Vertical and medio-lateral displacement in barefoot and shod running

Antonis Ekizos, Alessandro Santuz, Adamantios Arampatzis

Department of Training and Movement Sciences, Humboldt-Universität zu Berlin, Germany

Introduction

Barefoot running was prominent for millions of years until modern shod running. Several studies reported that barefoot running is more economical (2 to 6%) compared to shod running [1,2]. We hypothesized that a lower vertical displacement per unit of distance traveled while running would be a possible mechanism that may explain the lower energy cost in the barefoot condition. Therefore, we investigated the differences in the vertical and medio-lateral displacement for a long time interval (i.e. two minutes) between barefoot and shod running.

Methods

Twenty one volunteers were recruited in the study. Anthropometric data showed an age of 28 ± 6 years, height of 178 ± 8 cm and weight of 72 ± 12 kg. The participants performed randomly two minutes long barefoot and shod running trials (two of each), at their preferred velocities on a treadmill. Five cameras of the Simi Motion system (190 Hz) were used to measure the 3D coordinates of eleven reflective markers positioned on the back of the participants (fig. 1).

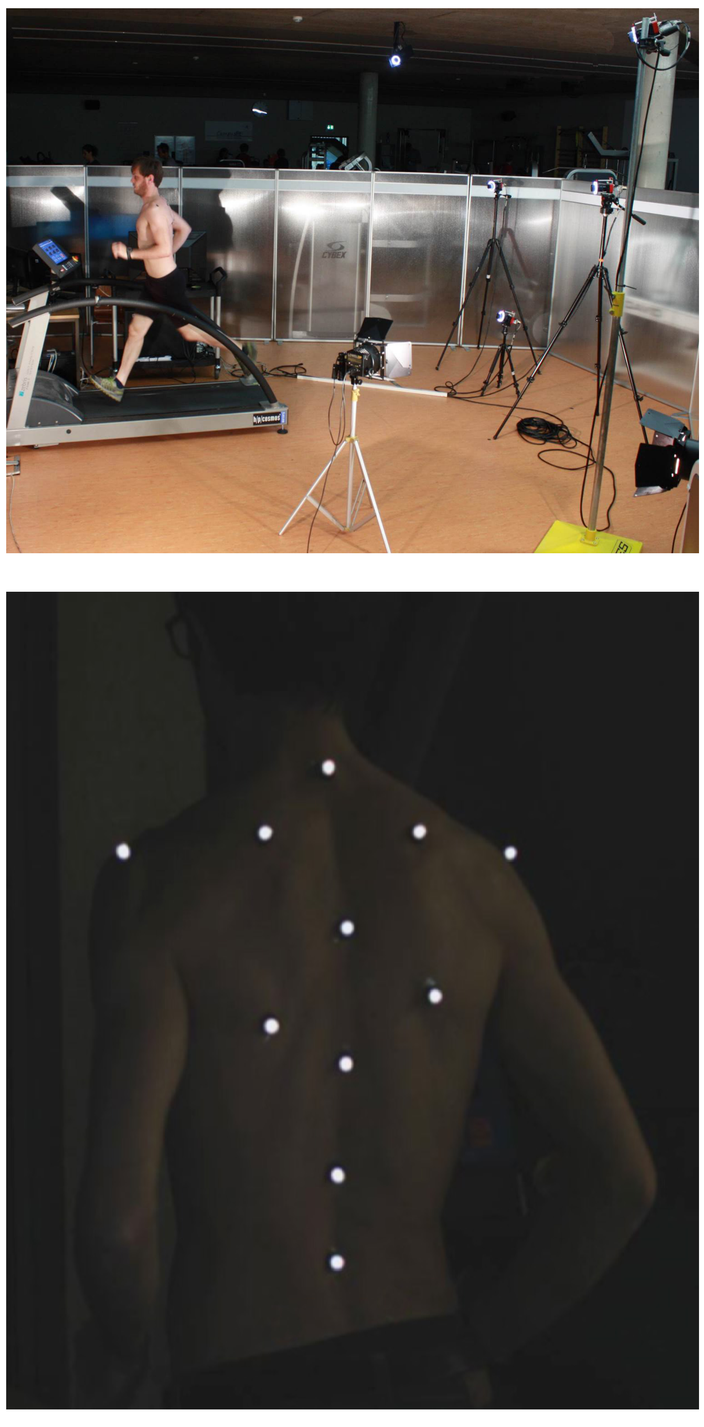

Fig. 1: Top: Experimental setup of the measurement consisting of the five Simi camera system and treadmill. Bottom: Marker placement (Spine: 1st, 6th, 10th, 12th thoracic vertebrae and 2nd lumbar vertebrae. Right and left scapula: acromion, inferior and superior angle).

The displacements of the spine -five markers- and the scapula -three markers unilaterally, six in total- were identified and analyzed separately. The vertical spine (VSp), vertical scapula (VSc), medio-lateral spine (MLSp) and medio-lateral scapula (MLSc) displacements have been extracted from the 3D coordinates of the markers. Further, kinetic data were measured using a pressure plate (Zebris FDM, 120 Hz), which was integrated in the treadmill.

Results

Lower displacements ($p<0.05$) were documented in the barefoot condition on VSp, VSc and MLSp but not in MLSc ($p>0.05$, fig. 2). The differences to the shod condition were 4.4%, 3.4% and 6% for VSp, VSc and MLSp respectively. Foot strike patterns changed significantly ($p<0.05$) towards the front of the foot and cadence increased ($p<0.05$) by ~2.5% in barefoot condition (tab. 1). The integral of ground reaction forces over the time of two minutes decreased significantly ($p<0.05$) by ~9.8% when barefoot (fig. 3).

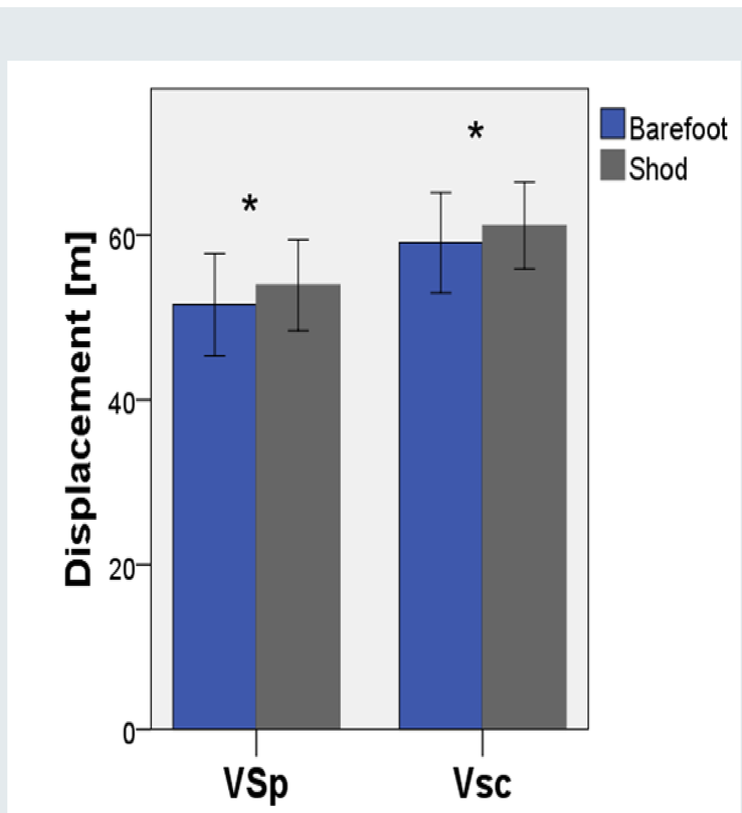

Fig. 2: Top: The vertical displacement of the spine (VSp), and scapula (Vsc) over the duration of two minutes in barefoot and shod conditions. Bottom: The medio-lateral displacement of the spine (MLSp) and scapula (MLSc) over the duration of two minutes in the same conditions, * significant effect of running conditions ($p<0.05$).

Tab. 1: Mean ±standard deviation values averaged over two minutes of cadence, contact and flight time, * significant effect of running conditions ($p<0.05$).

	Barefoot	Shod
Cadence [steps/min]*	163.9 ±10.9	159.8 ±9.3
Contact Time [ms]*	280 ±31	302 ±34
Flight Time [ms]*	87 ±24	74 ±28

We found a decreased total contact time (~4.9%) and an increased total flight time (~20.0%) in the barefoot compared to the shod condition (tab. 1).

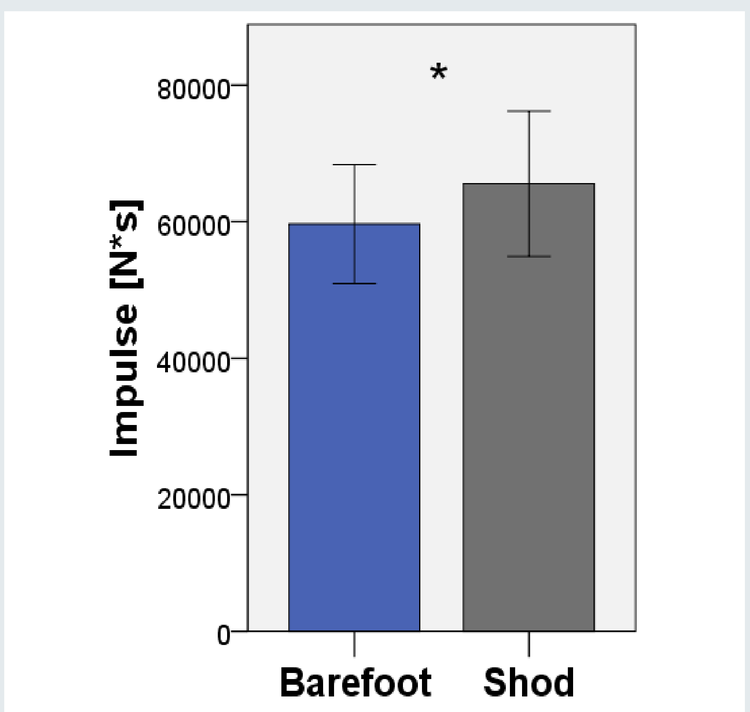

Fig. 3: Ground reaction forces over the time of two minutes in barefoot and in shod running, * significant effect of running conditions ($p<0.05$).

Discussion

Our results demonstrated a lower vertical displacement on VSp and VSc at the same running velocity in the barefoot compared to the shod condition supporting our hypothesis. The same was evident in the MLSp showing a lower displacement of the spine in both axes. The lower vertical displacement resulted from the lower vertical impulses of the ground reaction force in the barefoot condition. The lower vertical displacement during barefoot running might be an important mechanism affecting the energy cost of running.

References

[1] Hanson N.J. et al. (2011). Int J Sports Med 32: 401-406.

[2] Perl D.P. et al. (2012). Med Sci Sports Exerc. 44: 1335-1343.

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