11-2014

# Kinematics and Economy of Novel Barefoot Running

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November 5, 2014

## Abstract

The purpose of the study was to compare key physiological, anthropometric, and kinematic attributes between barefoot and shod runners while also comparing these variables to the running economy of their respective conditions. We hypothesize that when running in the acute barefoot condition participants will exhibit significant biomechanical, physiological, and kinematic differences compared to the shod condition that may be correlated with a superior or inferior running economy. Male (4) and female (5) test subjects (19.2±0.83 years, 171.06±6.89 cm, 71.09±14.52 kg) participated in two separate testing sessions. The first session involved collecting the weight, height, sitting height, ankle and hip widths, hamstring flexibility, and body fat percentage preceding a maximal oxygen consumption test. The second session required subjects to run at a variety of submaximal velocities while they were recorded with high speed video. Kinematic variables were measured using Dartfish Video Analysis Software. Results showed that $VO_2$ was greater when shod than barefoot at 2.68 m/s, but shod running required less oxygen at 3.58 m/s. There was no difference at 3.13 m/s. Body composition was the only physiological variable that correlated with economy. Knee angle decreased and stride frequency increased when switching from shod to barefoot running. These findings suggest that as habitually shod runners begin barefoot running they adapt to increased ground reaction forces by incorporating greater knee flexion and a faster stride frequency. These changes may cause a decrease in economy at slower speeds and an improvement in economy at greater velocities.

## Introduction

There are few differences between elite runners in the world. Elite runners tend to have very similar aerobic capacities and conditioning. However, where some runners differ is in their running economics. Running economy has been defined as the energy required to run a distance at a constant submaximal velocity. If two runners have the same aerobic capacities and are running at the same submaximal speed, then the more economical of the two runners is going to use less energy at that velocity. Running economy is influenced by numerous factors. Several physiological factors such as flexibility, leg length, and body fat percentage have been correlated to running economy with mixed conclusions. This study chose to look at the not only bodily measurements but also the difference between barefoot and shod running. Today the majority of runners are rearfoot strikers, meaning during each step the heel is first to make contact with the ground. The modernization of the running shoe has made it possible and more comfortable to run with a rearfoot-striking running pattern. It has been suggested, however, that humans evolved to run barefoot and only recently have humans begun to run shod. Some would argue that the modern running shoe imposes poor running mechanics on the runner. Many studies have attempted to study the differences between shod and barefoot running. Schüte et al (2013) investigated the immediate kinematic and spatio-temporal effects of shod runners switching to barefoot running, but the distance tested over was merely a 12-meter runway. We wish to extend this unhabituated barefoot run to a greater distance on a treadmill while recording running economics simultaneously. We hypothesize that when running in the acute barefoot condition participants will exhibit significant biomechanical, physiological, and kinematic differences not only from the start of testing to completion, but also between the barefoot and shod conditions.

## Methods

Subject characteristics are reported in Table 1. Subjects reported to the lab on two separate occasions.

Session 1:

- Height, weight, leg length, biiliac breadth, bimalleolar breadth and flexibility were measured.
- Body composition was measured by air displacement plethysmography (Bod Pod).
- Maximum oxygen consumption ($VO_{2max}$) was measured shod using a continuous ramp protocol where treadmill grade was increased 2% every two minute stage.

Session 2:

- Weight was recorded shod.
- Markers were placed on the right shoulder, hip, knee, ankle and foot.
- Subjects ran shod at 2.68, 3.13, and 3.58 m/s at 0% grade with each stage lasting three minutes.
- Subjects then removed their shoes and were weighed again.
- Subjects ran barefoot at 2.68, 3.13, and 3.58 m/s at 0% grade with each stage lasting three minutes.
- High speed (240 fps) video was recorded for the last 15 seconds of each three minute stage.

Video Analysis

- Video was uploaded to Dartfish Video Analysis Software for kinematic analysis.
- Ankle, knee, and hip angles were tracked throughout run.
- Stride frequency was calculated from video data.

## Results

Table 1 – Subject Characteristics (mean ± std)

| | |
|---|---|
| Height (cm) | 170.55± 6.51 |
| Mass (kg) | 66.85± 10.88 |
| Body Fat % | 17.53± 6.61 |
| $VO_2$ Max (ml/kg/min) | 49.23± 4.91 |
| Ankle Width (cm) | 6.67± 0.52 |
| Hip Width (cm) | 26.11± 0.97 |
| Flexibility (cm) | 32.83± 7.67 |
| Leg Length (cm) | 86.9±21.37 |

**Figure 1 –** results of submaximal oxygen consumption test. Barefoot running becomes more economical than shod running as velocity increases.

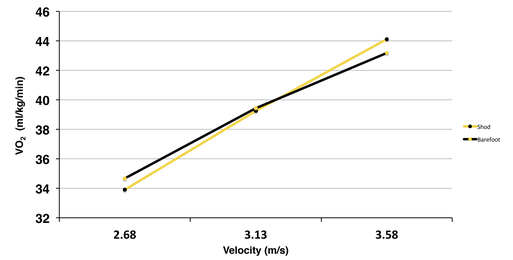



**Figure 2 -** results from high speed video analysis. As velocity increases stride rate increases. Barefoot running maintains a greater stride frequency at all speeds.

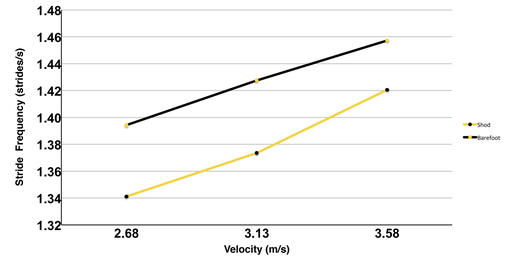
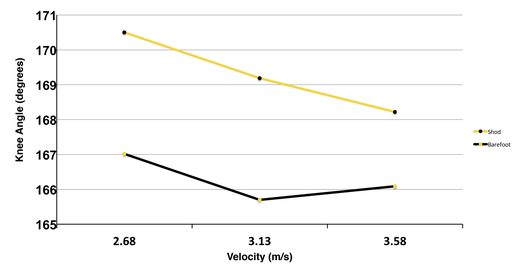



**Figure 3** – results from high speed video analysis. Knee angle decreases with speed. When running barefoot, runner's used greater knee flexion.




## Conclusions

In the barefoot condition, stride frequency was increased and knee angle was decreased compared to the shod condition. Novice barefoot runners change gait kinematics in order to decrease ground reaction forces with little effect on economy. The only variable that had a significant correlation with running economy was body composition.