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Rocker shoe, minimalist shoe, and standard running shoe: A comparison of running economy

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ABSTRACT

Objectives: Running with rocker shoes is believed to prevent lower limb injuries. However, it is not clear how running in these shoes affects the energy expenditure. The purpose of this study was, therefore, to assess the effects of rocker shoes on running economy in comparison with standard and minimalist running shoes.
Design: Cross-over design.
Methods: Eighteen endurance female runners (age = 23.6 ± 3 years), who were inexperienced in running with rocker shoes and with minimalist/barefoot running, participated in this study. Oxygen consumption, carbon dioxide production, heart rate and rate of perceived exertion were measured while participants completed a 6-min sub-maximal treadmill running test for each footwear condition. The data of the last 2 min of each shoe condition were averaged for analysis. A linear mixed model was used to compare differences among three footwear conditions.
Results: Oxygen consumption during running with rocker shoes was on average 4.5% higher than with the standard shoes ($p < 0.001$) and 5.6% higher than with the minimalist shoe ($p < 0.001$). No significant differences were found in heart rate and rate of perceived exertion across three shoe conditions.
Conclusions: Female runners, who are not experienced in running with the rocker shoes and minimalist shoes, show more energy expenditure during running with the rocker shoes compared with the standard and minimalist shoes. As the studied shoes were of different masses, part of the effect of increased energy expenditure with the rocker shoe is likely to be due to its larger mass as compared with standard running shoes and minimalist shoes.

1. Introduction

The high amount of load at the forefoot region during the push-off phase in walking and running, makes this region susceptible to different overuse injuries such as metatarsal stress fractures and metatarsalgia.[1] Rocker bottom shoes (hereafter referred to as rocker shoe) have been shown to be able to reduce the excessive plantar pressure in the forefoot region during walking.[2,3] Moreover, rocker shoes can reduce the peak plantar flexion moment (related to the force on the Achilles tendon) during propulsion phase of running, and therefore they might be beneficial for runners who are in the recovery phase of Achilles tendinopathy.[4] For these reasons, rocker shoes might play a role in the prevention and treatment of overuse injuries during running.

While the biomechanical effects of rocker shoes in relation with lower limb injuries have been subject to a number of studies,[5] no attention has been made to the possible side-effects such as the energy expenditure during running with these shoes. Some work, however, has been done in walking activities, and conflicting results have been reported. In one study no changes in metabolic cost between rocker bottom shoes and standard shoes were observed.[6] One study reported an increase in energy expenditure during walking with rocker shoes compared with standard shoes,[7] and the opposite was found in another study.[8]

The minimalist shoe is a rather new type of footwear, gaining popularity among runners. Minimalist shoes are presumed to simulate barefoot running and may therefore reduce running injuries.[9] For instance, minimalist shoe running is believed to promote a forefoot strike which reduces the impact force and impact loading

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rate during running.[10,11] Since these factors are related to running injuries, minimalist shoes are used by runners to prevent overuse injuries.[9,10] Apart from injury prevention, running with minimalist shoes is shown to be more economic than running with standard running shoes.[11,12] However, to date no comparison has been made between minimalist shoes and rocker bottom shoes regarding the running economy (RE).

RE can be an important factor for runners, and might affect the choice of footwear for their regular running activities. Therefore, the purpose of present study was to determine how rocker shoes affect RE, and compare it with minimalist and standard running shoes.

2. Methods

The experimental protocol of this research was approved by the Medical Ethics Committee of the University Medical Center Groningen (METc 2012.014). This study was part of a bigger research project focusing on running overuse injuries and shoe biomechanics with only the female sample population. The selection of females as the sample for the whole project was based on the higher incidence rate of overuse injuries reported for this gender.[13]

To be included, female runners needed to be between 18 and 55 years old, and be healthy with no history of cardiovascular and musculoskeletal (back and lower limb) problems. Participants had to have experience of running at least twice per week and at least five km per run in the past year. In addition, the runners needed to be familiar with treadmill running, and had the ability (self-reported) to run for approximately 30 min at sub-maximal pace on treadmill.

The investigated shoes in this research (European sizes 37–42) were as follows: rocker shoe (average mass per pair: 858 ± 96 g, Fig. 1A), standard running shoe (Dutchy™, average mass per pair: 541 ± 44 g, Fig. 1B), and minimalist shoes (Merrell™ Pace Glove, average mass per pair 321 ± 25 g, Fig. 1C). Rocker shoes were modified from standard shoes with a stiffened rocker sole by a certified orthopedic shoe technician. The apex (rolling-point) of the rocker shoes and baseline shoes were respectively positioned at 53% (proximal to metatarsal region), 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.

Oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were recorded and monitored continuously via face mask using an open circuit breath-by-breath gas analysis system (Cortex Metalyzer 3B, Leipzig Germany) and its dedicated software (MetaSoft 3.9.5, Germany). Prior to data collection, the gas analysis system was calibrated according to manufacture's instructions using ambient air and known gas concentrations. The volume calibration was performed using a 3-l syringe. Heart rate (HR) was measured using a wireless chest strap telemetry system (Polar Electro T31, Kempele, Finland).

Rating of Perceived Exertion (RPE) of running was determined using 15 points (6–20) Borg scale[14] for each shoe condition. This scale was used to subjectively measure the overall effort when running with three different shoes for the first time. The Borg scale has been shown to be a reliable method for rating perceived exertion in treadmill running.[15]

The experimental procedure was as follows: each participant visited the exercise laboratory once, and all testing procedures were conducted under similar conditions. Prior to data collection, the procedures were described in detail for participants and each participant read and signed a consent form. Then, body weight and height were recorded without shoes. After preparation, each participant ran on a treadmill (Valiant; Lode, B.V., Groningen, The Netherlands) with all three shoe conditions. Participants were randomly assigned to the six different orders in running with the shoes,

Fig. 1. Three investigated shoe conditions: (A) rocker, (B) standard, and (C) minimalist.

but with the restriction that the design would be balanced. The treadmill grade was set at 1% incline to compensate for lack of air resistance.[16] The sub-maximal running tests for each shoe condition included two running bouts: (1) running for 3 min at the speed of 7 km h^{-1} to help the participants to get familiar with experimental condition (e.g. face mask and shoes), (2) running for 6 min at the speed of 9 km h^{-1} to allow the runners to reach the steady state. The running pace for the economy test (9 km h^{-1} for 6 min) was assumed to be moderate enough as a sub-maximal test for our sample group who were experienced endurance runners. There was a 2 min rest between each measurement, which allowed participants to rate the perceived exertion, and change the shoes. In total a RE test for each participant took 31 min.

Descriptive statistics were used to describe the characteristics of the population. The data of the last 2 min of each shoe condition were averaged to calculate the mean VO_2 (ml kg^{-1} min^{-1}), respiratory exchange ratio (RER), and HR (bpm) for analysis. VO_2 and VCO_2 values were normalized to the participant's body mass (kg) while