Human Movement Science 52 (2017) 197–202

Contents lists available at ScienceDirect

Human Movement Science

journal homepage: www.elsevier.com/locate/humov

Full Length Article

A prospective comparison of lower extremity kinematics and kinetics between injured and non-injured collegiate cross country runners

Robert I. Dudley [a,b,*], Derek N. Pamukoff [b], Scott K. Lynn [b], Robert D. Kersey [b], Guillermo J. Noffal [b]

[a] Department of Exercise and Sport Science, Azusa Pacific University, 701 E. Foothill Blvd, Azusa, CA 91702, USA
[b] Center for Sport Performance, California State University, Fullerton, 800 N. State College Blvd., Fullerton, CA 92801, USA

ARTICLE INFO

Article history:
Received 4 August 2016
Revised 14 February 2017
Accepted 14 February 2017
Available online 23 February 2017

Keywords:
Kinematics
Kinetics
Running related injury
Prospective
Collegiate runners

ABSTRACT

Collegiate cross country runners are at risk for running related injuries (RRI) due to high training volume and the potential for aberrant lower extremity biomechanics. However, there is a need for prospective research to determine biomechanical risk factors for RRI. The purpose of this study was to prospectively compare ankle, knee, and hip kinematics and kinetics and ground reaction force characteristics between injured and non-injured cross country runners over a 14-week season. Biomechanical running analyses were conducted on 31 collegiate-cross country runners using a 3-dimensional motion capture system and force plate prior to the start of the season. Twelve runners were injured and 19 remained healthy during the course of the season. Peak external knee adduction moment (KAM), a surrogate for frontal plane knee loading, and peak ankle eversion velocity were greater in runners who sustained an injury compared to those who did not, and no differences were noted in ground reaction force characteristics, or hip kinematics and kinetics. Reducing the KAM and ankle eversion velocity may be an important aspect of preventing RRI.

1. Introduction

Recreational distance running is a popular sport in the United States, and 20% of Americans choose running as their physical activity, participating in a large number of running events such as marathons (Fields, 2011; Fields, Sykes, Walker, & Jackson, 2010). Furthermore, participation in competitive collegiate running has doubled within the past 30 years (Irick, 2011). Although distance running is beneficial for long-term cardiovascular and joint health (Lane et al., 1986; Willick & Hansen, 2010), the prevalence of running related injury (RRI) is high (Fields, 2011; Yang et al., 2012). Approximately 50% of recreational distance runners will become injured annually with at least 25% being injured at any given time (Fields, 2011). Among all collegiate sports, men's cross country athletes sustain the most injuries with 30% of runners developing a RRI (Yang et al., 2012). In addition to the physical injuries sustained, the financial burden of RRIs can be staggering. An examination of recreational runners in the Netherlands estimates financial burdens totaling close to $7 billion in direct and indirect costs given the high number of participants and injury rates (Hespanhol Junior, van Mechelen, Postuma, & Verhagen, 2016). As such, identification of the underlying factors for injury development is warranted.

* Corresponding author at: Department of Exercise and Sport Science, Azusa Pacific University, PO Box 7000, Azusa, CA 91702-7000, USA.
E-mail address: rdudley@apu.edu (R.I. Dudley).

http://dx.doi.org/10.1016/j.humov.2017.02.007
0167-9457/

The etiology of RRIs is multifactorial and certain biomechanical factors in running gait are linked to the development of RRI. For instance, greater vertical loading rates (Bredeweg, Kluitenberg, Bessem, & Buist, 2013; Davis, Bowser, & Mullineaux, 2016), greater external knee adduction moments (KAM) (Earl & Hoch, 2011), greater hip adduction angles (Ferber, Noehren, Hamill, & Davis, 2010; Milner, Hamill, & Davis, 2010), greater hip internal rotation (Niemuth, Johnson, Myers, & Thieman, 2005), ankle eversion angles (Kuhman, Paquette, Peel, & Melcher, 2016), peak ankle eversion velocity (Messier & Pittala, 1988), ankle eversion range of motion (ROM) (Viitasalo & Kvist, 1983), and rearfoot-strike types (Daoud et al., 2012) contribute to the incidence of various RRIs. Unfortunately, most studies (Daoud et al., 2012; Ferber et al., 2010; Milner et al., 2010) have utilized samples that were already injured at the time of testing, or were previously injured, and there are limited prospective data regarding biomechanical contributors to RRI. A recent study (Kuhman et al., 2016) examined the prospective influence of ankle kinematics and ground reaction force variables on RRI, but did not report knee or hip kinematics and kinetics. Importantly, knee and hip kinematics and kinetics (increased hip adduction angle, KAM) are retrospectively linked to RRI (Ferber et al., 2010; Nakagawa, Moriya, Maciel, & Serrao, 2012; Noehren, Hamill, & Davis, 2013), and the knee is the most commonly injured joint in runners (Fields, 2011). Therefore, ankle, knee, and hip kinematics and kinetics should be examined prospectively in order to build upon the current body of literature, particularly the findings regarding ankle kinematics and ground reaction force variables (Kuhman et al., 2016).

In addition to biomechanical alterations, anatomical, and training factors can contribute to RRI, and may confound any biomechanical influence on RRI. For example, retrospectively, greater training frequency (Taunton et al., 2003), and training to compete (Yang et al., 2012) contribute to RRI. Prospective research indicates that greater weekly mileage (van der Worp et al., 2016) and rapid increases in training volume (Gabbett, Hulin, Blanch, & Whiteley, 2016; Nielsen et al., 2014) lead to RRI, while greater navicular drop contributes to medial tibial stress syndrome (Bennett et al., 2001). Finally, many of the aforementioned studies have evaluated samples of recreational or novice runners (Bredeweg et al., 2013; Buist et al., 2010; Taunton et al., 2003; van der Worp et al., 2016), and collegiate runners may be at greater risk than recreational runners due to the competitive nature of their sport and volume of training (Yang et al., 2012). Despite the potential increase in risk, only two studies have examined collegiate cross country runners (Daoud et al., 2012; Kuhman et al., 2016).

The purpose of this study was to prospectively examine the influence of ankle, knee, and hip kinematics and kinetics, and GRF characteristics on RRI in a group of collegiate cross country runners over a 4-month period. We hypothesized that runners who sustained a RRI would exhibit altered biomechanics (greater vertical loading rate, greater KAM, greater hip internal rotation angle, greater hip adduction angle, greater hip adduction moment, greater knee abduction angle, greater ankle eversion angle, greater ankle eversion ROM, or greater peak ankle eversion velocity) prior to the start of the season compared to runners who did not sustain a RRI.

2. Methods

2.1. Participants

Thirty-two non-injured, NCAA Division 1, cross country athletes were initially included in the study (Table 1). As they were all part of the same collegiate team, running exposure (volume, duration, intensity, surface etc.) was similar for all participants. Participants were excluded if they were currently diagnosed with any RRI, or had sustained any RRI in the 6 months prior to the start of the study. Prior to any testing, all participants read and signed an informed consent document approved by the University's Institutional Review Board.

2.2. Experimental procedures

To account for the possible differences in static alignment of the foot between participants, navicular drop was measured (Bennett et al., 2001). The navicular tuberosity was marked with a non-toxic marker to facilitate measurement of navicular drop. The height from the flat surface of the floor to the mark was measured using a ruler while participants were seated with the knee flexed to 90°, and measured again while standing. The difference between the two measures was calculated

Table 1
Participant demographics by group (mean (95% CI)).

	Injured (n = 12)	Non-Injured (n = 19)	p-value
Sex (male/female)	4/8	11/8	–
Age (years)	20.00 (19.28, 20.72)	19.68 (19.28, 20.08)	0.422
Height (m)	1.73 (1.68, 1.78)	1.74 (1.70, 1.78)	0.710
Body Mass (kg)	62.36 (58.24, 66.48)	62.62 (59.51, 65.73)	0.923
Pre-Season Training Volume (km/week)	93.07 (82.12, 104.01)	84.54 (75.11, 93.97)	0.274
In Season Running Volume (km/week)	88.35 (80.66, 96.05)	91.27 (82.40, 100.13)	0.681
Average Training Pace (m/s)	3.85 (3.68, 4.03)	3.87 (3.74, 4.02)	0.844
Footwear Heel Drop (mm)	9.63 (7.42, 11.84)	11.15 (10.41, 11.89)	0.220
Navicular Drop (mm)	5.75 (3.85, 7.65)	6.79 (5.65, 7.93)	0.335
Tested Running Speed (m/s)	3.84 (3.65, 4.05)	3.86 (3.74, 4.00)	0.852