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Exertion and pain do not alter coordination variability in runners with iliotibial band syndrome

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ABSTRACT

Background: Iliotibial band syndrome is a common overuse running injury which results in altered mechanics. While injuries alter discrete mechanics, they may also cause a change in coordination variability, the stride-to-stride organization of runners' movement patterns. Uninjured and injured runners may experience a change in coordination variability during a run to exertion due to fatigue, pain, or a combination of these factors. The aim of the current study was to determine if runners with iliotibial band syndrome and uninjured runners display different segment coordination variability across the course of a run to exertion.

Methods: 3D kinematics were collected as 13 uninjured runners and 12 runners with iliotibial band syndrome ran on a treadmill. A modified vector coding technique was used to calculate coordination variability during stance for segment couples of interest. Coordination variability was compared between uninjured and injured runners at the beginning and end of the run. The influence of pain on coordination variability was also examined.

Findings: There were no differences in coordination variability at the beginning or end of the run between uninjured runners and those with iliotibial band syndrome. The change in coordination variability due to the run was not different between uninjured runners, injured runners who experienced no change in pain, and injured runners who did experience a change in pain.

Interpretation: Runners do not constrain the patterns of segment motion they use in response to exertion nor does it appear that occurrence of pain during running results in a differential change in coordination variability.

1. Introduction

Running is a popular form of exercise which results in overuse injury in as many as 79% of participants (van Gent et al., 2007). One of the most common overuse running injuries is iliotibial band syndrome (ITBS) (Taunton et al., 2002) which is characterized by pain in the lateral aspect of the knee that often worsens progressively throughout a run. The mechanism for ITBS injury is thought to be altered joint mechanics. Previous studies have demonstrated that runners with a history of (Ferber et al., 2010; Miller et al., 2007), those who go on to develop (Noehren et al., 2007) and those currently experiencing (Grau et al., 2011) ITBS display altered joint mechanics in comparison to healthy runners (Foch et al., 2015). Runners with a history of ITBS also have a different mechanical response to a run to exertion than that of uninjured runners (Miller et al., 2007). This differential response to an extended duration run in runners with a history of or current ITBS has been suggested to be a result of the onset or avoidance of pain. However, recent studies have found that, in comparison to uninjured runners, those with a history of ITBS or currently symptomatic ITBS display few (Brown et al., 2016) or none (Foch and Milner, 2014; Foch et al., 2015) of these specific differences in joint mechanics. Thus, studies of discrete kinematic variables fail to provide a clear picture of the role of both exertion and pain in the alteration of movement patterns with ITBS.

It has been proposed that as a consequence of altered muscle activity in response to or to avoid a painful stimulus, variability in the coordination of movement may decrease (Hamill et al., 1999; Hodges and Tucker, 2011). Overuse running injuries in general, and ITBS specifically, have been associated with decreased coordination variability (as assessed through various methods; (Heiderscheit et al., 2002, Miller et al., 2008)). Lower coordination variability suggests decreased flexibility of the motor system as an individual uses fewer patterns of joint or segment motion to produce a complex task, such as locomotion (Newell, 1985). As a consequence of using fewer patterns of segment motion, lower segment coordination variability may also be suggestive of mechanics that are restricted to a narrow area or range of tissues.

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Thus, decreased segment coordination variability in runners may be a manifestation of an individual's attempt to avoid pain during a run or an inability to access their full range of movement patterns due to an injury (Hamill et al., 2012). In uninjured runners and those with a history of injury, segment coordination variability appears to change over the course of a run, perhaps as a consequence of exertion or muscle fatigue (MacLean et al., 2010). Thus, the onset or presence of muscle fatigue during a run may compound the effects of injury on segment coordination variability. For runners with current ITBS, there is currently a lack of data on segment coordination variability, and it is unknown how this coordination variability may change during an extended run or in response to an increase in pain throughout a run.

The aim of the current study was to determine if runners with ITBS and uninjured runners display different segment coordination variability over the course of a run to high exertion. It was hypothesized that there would be differences in coordination variability between groups (uninjured coordination variability > ITBS coordination variability) and across time (beginning vs. end of run), and that the uninjured and ITBS groups would display a different change in coordination variability in response to the run (group × time interaction). While ITBS pain typically presents in response to running, our previous work with an ITBS population suggests there is significant inter-individual variance in this pain increase. If the current study participants displayed varied pain responses, we sought to explore whether different levels of induced pain altered the uninjured vs. ITBS comparisons.

2. Methods

2.1. Participants

Two groups of female runners were recruited for this study: those who were free from neuromuscular and musculoskeletal injury in the previous 6 months, and those who had iliotibial band syndrome. Based on previous studies, at least 10 participants per group were needed for between-group comparisons (Cunningham et al., 2014) and at least 4 participants per group were needed for repeated measures comparisons (Hafer et al., 2016) to achieve a power level of 0.8 with an alpha level of 0.05. Iliotibial band syndrome status was verified by a physician or a physical therapist based off of reported symptoms of lateral knee pain during a run and positive Noble Compression test. Individuals qualified for the study if they were currently running at least 15 miles/week, were able to run at least one 9-minute mile and were a rearfoot striker. A study investigator (AB) visually verified that each individual was a rearfoot striker prior to enrollment in the study. This was confirmed by inspection of kinematics after data were collected. All procedures were approved by the institutional review board for human subjects research. All participants provided written informed consent prior to completing any study procedures.

2.2. Instrumentation

Twelve motion analysis cameras (Motion Analysis Corporation, Santa Rosa, CA, USA) were used to collect 3-dimensional kinematic data. Retroreflective markers were placed on designated locations to define the trunk (right and left acromioclavicular joints and sacro-lumbar joint), pelvis (left and right ASIS and sacro-lumbar joint), thigh (functionally-determined hip joint center and medial and lateral femoral epicondyles), shank (medial and lateral femoral epicondyles, tibial tuberosity, and medial and lateral malleoli), foot (heel and first and fifth metatarsal heads), and rearfoot (superior and inferior, lateral and medial aspects of the proximal calcaneus). Additional array clusters were placed on the thigh and shank for segment tracking purposes. All participants wore standard, lab-provided footwear (New Balance 1062, Boston, MA, USA) and rearfoot markers were attached to participants' feet through windows cut in the shoes. Kinematic data were sampled at 120 Hz.

2.3. Experimental protocol

Data collection began with the collection of a static calibration trial used to calculate segment characteristics and knee and ankle joint centers. In addition, a dynamic calibration trial was captured and used to calculate a functionally determined hip joint center (Schwartz and Rozumalski, 2005). Next, participants ran on a treadmill at a self-reported 5-kilometer race pace for a 3 minute acclimatization period at which time 30 s of pre-exertion 'beginning of run' data were collected. Participants then continued their treadmill run at their self-selected race pace until volitional exhaustion with data captured every 3 min. Level of exertion and pain were also monitored every 3 min throughout the run to exertion. Exertion was quantified using the Borg Rating of Perceived Exertion (RPE) scale (Borg, 1982). Pain symptoms were monitored using the Borg CR-10 verbal numerical rating scale (vNRS). Once participants reached an RPE of 17/20 or a vNRS rating of 6/10, a final 30 s of post-exertion 'end of run' data were collected. An increase in vNRS pain of 2 points was considered a clinically significant change (Farrar et al., 2001).

2.4. Data processing

Ten strides of data were extracted for runners' dominant (uninjured participants) or injured (ITBS participants) limb from their pre- and post-exertion data collection (Hafer and Boyer, 2016). Data were processed with custom code written in LabView (National Instruments, Austin, TX) and Visual 3D (C-Motion, Inc., Rockville, MD). Bi-directional second-order low-pass Butterworth filters achieving fourth-order attenuation were used to smooth kinematic data at 8 Hz. Segment angles for the pelvis, thigh, shank, and rearfoot with respect to the global coordinate system were calculated and normalized to 100% of the gait cycle for each trial.

Segment coordination was calculated using a custom MATLAB (MathWorks, Natick, MA) program. Angle-angle plots of the couplings of interest were created and coupling angles (Θ) were calculated as the angle with respect to the right horizontal created by the vector connecting two consecutive time points (Chang et al., 2008):

$$\Theta_{i,j} = \tan^{-1}\left[(y_{i,j+1} - y_{i,j})/(x_{i,j+1} - x_{i,j})\right]$$

where $0 \leq \Theta \leq 360^\circ$ and j is a percent gait cycle of the ith trial. Coupling angles were calculated using circular statistics (Batschelet, 1981). Coordination variability was calculated as the circular standard deviation of the coupling angle at each individual point of the gait cycle across ten strides of data (Batschelet, 1981). This circular standard deviation was averaged across the stance phase for each subject. Couplings of interest included frontal pelvis rotation vs. frontal thigh rotation, sagittal thigh rotation vs. sagittal shank rotation, sagittal thigh rotation vs. transverse shank rotation, and transverse shank rotation vs. frontal rearfoot rotation couples. These couplings were selected as they contribute to joint kinematics which are thought to increase iliotibial band strain (Hamill et al., 2008; Miller et al., 2007).

2.5. Statistics

Statistical tests were carried out to compare the mean stance phase coordination variability between groups for each of the four coupling angle comparisons of interest. In accordance with the hypotheses that coordination variability would be different between 1) uninjured runners and those with ITBS and 2) the beginning and end of the run, coordination variability was compared by group (uninjured vs. ITBS) and across time (beginning vs. end of run) using 2-way ANOVAs with time as a within-subjects variable. If significant interactions were found, paired *t*-tests were used to examine main effects within the interaction. As it was discovered post-hoc that ITBS runners had varied pain responses to the run to exertion, exploratory statistics were