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Original Research—CME

Metabolic, Cardiopulmonary, and Gait Profiles of Recently Injured and Noninjured Runners

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Abstract

Objective: To examine whether runners recovering from a lower body musculoskeletal injury have different metabolic, cardiopulmonary, and gait responses compared with healthy runners.
Design: Cross-sectional study.
Setting: Research laboratory at an academic institution.
Methods: Healthy runners (n = 50) were compared with runners who were recently injured but had returned to running (n = 50). Both groups were participating in similar cross-training modalities such as swimming, weight training, biking, and yoga. Running gait was analyzed on a treadmill using 3-dimensional motion capture, and metabolic and cardiopulmonary measures were captured simultaneously with a portable metabolic analyzer.
Main Outcome Measures: Rate of oxygen consumption, heart rate, ventilation, carbohydrate and fat oxidation values, gait temporospatial parameters and range of motion measures (ROM) in the sagittal plane, energy expenditure, and vertical displacement of the body's center of gravity (COG).
Results: The self-selected running speed was different between the injured and healthy runners (9.7 ± 1.1 km/h and 10.6 ± 1.1 km/h, respectively; $P = .038$). No significant group differences were noted in any metabolic or cardiopulmonary variable while running at the self-selected or standard speed (13.6 km/h). The vertical displacement of the COG was less in the injured group (8.4 ± 1.4 cm and 8.9 ± 1.4, respectively; $P = .044$). ROM about the right ankle in the sagittal plane at the self-selected running speed during the gait cycle was less in the injured runners compared with the healthy runners ($P < .05$).
Conclusions: Runners with a recent lower body injury who have returned to running have similar cardiopulmonary and metabolic responses to running as healthy runners at the self-selected and standard speeds; this finding may be due in part to participation in cross-training modes that preserve cardiopulmonary and metabolic adaptations. Injured runners may conserve motion by minimizing COG displacement and ankle joint ROM during a gait cycle.

Introduction

Lower extremity noncatastrophic injuries are common in runners, with annual estimates ranging from 37% [1] up to 68% [2]. Prevalence of specific injuries is estimated to be 5%-14% for iliotibial band syndrome [3], 7.4%-15.6% for patellofemoral syndrome [4], and between 9.5%-20.0% for tibial stress syndrome and plantar fasciitis, respectively [4]. Runners who have longer running histories are less likely to incur injury compared with runners who have fewer years of running experience [5]. During the return to run phase after injury, physiologic factors such as pain may affect overall performance and running economy. For example, altered gait patterns [6], foot strike, or cadence values may occur in an effort either consciously or subconsciously to offload the injured limb. Injury may cause runners to constrain running motion either by minimizing vertical displacement of the center of gravity (COG) or reducing the joint range of motion (ROM) excursion during a gait cycle, or both. All of these factors can contribute to metabolic and cardiopulmonary alterations that change the demand for oxygen delivery. A reduction in running economy can translate into significant additional caloric requirements over time, which results in increased heart rate (HR) and ventilation, premature fatigue [7], and suboptimal performance. Performance can also be limited by suboptimal

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energy management of fats and carbohydrates [8], with heavy reliance on carbohydrates leading to premature muscle fatigue. Also, it can be speculated that residual fear of reinjury during the return to run phase may cause the runner to adopt aberrant running mechanics, conserve running motion, or reduce training speed.

Presently, it is not known whether runners who are recovering from a recent, noncatastrophic lower body injury have similar metabolic, cardiopulmonary, or gait profiles as their healthy counterparts. A possible scenario is that runners who are coping with recent injury have since adopted symmetrical or conservative gait patterns to protect the body against further injury. The purpose of this study was to determine the metabolic, cardiopulmonary, and gait responses of runners recovering from a noncatastrophic lower body musculoskeletal injury compared with healthy noninjured runners. It was hypothesized that injured runners would demonstrate higher metabolic and cardiopulmonary responses to a given exercise workload than would noninjured healthy runners because of a decrease in training volume. It was also hypothesized that injured runners would demonstrate more constrained temporospatial gait parameters and less lower extremity joint ROM during running than would healthy runners. These findings will be clinically relevant in providing recovery performance expectations and customized, multicomponent rehabilitation programs for runners returning to running after a lower body musculoskeletal injury.

Methods

Study Design

The subjects are a subset of participants from a larger cross-sectional study (N = 300). A total of 100 runners volunteered for this study. Subjects were stratified on the basis of their injury history (healthy or injured) for statistical analysis of study outcomes. This study and its procedures were approved by the University of Florida Institutional Review Board, and the study complies with the guidelines of Declaration of Helsinki for the treatment of human subjects.

Participants and Study Inclusion/Exclusion Criteria

Runners were recruited using study flyers, Web-based advertisements, and the clinical trials register. Inclusion criteria included persons aged 16-75 years who were currently running at least 12 km/wk and were able to run on a treadmill continuously for at least 20 minutes. Healthy runners reported no injuries within the preceding 6 months causing a decrease in weekly running mileage, a score no less than 72/80 on the Lower Extremity Functional Scale (LEFS) [9], and no greater than a 6% disability score on the Oswestry Disability Index [10].

Exclusion criteria included the presence of an acute or catastrophic injury that prevented the ability to run continuously for 20 minutes on a treadmill; physician orders to avoid running; symptomatic cardiovascular disease; severely impaired intellectual capacity; medications that could affect balance; and dementia or other neurodegenerative diseases that would preclude appropriate cognitive or physical ability to understand or perform the study protocol. All participants read and signed an informed consent form approved by the University's Institutional Review Board. A health history and training history form was completed for self-reporting of demographics, comorbidities, previous injuries, running experience, and foot strike. Participants were matched for gender, age, and body mass index (BMI).

Demographics and Running Histories

Demographics were collected on an electronic survey and included race, gender, height, weight, BMI, marital status, and self-classification of running competition (ie, elite, recreational competitive, recreational, high school, or college competitive). A detailed running history was documented on this electronic record and included preferred training surface, average weekly running distance, average distance of long runs, participation in and frequency of speed work, and current running shoes. Characteristics of the running shoe worn during the testing session were recorded (ie, weight and heel to toe drop [the length in millimeters that the sole of the shoe decreases in thickness from the heel to the toe]) to account for potential variables that could affect metabolic parameters. Other training modalities were assessed using checkbox choices for swimming, biking, stair climbing/stadium stairs, weights and resistance exercise, yoga, and other.

Injury Status

Participants' injury history included information about the side and area of injury and current discomfort levels. The LEFS was designed to measure a broad spectrum of lower extremity problems to address the difficulty of utilizing multiple joint or structure specific scoring systems. The LEFS is reliable and sensitive to changes in physical function of patients with lower extremity dysfunction. The LEFS is also efficient to administer and score and is applicable to research populations. An LEFS score of $>$72 out of 80 points was considered "injured" status. The injuries were self-reported as chronic conditions (pain onset over time) or as a nagging musculoskeletal pain that worsened after a competitive event. None of the injuries was catastrophic in nature. The injuries were grouped by