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JSAMS-1001; No. of Pages 6

ARTICLE IN PRESS

Journal of Science and Medicine in Sport xxx (2014) xxx–xxx

Contents lists available at ScienceDirect

Journal of Science and Medicine in Sport

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

Original research

Rocker shoes reduce Achilles tendon load in running and walking in patients with chronic Achilles tendinopathy

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ARTICLE INFO

Article history:
Received 25 October 2013
Received in revised form 7 January 2014
Accepted 6 February 2014
Available online xxx

Keywords:
Biomechanics
Kinetics
Kinematics
Footwear
Rocker sole
Rocker bar

ABSTRACT

Objectives: Relative rest and pain relief play an important role in the management of Achilles tendinopathy, and might be achieved by reducing the load on the Achilles tendon. Previous studies have provided evidence that rocker shoes are able to decrease the ankle internal plantar flexion moment in healthy runners during walking and running. Since plantar flexion moment is related to the Achilles tendon loading, rocker shoes might be considered in the conservative management of Achilles tendinopathy. Therefore, the aim of this study was to investigate the biomechanics of running and walking in a group of patients with Achilles tendinopathy wearing standard shoes versus rocker shoes.
Design: Cross-over.
Methods: Thirteen Achilles tendinopathy patients (mean age 48 ± 14.5 years) underwent three-dimensional gait analysis wearing standard running shoes and rocker shoes during running and walking. Surface electromyography of triceps surae and tibialis anterior was recorded simultaneously.
Results: Patients had symptoms for an average of 22.5 months (median 11.5 months) and VISA-A scores were 54 ± 16. With the rocker shoes, the peak plantar flexion moment was reduced by 13% in both running (0.28 N m/kg, $p < 0.001$) and walking (0.20 N m/kg, $p < 0.001$). The peak activity of tibialis anterior was increased by 35% ($p = 0.015$) for the rocker shoes in walking. There was no difference between electromyography peak amplitudes of triceps surae between two shoe sessions in both activities.
Conclusions: When used by patients with chronic Achilles tendinopathy, rocker shoes cause a significant reduction in plantar flexion moment in the late stance phase of running and walking without substantial adaptations in triceps surae muscular activity.

1. Introduction

Achilles tendinopathy (AT) is the most frequently reported injury related to the ankle and foot in different sport activities.[1] High incidence rates of 7.8 (per 1000 athlete-week exposure), 83.3 (per 1000 athlete-year exposure) and 107.1 (per 1000 athlete-season exposure) have been reported for AT among runners.[1] AT is not limited to athletic populations only. An incidence rate of 2.35 per 1000 subjects was reported for this injury in the general population (21–60 years) as well.[2] AT is characterized by localized pain and swelling at the Achilles tendon which often becomes a chronic condition that leads to loss of occupational capacity and reduced athletic performance.[3] The aetiology of Achilles tendinopathy is likely to be multifactorial but the exact underlying mechanism has not been clarified completely. Overuse, poor tissue vascularity, mechanical imbalances of the extremity, and a genetic predisposition are believed to be related to Achilles tendinopathy.[4]

Load management plays an important role in conservative management of overuse tendinopathies. Load reduction might help to relieve pain and allows for tendon adaptation.[5] The Achilles tendon is highly vulnerable to overuse injuries because of the repetitive overload to which it is subjected during running and walking activities. In the propulsion phase of running for instance, the load to the Achilles tendon can exceed eight times body weight per step.[6,7]

Forward progression in gait is primarily caused by *the internal plantar flexion moment* (hereafter referred to as PFM) generated by

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http://dx.doi.org/10.1016/j.jsams.2014.02.008

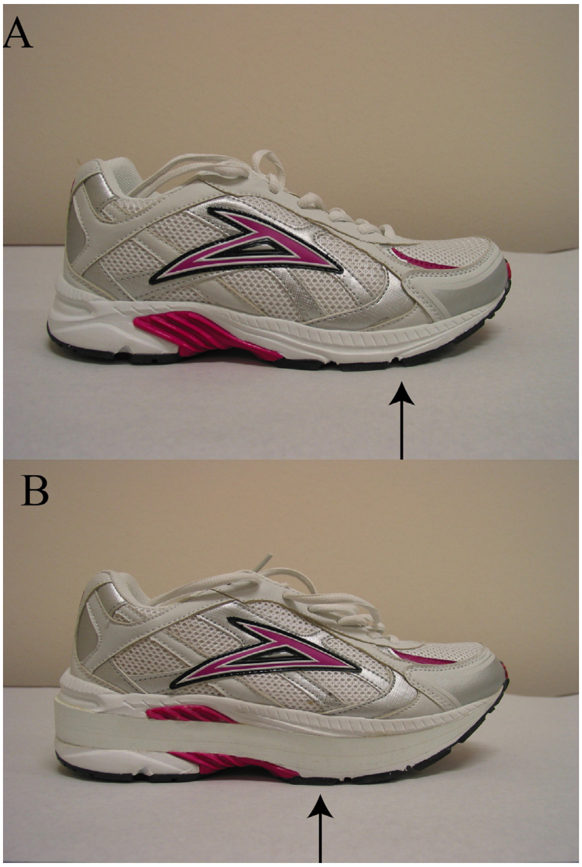

Fig. 1. Investigated shoes in this study: (A) standard running shoes, and (B) rocker shoes. The black arrows indicate the shoe apex (rolling-point).

the triceps surae.[8–10] PFM is calculated as a product of Achilles tendon force (estimated from external forces) and the Achilles tendon moment arm during the plantar flexion effort.[10,11] Thus, PFM is generally used to quantify the magnitude of the load applied to the Achilles tendon.[11–13]

One possible way to reduce PFM and consequently load on the Achilles tendon is to use rocker shoes during locomotion. During the roll-off, the application point of the ground reaction force is normally located at the metatarsophalangeal joint with standard shoes (see black arrow in Fig. 1A). With rocker shoes, however, the application point is applied at the rocker apex instead, proximal to the metatarsophalangeal joint (see black arrow in Fig. 1B). This proximal shift in the position of the ground reaction force vector causes a smaller external dorsiflexion moment due to a shorter moment arm. Since internal moments need to be counterbalanced, a smaller external dorsiflexion moment indicates a smaller PFM (the simplified mechanism, as a static condition, is illustrated in Fig. S1 as Supplementary file).

Previous studies in healthy people have provided considerable evidence that wearing rocker shoes are effective in reducing PFM in both running and walking activities.[14–16] Rocker shoes, therefore, are believed to be useful in the conservative management of Achilles tendinopathy by reducing PFM.[14,15]

Since we do not know if AT patients adapt their gait pattern, it is still unknown if similar results, as for healthy runners, can be observed for AT patients.[14,15] Therefore, the purpose of this study was to extend previous research by investigating the biomechanics of slow running (referred to as running hereafter) and walking in response to a rocker shoe in AT patients, with the ultimate goal to obtain more insight into the possible role of rocker shoes in the conservative management of AT.

2. Methods

The study protocol received the approval of local medical ethical committee (METc2011/030). Eligible patients were invited to participate in the study after a clinical examination by an experienced sports physician (JZ). The following criteria were considered: (a) unilateral tendinopathy located 2–6 cm proximal to the insertion of the Achilles tendon on the calcaneus, (b) pain for at least 3 months, (c) Achilles tendon abnormality objectified in power Doppler ultrasound imaging (hypoechogenity, thickening of tendon, neovessels), (d) a score <80 on the Victorian Institute of Sport Assessment-Achilles (VISA-A),[17,18] (e) experiencing no other medical problem or pain over the last year that could interfere with normal running and walking patterns. Those patients who were interested received information on the purpose and conduct of the study and signed written informed consent.

A pair of standard running shoes was used as the baseline shoe (Fig. 1A). Another pair of the same model of shoes was modified with a stiffened rocker profile by a certified orthopaedic shoe technician (Fig. 1B). The shoes were available for participants in different sizes. The apex (rolling point) of the standard and rocker shoes was respectively at 65% and 53% (proximal to metatarsal region)[19] of the shoe length from the heel. The rocker profile thickness for different sizes was 2.2 ± 0.1 cm at the apex and under the heel. Depending on shoe sizes, the mass of a pair of standard shoes was on average 467 ± 87 g, and the mass of a pair of rocker shoes was 805 ± 157 g.

An eight-camera motion capture system (Vicon, Oxford, UK) was used to measure the kinematics by tracking sixteen reflective markers placed bilaterally on the following anatomical landmarks (lower body Plug-in-Gait model): the posterior superior iliac spine, anterior superior iliac spine, lateral thigh, lateral femoral epicondyle, lateral shank, lateral malleolus, calcaneus and second metatarsal head. Analogue force data were measured by two force plates (AMTI; Watertown, MA). A wireless electromyography (EMG) system (Zero-wire, Aurion, Italy) was used simultaneously to record the muscle activity. EMG measurements were conducted according to the SENIAM guidelines for surface EMG.[20] EMG electrodes were placed bilaterally on lateral gastrocnemius, medial gastrocnemius, soleus and tibialis anterior muscles, and they were not removed during the entire measurement session.

The experimental procedures were conducted in a 10-m long gait lab and lasted about 2 h for each participant. The design used in this study was a type of cross-over design. For each participant all measurements, consisting of two parts (standard and rocker shoes), were completed in one session. Participants were asked to run and walk overground with the standard shoes in one part, and run and walk with the rocker shoes in another part at their own comfortable speed. The order of activities (running and walking) and shoes (standard and rocker) was randomly assigned to participants, trying to maintain a balance in the number of participants for the eight different orders.

Participants were given 15 min to get accustomed to each kind of shoes. After this period, we asked the patients if they needed more time. If the patients asked for more time, additional familiarization was permitted until they felt comfortable with the shoes. After instrumentation, each patient was asked to perform six running and walking trials at their comfortable speed to determine the average speeds. To minimize the effect of speed on biomechanical parameters, all actual trials were required to be within $\pm 5\%$ of the determined average self-selected speed.[21] Speed was monitored with an iPad positioned 1.5 m from the force plates using a video radar application (SpeedClock, Sten Kaiser©, version 3.1). Seven acceptable trials were required (for each shoe and activity) and were defined as those in which participants completely contacted the force plate with the injured leg with the appropriate