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Influence of different footwear on mediolateral stability during gait at different speeds in healthy people

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1. Introduction

Among the different possibilities of locomotion available to humans, walking is the most common form. To carry out this movement, it is advisable to wear shoes to protect the foot from the ground. There are many types of everyday life shoes which each have specific characteristics seeking a compromise between functionality, comfort and design. We can thus find for example: a narrow box for the toes, a rigid heel tip, a curved plantar region, a significant heel height, etc. These specificities can more or less interfere with the natural movement of the foot. They can then disrupt the motor performance of the user (Bates et al. 1983). In particular, balance control is a challenge for human bipedism, especially in the mediolateral direction (ML) (Kuo 1999). One of the classic metrics characterizing the balance control is the so-called “margin of stability” (MoS) (Hof et al. 2007), that is to say the distance at toe-off between the Center of Pressure (CoP) and the Extrapolated Center of Mass (XCoM). Impact of the footwear on gait stability has only been sparsely investigated in the literature. Some effects were reported on the overall stability (Arnadottir and Mercer 2000; Menant et al. 2008), but the impact on the underlying control mechanisms was not described. Surprisingly, a recent study (Delafontaine 2019) showed that high heel shoes did not influence the mediolateral MoS during gait initiation. The present study was thus designed to test the hypothesis that different types of footwear could induce a change in mediolateral stability.

2. Methods

Six women and twelve men who were all healthy carried out different series of walking acquisitions on a treadmill at two imposed speeds (3 and 5 km/h) under the following three conditions: wearing of shoes known as “classic”, wearing of shoe known as “city” and barefoot. For women (Figure 1(A)), the classic shoe was a 6 cm high heel shoe and the city shoe was a flat sole ballerina. For men (Figure 1(B)), the classic shoe was a derby type shoe with a slight heel and the city shoe was a sneaker type shoe with flat sole. This panel of consumers volunteered to participate in the experiment. They gave their written informed consent to participate in this experiment which was approved by the ethics committee of CTC Groupe. For each acquisition, the participant will walk for 3 minutes at the set speed. The last minute will be used for the analysis of our variables using 50 steps.

In order to carry out this study on the impact of footwear on the regulation of spatiotemporal parameters of walking, we used a dual-belt treadmill instrumented with three-dimensional strain-gauge force platforms under each belt (Fully Instrumented Treadmill; Bertec, Columbus, OH, USA) to record the reaction forces of the ground. The acquisition frequency was set at 2000 Hz.

The data processing was carried out using MATLAB software (MATLAB ver. R2015a, Natick, MA, USA). The data from the force platforms were filtered using a low-pass filter of order 4 and cut-off frequency of 50 Hz. The heel-strike and toe-off events were detected using the vertical ground reaction forces (GRF), with a threshold set at 5% of the body weight. Step width (SW) was estimated using the average position of the CoP during single stance phases. CoM and XCoM trajectories were estimated by low-pass filtering of GRF (Hof et al. 2007). MoS were estimated as the ML distance between CoP and XCoM at toe-off, with positive value in the medial direction.

The normality of the data was checked using the Shapiro-Wilk test and the homogeneity of variances was checked using the Levene test. Two way repeated measures ANOVAs with the conditions of the shoe (“classic”, “city”, “bare feet”) and the speed conditions



Figure 1. Models of shoes used for the experiment with the elodi model (A1) and the laria model (A2) from the Parallel brand and the barmera model (B1) and the mayfair model (B2) from the Bexley brand.

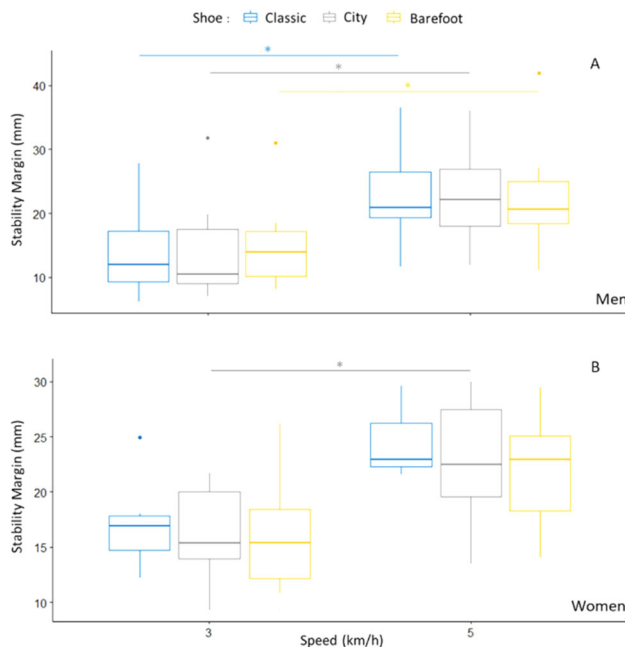


Figure 2. ML MoS for men (A) and for women (B) with 2 imposed speeds and 3 shoe conditions. * indicates significant differences from the speed condition (repeated measures anova, $p < 0.05$).

(“3 km/h”, “5 km/h”) independently for women and men were used. A significant result was followed with the post hoc test of Emmeans with an adjustment of Bonferroni.

3. Results and discussion

Figure 2 shows the average MoS for men and women, with three conditions footwear conditions: wearing “classic” shoes, wearing “city” shoes and barefoot for two walking speeds (3 and 5 km/h).

The data from our analysis are comparable to those presented in previous MoS studies (Hof et al. 2007; Robert 2019): they ranged between 5 mm and 40 mm and we observed an effect of speed on the MoS already known in the literature (Hak et al. 2013; Robert 2019). Indeed, the MoS increases with the speed due to the modification of the gait spatio-temporal parameters (decrease of single stance durations with speed while the SW remains constant). However, for women, we do not find any significant differences for the c3classic” and c3barefoot” conditions with the

increase in speed ($p = 0.055$ and $p = 0.078$, respectively). We assume that the significance threshold is not reached because of the small number of participants.

It follows from these results that there is no significant effect on the MoS or even a trend between our different footwear conditions, although some shoes are very different in design (Barefoot vs. High Heel for women). This is rather positive for the three types of footwear considered which does not impact the stability margin. This result seems to be on the same line as the one found by Delafontaine (2019) where the MoS remained invariant across the different footwear conditions (6 and 9 cm high heel shoes).

One of the limits of this study is the non-normalization of MoS by the length of the legs, which introduces an inter-subject variability on the MoS and might overcome other effects. Nonetheless, the use of repeated measure ANOVA limit this possible bias. In addition, the study being carried out on a treadmill and not on overground, modifications may appear in the biomechanics of walking between these conditions.

It is also important to emphasize that the MoS is a very global indicator characterizing the balance regulation during walking in the mediolateral direction. By construction, it considers only the main regulation mechanism (the foot placement). However, alternative mechanisms, such as the regulation of the CoP mediolateral position during the foot roll over, plays a role in lateral balance regulation (Hof et al. 2007) and should be considered to further investigate a potential effect of the footwear condition.

4. Conclusions

We have investigated the mediolateral stability of three different types of shoes according two speed conditions for two distinct populations using the “margin of stability” (MoS) metric. Contrary to what we expected, we found that the footwear conditions did not affected this global metric. Further investigations should focus more specifically on the control mechanisms, such as the trajectory of the CoP during the single support.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

- Arnadottir SA, Mercer VS. 2000. Effects of footwear on measurements of balance and gait in women between the ages of 65 and 93 years. *Phys Ther.* 80(1):17–27.
- Bates BT, Osternig LR, Sawhill JA, James SL. 1983. An assessment of subject variability, subject-shoe interaction, and the evaluation of running shoes using ground reaction force data. *J Bio.* 16(3):181–191.
- Delafontaine AL. 2019. High-heel shoes wear affects postural control during gait initiation in healthy young female adults [abstract]. In: 44th Congress of the Société de Biomécanique.
- Hof AL, van Bockel RM, Schoppen T, Postema K. 2007. Control of lateral balance in walking. *Experimental findings in normal subjects and above-knee amputees. Gait Posture.* 25(2):250–258.
- Hak L, Houdijk H, Beek PJ, van Dieën JH. 2013. Steps to take to enhance gait stability: the effect of stride frequency, stride length, and walking speed on local dynamic stability and margins of stability. *PLoS ONE.* 8(12):e82842.
- Kuo AD. 1999. Stabilization of lateral motion in passive dynamic walking. *Int J Robot Res.* 18(9):917–930.
- Menant JC, Perry SD, Steele JR, Menz HB, Munro BJ, Lord SR. 2008. Effects of shoe characteristics on dynamic stability when walking on even and uneven surfaces in young and older people. *Arch Phy Med Reh.* 89(10):1970–1976.
- Robert AL. 2019. Medio-lateral stability in induced asymmetric walking [abstract]. In: 44th Congress of the Société de Biomécanique.

KEYWORDS Footwear; walking; stability

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