussion

Participation in collegiate athletics comes with an inherent risk for injury. Being able to identify factors related to injury that may be modified has significant value in sport health care. We sought to determine the utility of examining hip and pelvis biomechanics that have been linked to RRI in previous studies with recreational runners. Mechanical overload inherent in distance running in general is recognized as a risk factor for developing RRI.[12] A key finding of this study was that these collegiate runners who sustained a RRI had larger values of HADD. Excessive HADD is described as the thigh being angled toward the midline. The finding of significantly greater peak HADD during stance as a predictor of RRI supports that of other studies with specific regard to patellofemoral pain (PFP).[8,13] Increased HADD has been shown to concentrate the contact stress on the lateral aspect of the patella. Patients with PFP exhibit greater contact stress. Increased HIR has been shown to also increase contact stress on the lateral aspect of the patella.[14] Interestingly, peak HIR was greater, but by only 2.7^0 in the uninjured group. It should be noted that transverse plane motions are the most sensitive to measurement errors and tend to be the most variable of all planes of motion. Further, in the present study only one participant was diagnosed with PFP. Three participants were diagnosed with patellar tendonitis which may be associated with abnormal patella tracking resulting from excessive HADD.

Neuromuscular reeducation through gait retraining has been successful in altering faulty hip mechanics during running. Thus, this study's findings add to a recent body of literature supporting identifying faulty mechanics as part of injury prevention as well as treatment strategies since hip mechanics appear to be a modifiable risk factor for RRI. Increased HADD is usually accompanied by CPD. When the thigh angles more toward the midline in the stance leg, there is a typical concomitant lowering of the contralateral (nonstance) side of the pelvis. CPD was not a significant risk factor in the present study, nor was it greater in the injured group. The present study did not employ gait retraining, but it may be a valuable intervention tool for the excessive HADD.

The area under the curve was 0.840 which reflected a "good" test of RRI prediction from peak values of HADD during running. Sensitivity and specificity of HADD were .80 and .40, respectively. This indicates that 80% of the runners who have sustained a RRI will have $\geq 8.9^0$ of HADD during stance. Additionally, 40% of the runners who have sustained a RRI will have $<8.9^0$ of HADD during stance. HADD has better utility for supporting a true-positive result than a true-negative result.

Despite this study's limitations, we conclude that collegiate distance runners may be at elevated risk for lower extremity RRI if they run with increased HADD, specifically greater than $\sim 9^0$ of HADD. Running mechanics may be modifiable, thus runners would benefit from motion analysis in the off-season as part of injury prevention.

Media-Friendly Summary

Identifying risk factors for running related injuries is of interest to coaches, athletes and researchers alike. Our prospective study found that collegiate runners were at greater risk of sustaining a running-related injury if they ran with faulty biomechanics; specifically, with a large hip adduction angle. Runners may want to consider using 3D gait analysis as a method of injury risk identification.

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