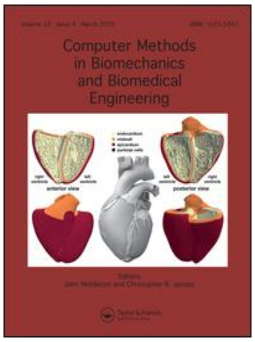

Computer Methods in Biomechanics and Biomedical Engineering

ISSN: 1025-5842 (Print) 1476-8259 (Online) Journal homepage: https://www.tandfonline.com/loi/gcmb20

Effect of shoe bending stiffness on lower limb kinetics of female recreational runners

C. Morio & N. Flores

To cite this article: C. Morio & N. Flores (2017) Effect of shoe bending stiffness on lower limb kinetics of female recreational runners, Computer Methods in Biomechanics and Biomedical Engineering, 20:sup1, S139-S140, DOI: 10.1080/10255842.2017.1382900

To link to this article: https://doi.org/10.1080/10255842.2017.1382900

COMPUTER METHODS IN BIOMECHANICS AND BIOMEDICAL ENGINEERING, 2017
VOL. 20, NO. S1, S139–S140
https://doi.org/10.1080/10255842.2017.1382900

Taylor & Francis
Taylor & Francis Group

Effect of shoe bending stiffness on lower limb kinetics of female recreational runners

C. Morio and N. Flores

Decathlon SportsLab, Movement Sciences Department, Villeneuve d'Ascq, France

KEYWORDS Footwear; longitudinal bending stiffness; ground reaction forces; joint power; women

1. Introduction

Running performance is strongly influenced by the stretch-shortening cycle mechanisms in which the force production is potentiated by the storage-restitution of elastic energy in the muscle-tendon structures (Komi 2000). Moreover, gender-specificity were found in the muscle-tendon structures, like the lower patellar or Achilles tendon stiffness observed in females compared to males (Onambélé et al. 2007; Burgess et al. 2009).

Then, the shoe longitudinal bending stiffness was shown to be another parameter which greatly influences running biomechanics and therefore performance (Stefanyshyn and Wannop 2016). Nevertheless most of the previous studies were performed with male participants. Only one study compared male and female response to different shoe bending stiffnesses (Kleindiest et al. 2005). The authors reported gender specific reaction pattern at the metatarsophalangeal joint, but they did not investigate the global lower limb pattern.

The aim of the present study was to investigate the role of the shoe longitudinal bending stiffness in the lower limb kinetics of female runners. It was hypothesized that increasing the shoe bending stiffness compared to a standard shoe would improve the stretch-shortening cycle mechanism, favouring the energy storage in the braking phase and the energy restitution in the push-off phase.

2. Methods

Sixteen female recreational runners (26.7 ± 7.3 years; 1.68 ± 0.03 m; 64.1 ± 9.0 kg) volunteered to participate and gave their written informed consent.

After a warm-up of 5 min with each pair of shoes, the participants ran on a 15 m pathway at 10 ± 1 $km.h^{-1}$. Running speed was checked with photocells 2 m before and after the force plate. Kinematics of the right lower limb (Qualisys, Sweden) and ground reaction force (Kistler, Switzerland) were recorded for five trials for both shoe conditions. Two identical pairs of shoes were tested, which differed only in term of longitudinal bending stiffness. The bending stiffness was tested with the FlexerII device (Exeter Res., USA) at 2 Hz with 45 deg of flexion. The bending stiffness of the 'stiff' shoes was 485 $Nmm.deg^{-1}$ compared to 210 $Nmm.deg^{-1}$ for the 'standard' shoes.

Ankle, knee and hip joint angles, net moments and net powers were calculated with the Visual3D software (C-Motion, USA) according to ISB recommendations (Wu et al. 2002). The adjusted Zatsiorsky-Seluyanov's anthropometric table (De Leva 1996) was preferred to match young female characteristics. The total eccentric (braking phase) and concentric (push-off phase) works were also calculated for each joints. Both kinematics and kinetics were time normalized to the stance phase.

In order to investigate the influence of bending stiffness on the whole kinetics time series, statistical parametric mapping (SPM) was preferred (Pataky et al. 2015). SPM paired t-tests were performed on the ground reaction forces and kinetics time series. Simple Student t-tests were performed on the net joint works. Statistics were computed in Matlab (The Mathworks, USA) with the α-level set at 0.05.

3. Results and discussion

With the stiff shoes, participants exerted lower push-off forces (79–88% of the stance phase) in the antero-posterior axis compared to the standard shoes (Figure 1). Vertical forces during the push-off phase (55–92% of the stance phase) were also lower with the stiff shoes compared to the standard shoes. Thus, the stiff shoes induced a reduction in propulsion forces in female recreational runners like it was previously observed in male runners (Flores et al. 2017).

The stiff shoes induced lower ankle and knee powers during the push-off phase (77–96% and 71–73% of the

CONTACT C. Morio ✉ cedric.morio@hotmail.fr

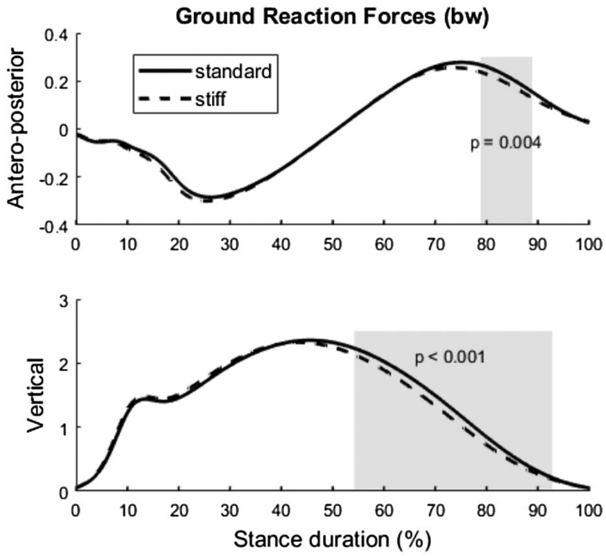

Figure 1. Antero-posterior (top) and vertical (bottom) components of the GRF normalized with the body weight and the stance duration during running with the standard (plain lines) and stiff shoes (dashed lines). Shade time periods represent significant differences (paired t-test SPM) between both shoe conditions.

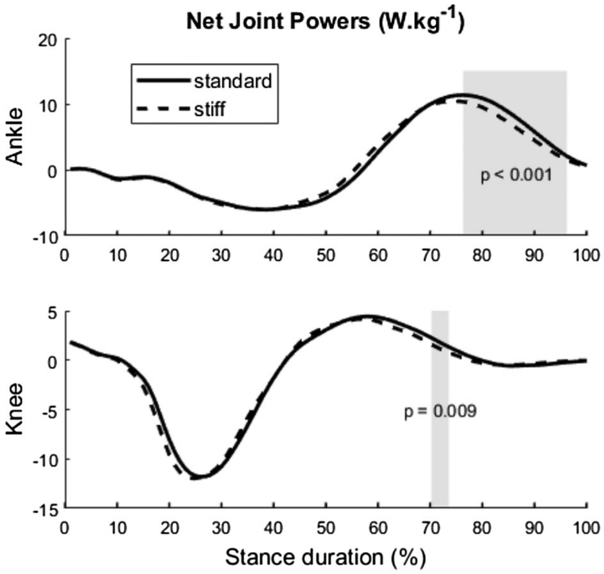

Figure 2. Ankle (top) and knee (bottom) net joint powers normalized with the body mass and the stance duration during running with the standard (plain lines) and stiff shoes (dashed lines). Shade time periods represent significant differences (paired t-test SPM) between both shoe conditions.

stance phase, respectively) compared to the standard shoes (Figure 2). These changes in joint powers were associated with significant reductions of the concentric work at the knee joint (0.21 ± 0.09 vs. 0.23 ± 0.09 J.kg^{-1}; $p = 0.04$) and the hip joint (0.45 ± 0.11 vs. 0.51 ± 0.16 J.kg^{-1}; $p = 0.02$) during the push-off phase with the stiff shoes compared to the standard shoes.

As there was no change in the braking power and joint energy absorption, the reduced power in the push-off phase and the lower energy generation might reflect an improvement of the stretch-shortening cycle during running with the stiff shoes (Komi 2000). The increase of bending stiffness might have been beneficial in the storage-restitution of elastic energy of the human-shoe system. This would have limited the need of energy production of the lower limb joints to run at the same speed with the stiff shoes compared to the standard shoes.

4. Conclusions

To conclude, the increase of longitudinal bending stiffness of the shoes could have a positive effect on the stretch-shortening cycle and therefore on running performance of female recreational runners. However, previous studies in male runners have determined an optimal bending stiffness to warrant an optimal running performance (Stefanyshyn and Wannop 2016). Thus, investigation about the optimal bending stiffness would be useful to ensure performance without increasing the injury risk in female runner population.

References

Burgess KE, Graham-Smith P, Pearson SJ. 2009. Effect of acute tensile loading on gender-specific tendon structural and mechanical properties. J Orthop Res. 27:510–516.

De Leva P. 1996. Adjustements to Zatsiorsky-Seluyanov's segment inertia parameters. J Biomech. 29:1223–1230.

Flores N, Delattre N, Berton E, Rao G. 2017. Effects of shoe energy return and bending stiffness on running economy and kinetics. Footwear Sci. 9(S1):S11–S13.

Kleindienst FI, Michel KJ, Krabbe B. 2005. Influence of midsole bending stiffness on the metatarsophalangeal joint based kinematics and kinetics data during running. 7th Symposium on Footwear Biomechanics, 27–29 July, Cleveland.

Komi PV. 2000. Stretch-shortening cycle: a powerful model to study normal and fatigued muscle. J Biomech. 33:1197–1206.

Onambélé GNL, Burgess K, Pearson SJ. 2007. Gender-specific in vivo measurement of the structural and mechanical properties of the human patellar tendon. J Orthop Res. 25:1635–1642.

Pataky TC, Vanrenterghem J, Robinson MA. 2015. Zero- vs. one-dimensional, parametric vs. non-parametric, and confidence interval vs. hypothesis testing procedures in one-dimensional biomechanical trajectory analysis. J Biomech. 48:1277–1285.

Stefanyshyn DJ, Wannop JW. 2016. The influence of forefoot bending stiffness of footwear on athletic injury and performance. Footwear Sci. 8:51–63.

Wu G, Siegler S, Allard P, Kirtley C, Leardini A, Rosenbaum D, Whittle M, D'Lima DD, Cristofolini L, Witte H, et al. 2002. ISB recommendation on definitions of joint coordinate system of various joints for the reporting of human joint motion part I: ankle, hip, and spine. J Biomech. 35:543–548.