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Published in:
Journal of Science and Medicine in Sport

DOI:
10.1016/j.jsams.2014.02.008

IMPORTANT NOTE: You are advised to consult the publisher's version (publisher's PDF) if you wish to cite from it. Please check the document version below.

Document Version
Publisher's PDF, also known as Version of record

Publication date:
2015

Link to publication in University of Groningen/UMCG research database

Citation for published version (APA):
Sobhani, S., Zwerver, J., van den Heuvel, E., Postema, K., Dekker, R., & Hijmans, J. M. (2015). Rocker shoes reduce Achilles tendon load in running and walking in patients with chronic Achilles tendinopathy. *Journal of Science and Medicine in Sport*, *18*(2), 133-138. https://doi.org/10.1016/j.jsams.2014.02.008

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Journal of Science and Medicine in Sport 18 (2015) 133–138

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 14 February 2014

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
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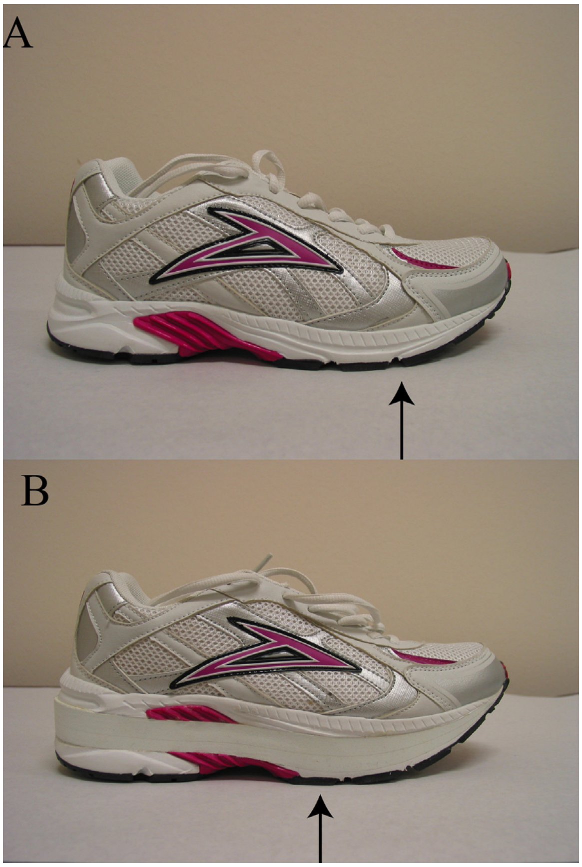

Fig. 1. Investigated shoes in this study: (A) standard running shoes, and (B) rocker shoes. The black arrows indicate the shoe apex (rolling-point).

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 ±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 speed and without targeting. Immediately after the 7 trials of each activity, the Achilles tendon pain was assessed using an 11 points scale (0 no pain, 10 extreme pain). The exact same procedures were followed for the second part of the session with the other shoes.

VICON Nexus® software (Plug-in-Gait model) was used to compute joint kinematics and kinetics, and together with EMG data were exported to MatLab™ software (R2010a) for further processing. The time–distance parameters were calculated using MatLab. Moreover, electrode artefacts were removed from raw EMG data, with a 20 Hz high-pass filter (Butterworth, 4th order), and then rectified and smoothed with a 24 Hz low-pass filter (Butterworth, 4th order).[22] Then, kinetics, kinematics and EMG data were scaled as a percentage of a stride (heel contact of one foot to heel contact of the same foot). Kinetic variables were all normalized for body mass.

To assess the changes of PFM, two parameters were considered, maximum PFM (peak) and the area under the PFM time graph (impulse). The other kinetic variables included ankle power generation (the peak positive values in late stance), and peak knee and hip flexion moment. The kinematic data were only assessed for the ankle joint and included peak angle (in late stance) and total range of motion (RoM) during the total gait cycle. For each muscle, the peak and time of peak occurrence (% gait cycle) were calculated from enveloped EMG signals. Calculated time-distance variables included speed (m/s), step length (m), cadence (steps/min) and stance phase (as % of the gait cycle). Among biomechanical variables, the primary outcome was peak PFM, and all other variables were secondary. Sagittal plane kinetic and kinematic variables were assessed in the late stance (LS) phase of running and walking. LS was defined as 20–40% of the gait cycle for running (propulsion phase),[23,24] and 30–60% of the gait cycle (combined phases of terminal stance and pre-swing) for walking.[25] The only exemption was PFM impulse which was calculated as the area under PFM/time curve in stance without normalization (N m s). To provide insight into a possibly sudden change (positive or negative) in Achilles tendon pain, the level of pain was also assessed as a secondary outcome.

Descriptive statistics are presented for some of the characteristics of the study participants (PASW Statistics 18.0). For the biomechanical variables the results of the seven trials were first averaged for each participant under each testing condition, leading to four responses (two shoes and two activities) per participant. A marginal linear mixed model, using an unstructured four-dimensional variance-covariance matrix, was fitted with SAS (Institute, Inc., version 9.3), to the four average values per participant for each parameter separately. The same statistical model was used to analyze the pain scores. Type III tests, using Kenward–Rogers degrees of freedom, were used to determine the effect of type of shoes for running and walking separately. To correct for multiplicity, these tests were considered significant at the level of 0.025. Furthermore, the effects of type of shoe were all corrected for effects due to the part of the session (i.e. period effect in cross-over terminology), the order in shoes, and the order of movement nested within the part of the session.

3. Results

During the recruitment period, 14 patients were eligible for this study. One patient refused to participate because of time constraints, and therefore in total 13 patients (11 females and 2 males) were included. The population's characteristics (mean ± standard deviation) were as follows: age 48 ± 14.5 years, height 172 ± 7 cm and weight 77 ± 14 kg. Duration of the AT ranged from 4 months to 9 years (mean 22.5 months, median 11.5 months) and VISA-A scores were 54 ± 16. For 8 patients AT was diagnosed on the right side and for 5 patients on the left side. Patients developed symptomatic AT while participating in different sports activities: running (5 patients), body fitness (4 patients), gymnastics (1 patient), golf (1 patient), and yoga (1 patient). One patient was physically active without doing any specific sports.

The linear mixed model demonstrated no order effects for the shoes and activities. The mean and 95% confidence interval of all outcome variables, differences and statistical comparisons between two shoe conditions are presented in Tables 1 (running) and 2 (walking). The joint moments during running and walking, collected from one participant, are presented as a Supplementary file. The main findings are presented in the next two paragraphs, first for running and then for walking. The numbers in the parentheses (with two values) are, respectively, mean difference and mean percentage difference between two shoes for associated outcome measures.

Running with the rocker shoes caused a significant ($p < 0.001$) reduction in PFM (0.28 N m/kg, 13%), PFM impulse (0.05 N m s/kg, 15%) and peak ankle power generation (1.80 W/kg, 23%). While the ankle RoM was not affected by the rocker shoes, the dorsiflexion peak angle in LS was reduced significantly ($p < 0.001$) (3.21°, 11%). No significant differences were observed in the peak knee and hip flexion moments between rocker and standard shoes in LS. The only significant changes in EMG variables in response to the rocker shoes was a delay of about 4% of the gait cycle in time of peak activity of lateral gastrocnemius ($p = 0.001$).

The time–distance parameters did not differ significantly between rocker and standard shoes. There was no difference between the Achilles tendon pain between the two shoes ($p = 0.845$).

Walking with the rocker shoes caused a significant ($p < 0.001$) reduction in the peak PFM (0.20 N m/kg, 13%), PFM impulse (0.06 N m s/kg, 19%) and peak ankle power generation (0.80 W/kg, 21%). Walking with the rocker shoes reduced significantly ($p < 0.001$) both the dorsiflexion peak angle (3.23°; 20%) and RoM (3.75°, 14%) when compared with the standard shoes. Walking with the rocker shoes did not change the knee flexion moments in LS. The hip flexion moments however, were reduced (0.09 N m/kg, 8%) significantly ($p = 0.019$). While EMG peak amplitude of triceps surae was not changed, the peak activity of tibialis anterior was significantly ($p = 0.015$) increased (61.77 μV, 35%) for the rocker shoes. The time–distance parameters did not significantly differ between rocker and standard shoes. There was no difference between the Achilles tendon pain between the two shoes ($p = 0.982$).

4. Discussion

To the best of our knowledge, this is the first study that demonstrated that rocker shoes can effectively decrease PFM during running and walking in AT patients. Our findings confirm previous work in healthy people and provide additional biomechanical information to support the possible role of rocker shoe in the conservative management of patients with chronic AT.

Our results showed that ankle kinetics in the sagittal plane were considerably reduced by the rocker shoes compared with the standard running shoes during running. Peak PFM and PFM impulse were reduced by 13% and 15% respectively, and peak power generation was 23% lower for the rocker shoes. These findings are very similar to previous work in healthy group[14] where peak PFM, PFM impulse and peak power generation were all reduced by more than 10% with the rocker shoes.[14] In another study with a healthy group, Boyer and Andriacchi reported a reduction of 12% in ankle peak PFM in late stance of running with MBT™ rocker shoes relative to the standard shoes.[15]

Table 1
Comparison of all outcome variables between standard and rocker shoes during slow running.

Variables	Standard shoe[a] [95% CI]	Rocker shoe[a] [95% CI]	Difference [95% CI]	*p*-Value[b]
Ankle				
Plantarflexion moment				
Peak (N m/kg)	2.12 [1.95; 2.28]	1.84 [1.67; 2.02]	0.28 [0.16; 0.32]	<0.001
Impulse (N m s/kg)	0.32 [0.27; 0.35]	0.27 [0.23; 0.31]	0.05 [0.03; 0.06]	<0.001
Power				
Peak power generation (W/kg)	7.67 [6.75; 8.59]	5.87 [4.92; 6.82]	1.80 [1.22; 2.38]	<0.001
Angle				
Max dorsiflexion (°)	28.40 [26.34; 30.47]	25.20 [23.10; 27.34]	3.21 [1.79; 4.64]	<0.001
Range of motion (°)(GC)	41.86 [37.44; 46.27]	41.01 [36.53; 45.49]	0.84 [−0.20; 1.89]	0.100
Knee flexion moment				
Peak (N m/kg)	0.18 [0.09; 0.27]	0.19 [0.11; 0.28]	−0.02 [−0.10; 0.13]	0.753
Hip flexion moment				
Peak (N m/kg)	0.72 [0.65; 0.80]	0.71 [0.65; 0.78]	0.01 [−0.06; 0.07]	0.778
EMG				
Medial gastrocnemius				
Peak (μV)	251.10 [185.35; 316.86]	255.81 [190.43; 321.18]	−4.70 [−28.10; 18.70]	0.670
Time of peak (% GC)	21.51 [18.90; 24.13]	24.08 [21.63; 26.54]	−2.57 [−5.68; 0.54]	0.094
Lateral gastrocnemius				
Peak (μV)	215.65 [155.95; 275.36]	237.24 [181.87; 292.61]	−21.59 [−90.95; 47.77]	0.509
Time of peak (% GC)	20.51 [17.47; 23.56]	24.45 [21.61; 27.30]	−3.94 [−5.80; −2.09]	0.001
Soleus				
Peak (μV)	224.94 [140.05; 309.83]	247.50 [166.92; 328.08]	−22.56 [−87.01; 41.90]	0.449
Time of peak (% GC)	19.52 [15.10; 23.95]	21.15 [16.98; 25.32]	−1.63 [−6.20; 2.94]	0.424
Tibialis anterior				
Peak (μV)	198.56 [142.57; 254.55]	228.23 [170.87; 285.59]	−29.67 [−79.96; 20.62]	0.211
Time of peak (% GC)	8.51 [4.88; 12.14]	4.72 [0.69; 8.75]	3.79 [−1.46; 9.04]	0.139
Speed (m/s)	2.11 [2.00; 2.24]	2.08 [1.97; 2.20]	−0.03 [−0.04; 0.10]	0.387
Step length (m)	0.86 [0.81; 0.91]	0.84 [0.79; 0.89]	0.02 [−0.03; 0.07]	0.349
Cadence (steps/min)	140.60 [131.27; 149.86]	145.31 [137.00; 154.00]	−4.74 [−12.30; 2.83]	0.193
Stance (%GC)	45.6 0 [43.9; 47.3]	44.24 [42.50; 46.02]	1.35 [0.03; 2.67]	0.046
Pain (0–10)	2.83 [1.57; 4.09]	2.97 [1.58; 4.36]	0.14 [−1.82; 1.55]	0.845

GC, complete gait cycle.

[a] Values include mean [95% confidence interval].

[b] The statistical significance level is set at $p < 0.025$.

The reduced peak PFM coincided with a small (approximately 3 degrees) reduction in ankle dorsiflexion angle in late stance which was also observed in previous research.[14] These changes in ankle kinetics and kinematics were not accompanied with significant changes in knee and hip moments. Regarding EMG data, the only significant change was a delay in the peak activation of lateral gastrocnemius. Interestingly, this pattern was observed for medial gastrocnemius for healthy people.[14] Based on these initial observations, it seems that when using the rocker shoes for AT patients, biomechanical adaptations in the lower extremity are similar to the healthy population in running.

In walking, the amount of reduction in peak PFM, PFM impulse and peak power generation were respectively 13%, 19% and 21% when using the rocker shoes. These changes were very similar to what previously was observed in healthy participants (10%, 12% and 22% reduction respectively).[14]

Lack of change in knee moment and reduced ankle angle in late stance were other biomechanical observations in response to the rocker shoes which were also reported in healthy populations.[14,15] Triceps surae were previously found to have a delay in the peak activation when healthy subjects used the rocker shoes.[14] This pattern was not observed in our patient group.

Currently, eccentric loading exercises are considered as a gold standard for the conservative management of AT. Yet about 40% of patients with chronic AT (athletes and non-athletes) do not benefit from this intervention.[26,27] This necessitates further research for alternative treatment methods for this injury. Although the multifactorial and complex aetiology of AT has not been fully elucidated yet, excessive and/or repetitive loads on the Achilles tendon are believed to be important etiological factors.[28,29] In line with the continuum model of tendon pathology,[5] load management plays an important role in conservative treatment of AT. Our findings show that peak PFM and PFM impulse can be both reduced on average by more than 10% during running and walking with the rocker shoes. Considering the repetitive load on the Achilles tendon in each step of running and walking activities, this decrease in PFM per step can cumulatively contribute to considerable reduction of Achilles tendon load. Therefore, wearing rocker shoes might be useful in the management of pain in AT patients during both the early and recovery phases.

In this study, the pain was assessed to provide an initial insight into a possibly immediate effect of the rocker shoes on chronic Achilles tendon pain. Neither positive nor negative effects on pain were evident in running and walking when comparing pain levels immediately after use of the rocker shoes and standard shoes. An instantaneous pain reduction, following 10–15 min of using rocker shoes, was not expected in this cohort of patients who suffered from chronic (on average 22.5 months) tendinopathy. The pain might be partly related to the Achilles tendon force, but most likely it is also related to tendon pathology, which needs time and relative unloading to heal. Based on clinical experience, one might expect a more prominent pain relief in patients with acute reactive AT, or after prolonged use of rocker shoes in patients with more chronic degenerative tendinopathy. Therefore, further clinical trials are warranted to evaluate the effectiveness of rocker shoes in treatment of AT.

It should also be noted that observing the pain relief was not the only reason for evaluating the pain. Our rocker shoes had quite different characteristics (e.g. mass and thickness of the soles) from standard running shoes. Thus, beforehand, we did not rule out the possibility of even a sudden increase in pain since these shoes were used for the first time. No increase in pain was observed.

Table 2
Comparison of all outcome variables between standard and rocker shoes during walking.

Variables	Standard shoe[a] [95% CI]	Rocker shoe[a] [95% CI]	Difference [95% CI]	*p*-Value[b]
Ankle				
Plantarflexion moment				
Peak (N m/kg)	1.55 [1.47; 1.63]	1.35 [1.26; 1.44]	0.20 [0.14; 0.27]	<0.001
Impulse (N m s/kg)	0.32 [0.29; 0.36]	0.27 [0.23; 0.30]	0.06 [0.03; 0.08]	<0.001
Power				
Peak power generation (W/kg)	3.86 [3.51; 4.21]	3.06 [2.68; 3.44]	0.80 [0.52; 1.08]	<0.001
Angle				
Max dorsiflexion (°)	15.96 [13.74; 18.18]	12.72 [10.42; 15.03]	3.23 [1.43; 5.04]	<0.001
Range of motion (°)(GC)	27.94 [25.89; 29.98]	24.18 [22.09; 26.27]	3.75 [2.06; 5.44]	<0.001
Knee flexion moment				
Peak (N m/kg)	0.21 [0.10; 0.31]	0.17 [0.07; 0.27]	0.04 [−0.01; 0.08]	0.111
Hip flexion moment				
Peak (N m/kg)	1.09 [0.96; 1.22]	1.00 [0.87; 1.13]	0.09 [0.02; 0.16]	0.019
EMG				
Medial gastrocnemius				
Peak (μV)	145.18 [99.43; 190.94]	141.18 [94.92; 187.44]	4.00 [−12.73; 20.73]	0.606
Time of peak (% GC)	40.85 [39.70; 42.63]	40.81 [39.14; 42.47]	0.05 [−1.74; 1.83]	0.956
Lateral gastrocnemius				
Peak (μV)	120.18 [78.79; 161.57]	150.09 [108.50; 191.69]	−29.92 [−81.32; 21.49]	0.226
Time of peak (% GC)	41.89 [38.99; 44.79]	44.22 [41.54; 46.91]	−2.34 [−5.12; −0.45]	0.092
Soleus				
Peak (μV)	98.38 [36.61; 328.08]	143.33 [88.50; 198.15]	−44.95 [−132.72; 42.82]	0.276
Time of peak (% GC)	45.16 [40.39; 49.93]	45.07 [40.56; 49.58]	0.09 [−3.75; 3.93]	0.957
Tibialis anterior				
Peak (μV)	173.63 [135.54; 211.72]	235.40 [194.87; 275.93]	−61.77 [−106.38; −17.16]	0.015
Time of peak (% GC)	5.25 [2.83; 7.67]	4.16 [0.96; 7.37]	1.94 [−2.67; 3.79]	0.591
Speed (m/s)	1.41 [1.33; 1.49]	1.40 [1.32; 1.49]	0.00 [−0.05; 0.06]	0.920
Step length (m)	0.75 [0.72; 0.78]	0.75 [0.72; 0.78]	0.00 [−0.01; 0.01]	0.715
Cadence (steps/min)	115.30 [111.11; 119.40]	114.10 [119.71; 118.40]	1.19 [−2.88; 5.27]	0.522
Stance (%GC)	62.66 [61.77; 63.54]	61.92 [61.06; 62.78]	0.74 [0.09; 1.39]	0.030
Pain (0–10)	2.49 [1.47; 3.51]	2.50 [1.40; 3.60]	0.01 [−1.17; 1.15]	0.982

GC, complete gait cycle.

[a] Values include mean [95% confidence interval].

[b] The statistical significance level is set at $p < 0.025$.

It might be argued that rocker shoes will not be accepted by athletes with AT because the shoes are relatively unstable and heavy. Unlike heel-to-toe rockers, our rocker shoes only have a forefoot rocker which makes them more stable than shoes with double rockers (e.g. MBT$^{\text{TM}}$ shoes). None of our patients complained about instability of rocker shoes. The mass of the shoes needs to be reduced though. Using lighter materials or creating a number of cavities inside rocker profiles could be possible ways to reduce the mass of rocker shoes.

Although this study had enough power to detect substantial changes in ankle kinetics and kinematics, we were limited by sample size in the analysis of some of the secondary outcome measures. The current study only assessed the biomechanical adaptation to a specific rocker shoe design, and the results might differ for other rocker bottom shoe designs. In addition, the biomechanical changes in response to the rocker shoes were assessed for the sagittal plane. Because of extra height of rocker shoes and reduced sole compliance (due to rigidity) some adaptations might have occurred in the frontal plane and needs further investigations. In this study, participants chose to run at a slow speed. One reason was the short running path which did not allow them to accelerate enough. Moreover, participants might have run slowly to avoid an increase in pain. Despite the low speed, a double swing phase was observed in all running trials. Further studies are necessary to demonstrate whether the discussed biomechanical effects of rocker shoes can also be observed at faster speeds.

5. Conclusion

When used by patients with chronic AT, shoes with a proximally placed rocker profile cause a significant reduction in peak PFM in late stance of both running and walking without major adaptations in knee and hip joints moments and triceps surae muscular activity. These findings suggest that rocker shoes might be useful in unloading the Achilles tendon, and therefore might play a role in the management of symptomatic AT. No immediate effect on the pain was found in a group of patients with chronic symptomatic AT. A randomized controlled trial, with pain as clinical outcome, is needed to assess the efficacy of rocker shoes in reducing pain in patients with AT.

Practical implications

- When used by patients with chronic Achilles tendinopathy, shoes with a proximally placed rocker profile cause a significant reduction in peak plantar flexion moment in late stance of both running and walking.
- Reduced plantar flexion moment per step can cumulatively contribute to considerable reduction in Achilles tendon load, and therefore wearing rocker shoes might be useful in the management of pain in tendinopathy patients during both the early and recovery phases.
- No immediate increase or decrease in the level of Achilles tendon pain should be expected in response to rocker shoes.

Acknowledgements

The authors wish to thank gratefully Ronald Davidsz for his assistance with data collection. We would like to thank all patients who took part in the study and also OIM Orthopedie for fabricating the rocker profiles under the shoes.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jsams.2014.02.008.

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