Human Movement Science 30 (2011) 606–613

Contents lists available at ScienceDirect

Human Movement Science

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

Comparison of longitudinal biomechanical adaptation to shoe degradation between the dominant and non-dominant legs during running

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ARTICLE INFO

Article history:
Available online 18 February 2011

PsycINFO classification:
3720

Keywords:
Asymmetry
Joint angles
Kinetics
Kinematics
Footwear

ABSTRACT

This study compared the biomechanical adaptation to running shoe degradation between the dominant (D) and non-dominant (ND) leg. Twenty-four runners performed a pre-test in the laboratory, completed 200 miles of road running in a pair of assigned shoes and then returned for a post-test. Kinetic and kinematic data of running in new and worn shoes were collected. Repeated measures ANOVA (Shoe × Leg) were used to analyze temporal, kinetic and kinematic variables ($\alpha = .05$). A symmetry index (SI) was calculated for the temporal and kinetic variables and paired *t*-tests were used to compare the SI between shoe conditions. Stance time increased by approximately 7 ms in worn shoes ($p = .027$). Bilateral differences in the kinematic change (Shoe × Leg interaction) were seen in the torso ($p < .05$), knee ($p < .05$), marginally at the hip ($p < .10$) but not the ankle. No difference in kinetic variables or SI was observed. When running in worn shoes, the torso displayed reduced forward lean for both sides and to a greater extent during the D leg strike. The D hip and knee showed a more extended position for the worn shoe condition while an increased flexion was observed in the ND leg. Most of the kinematic differences observed were small and within the intra-subject variability measured during the same session. Future studies may consider performing a three-dimensional analysis at a higher sample rate and further explore whether asymmetrical adaptation is related to running injuries.

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doi:10.1016/j.humov.2010.10.008

1. Introduction

Footwear cushioning properties degrade with increasing mileage (Cook, Kester, Brunet, & Haddad, 1985). As a result, runners modify their kinematics in order to maintain constant external loads (Kong, Candelaria, & Smith, 2009). In healthy individuals, left–right gait symmetry is generally assumed and therefore biomechanical studies commonly use an average value of both sides (e.g., Kong et al., 2009; Munro, Miller, & Fuglevand, 1987; Willems, Witvrouw, de Cock, & de Clercq, 2007) or only the right side (e.g., Bus, 2003; de Wit, de Clercq, & Aerts, 2000; Hardin, van den Bogert, & Hamill, 2004). However, inspection of worn shoes often reveals different degree and/or region of degradation between the two sides. Such difference in shoe degradation can be seen as a reflection of bilateral gait asymmetry over time. At the same time, running in a pair of worn shoes with different cushioning properties and/or geometries between the two sides may further encourage asymmetrical gait pattern.

In response to different material properties and/or geometry of the shoes, the human body adapts by adjusting the kinematics in order to regulate the external loads. These adaptation strategies can be active or passive (Boyer & Nigg, 2007; Wright, Neptune, van den Bogert, & Nigg, 1998). While previous cross-sectional studies have investigated bilateral asymmetry in running kinetics and kinematics (Karamanidis, Arampatzis, & Brüggemann, 2003; Zifchock, Davis, & Hamill, 2006), the longitudinal adaptation to footwear degradation between the two legs has not been addressed in the literature. Thus, the purpose of this study was to compare the longitudinal change in running biomechanics due to shoe degradation between the two legs.

2. Methods

2.1. Participants

Twenty-four participants (14 males, mean (*SD*): age = 27.8 (7.3) yrs., mass = 68.6 (14.1) kg, height = 170.2 (7.3) cm) gave consent and participated in the study. All procedures were approved by the University of Texas at El Paso Institutional Review Board. Participants ran at least 20 miles per week for 2 years preceding the study and had not experienced any lower extremities injuries during this period.

2.2. Experimental procedures

On the pre-testing day, participants completed a standardized 10-min warm-up session that included stretching and a treadmill run in a pair of assigned new running shoes. Originally, participants were divided into three groups, each assigned with different types of running shoes. Since no difference in any measured variables was found among the three types of footwear (Kong et al., 2009), data from all three groups were combined in the present study. After the warm-up, participants were asked to run along a 20-m runway at 4.5 m s^{-1} while synchronized kinetic and kinematic data were recorded. Each participant made five right followed by five left foot contacts with a force platform (Advanced Mechanical Technology Inc., Model OR6-6-2000, Watertown, MA) located in the middle of the runway. A successful contact was defined as the participant's foot striking the force platform while running at a speed of 4.5 m s^{-1} (±1%) without altering their running technique. Speed was measured by a radar gun (Radar Sales, Plymouth, MN). At the end of the pre-testing participants were instructed to complete 200 miles of road running in their assigned shoes before returning to the laboratory for post-testing of which the procedures were identical to the pre-testing. Since many participants alternated testing shoes with personal shoes during their training, the completion time for 200 miles varied from 3 to 22 weeks (mean ± *SD* = 16.5 ± 5.0 weeks).

2.3. Data reduction

During the running trials, ground reaction forces (GRF) were collected at 1200 Hz and low-pass filtered at 100 Hz in MATLAB (The MathWorks, Natick, MA). To obtain kinematic data, reflective markers