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Effect of rocker shoes on plantar pressure pattern in healthy female runners

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ABSTRACT

Rocker profile shoes (rocker shoes) are one of the treatment options of metatarsalgia and forefoot stress fractures. The efficacy of rocker shoes in unloading the forefoot pressure has been shown in walking. In running, however, the effect of rocker shoes on forefoot pressure is unknown. Eighteen healthy female runners participated in this study. In-shoe plantar pressures were recorded during running with the standard running shoes and rocker shoes. Shoe comfort was assessed after each shoe measurement. Peak pressure (PP), maximum mean pressure (MMP) and force-time integral (FTI) were determined for seven foot areas. The effects of shoes on the different outcome variables were statistically analyzed using a linear mixed model. Running with the rocker shoes caused a significant reduction ($p < 0.001$) in all pressure parameters in the central and lateral forefoot. FTI and MMP were also reduced by 11% and 12% in the medial forefoot while running with rocker shoes. Running with rocker shoes resulted in a significant increase in all pressure parameters at the heel region ($p < 0.001$). Running with rocker shoes received a significant ($p < 0.01$) lower comfort rate than running with standard running shoes. Rocker shoes might be beneficial for runners who are recovering from metatarsalgia or stress fractures of the forefoot region, as it reduces plantar pressure in the forefoot region.

1. Introduction

Forefoot overuse injuries such as metatarsal stress fractures and metatarsalgia are fairly common in the athletic population, especially in runners [1–3]. A potential cause of these injuries is excessive plantar pressure in the forefoot region [4,5], and reducing plantar pressure in this region might be an effective treatment [6–9]. This treatment goal may be achieved with shoes having a stiffened rocker profile (further called as rocker shoes) with the apex positioned proximal to the metatarsal heads [10] (Fig. 1). The unloading mechanism of the forefoot region due to rocker shoes is not fully understood. Factors such as the restricted motion at the metatarsophalangeal joint and the shorter loading time at the forefoot during the propulsion phase of gait are thought to be the main mechanisms [7,11,12].

The efficacy of rocker shoes in reducing plantar pressure loading in the forefoot region has been well documented in walking for both healthy individuals and patients with forefoot problems such as metatarsalgia [7,11,13–16]. So far, two studies have investigated the effects of rocker shoes on running biomechanics. The focus of these studies has been on the kinetics, kinematics and lower limb muscular activity in response to rocker shoes [17,18]. To date, there have been no studies that have investigated the effects of rocker shoes on the plantar pressure pattern during running. More information in this regard gives a better understanding of the capability of rocker shoes to reduce forefoot plantar loading during running which might give direction to alternative prevention and treatment options for foot overuse injuries.

Therefore, the purpose of the current study was to examine the effect of rocker shoes on the foot plantar pressure in running. A sample of healthy female runners was chosen because a higher incidence rate of overuse injuries is reported for females [19–21]. We hypothesized that during running, the rocker shoes would significantly reduce forefoot plantar pressure when compared with standard running shoes. Secondary outcome of this research was

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Fig. 1. (A) Standard shoe and (B) shoe with a proximally placed rocker profile. The black arrows indicate the apex (rolling point) of the shoe.

shoe comfort, since this factor might influence the regular use of footwear.

2. Methods

2.1. Participants

In this study, female runners were recruited from local running clubs. To be eligible, female runners needed to be between 18 and 50 years old, run at least twice per week and at least five km per run, and be healthy with no history of injuries to the back or lower limb. The experimental protocol of this research was approved by the local Medical Ethics Committee (METc 2012.014).

2.2. Shoe conditions

In this study a standard running shoe was used as the baseline condition (Fig. 1A). Another pair of these shoes (same brand and model) was modified with a stiffened rocker profile by a certified orthopedic shoe technician to be used as the rocker shoe condition (Fig. 1B). The apex (rolling point) of the rocker shoes and baseline shoes were, respectively, positioned at 53% (proximal to metatarsal region) [22], and 65% 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. Due to extra weight of the rocker profiles, a pair of rocker shoes was heavier than a pair of standard shoes. Depending on shoe size a pair of standard running shoes weighed on average 541 ± 44 g, and a pair of rocker shoes weighed 858 ± 96 g.

2.3. Plantar loading assessment

In-shoe plantar pressure was measured using flexible Pedar® insoles (Pedar-X system; Novel Inc.; Munich, Germany). Each insole was 1.8 mm thick and consisted of 99 pressure sensors. All insoles were calibrated by the manufacturer. The data were collected from both feet with a sampling frequency of 100 Hz and sent to a computer via Bluetooth® wireless communication.

Using the Pedar® medical professional software, the foot area was divided into seven anatomical regions (masks): heel, midfoot, medial forefoot, central forefoot, lateral forefoot, first toe, and small toes (Fig. 2). For each mask the following parameters were determined: peak pressure (PP), maximum mean pressure (MMP), and force-time integral (FTI). PP was the maximum pressure over all individual sensors within a mask and all time frames of each step. While PP takes only one value into account, MMP represents the highest average loading of all sensors within one mask during one step. MMP was calculated for each mask as follows: for each time frame the mean pressure of all sensors within a mask was calculated, and then the maximum value over frames was selected as the MMP (for each step).

While the repetitive high amount of load during running is a critical factor in overuse injury development, the duration of the high loading is an important parameter too, and cannot be understood from PP and MMP. Therefore, we also included FTI, calculated as the area under the force–time curve within each mask and also for the entire foot. The reason for including FTI for the entire foot was to check whether the observed changes in the plantar pressure were caused by the footwear itself and not by other factors which can affect the total force during locomotion [23] (e.g. different running technique or fatigue with one shoe condition).

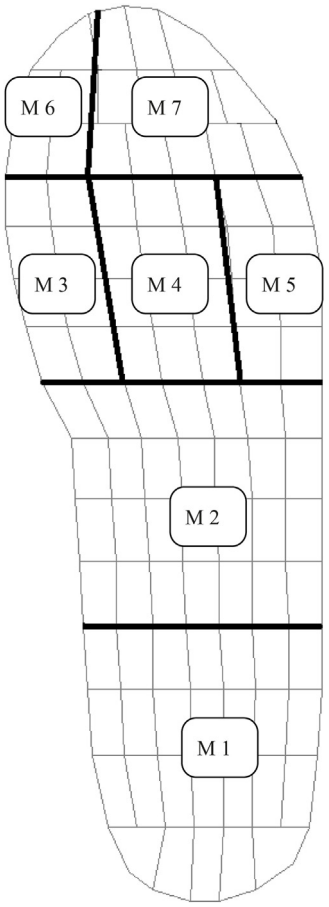

Fig. 2. Seven anatomical foot regions (masks) defined in this study: M1 (heel), M2 (midfoot), M3 (medial forefoot), M4 (central forefoot), M5 (lateral forefoot), M6 (first toe), and M7 (small toes).