was observed in the running shoes compared to all FS blade conditions.

Discussion and conclusion

The reduced landing forces and unaffected take-offs suggest an appropriate stiffness of the damping units included in the FSB-IDS-Soft for skaters of mass: 69.5 ± 12.5 kg. The FSB-IDS could be a valuable tool to reduce the harmful effects of impacts during landings in FS. No differences in maximal VGRF at the landing and take-off were seen between the conventional FS blades. The maximal jump height achieved in take-off trials was the same for all FS blade conditions, despite the damping units included in the FSB-IDS and a 44% weight difference between the lightweight and traditional FS blades.

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The effect of shoe cushioning on injury risk, landing impact forces and spatiotemporal parameters during running: results from a randomised trial including 800+ recreational runners

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KEYWORDS Sports injuries; sports biomechanics; running shoe; cushioning (property); ground reaction forces

Introduction

Shoe cushioning technology is expected to protect runners against repetitive loading of the musculoskeletal system, and therefore, running-related injuries (RRI). It is a common belief that heavier runners should use footwear with increased cushioning properties to prevent RRI. Surprisingly, no study has provided evidence on the beneficial effect of increased cushioning properties on injury risk so far. Furthermore, the underlying mechanisms that may explain the potential protective effect of greater shoe cushioning are yet to be uncovered.

Purpose of the study

The main purpose was to test if running in a Soft or Hard cushioned shoe influences injury risk in recreational runners and whether the association depends on the runner’s body mass.
The second objective was to compare the Soft and Hard shoe groups regarding kinetic and spatio-temporal variables to find a functional explanation for any protective effect of shoe cushioning.

**Methods**

This was a double-blinded randomised trial with a biomechanical running analysis at baseline and a 6-month follow-up on running exposure and injury risk. Healthy recreational runners (n = 848) randomly received one of two shoe prototypes that differed only in their cushioning properties, while being geometrically similar. Global stiffness was $61 \pm 3$ and $95 \pm 6$ N/mm in the Soft and Hard versions, respectively. Participants were tested in the allocated shoe conditions on an instrumented treadmill. Ground reaction force (GRF) data were recorded over 2 minutes at the participant’s preferred running speed and expressed in multiples of body weight (BW).

Training and injury data were collected for 6 months on an internet-based platform. An RRI was defined as any running-related musculoskeletal pain in the lower limbs that causes a restriction or stoppage of running for at least 7 days.

Cox regression analyses were used to compare RRI risk between the two groups based on hazard rate ratios (HR) and their 95% confidence intervals (95% CI), controlling for potential confounders. A stratified analysis was conducted to separately investigate the effect of shoe cushioning on RRI risk in lighter and heavier runners (Malisoux, Delattre, Urhausen, et al., 2020). An analysis of variance was used to compare kinetic and spatiotemporal variables between the two study groups, with speed as a co-variable (Malisoux, Delattre, Meyer, et al., 2020b).

**Results**

22,521 hours of running were reported. 128 participants (15%) sustained at least one RRI during the intervention. The overall incidence [95% CI] was $5.7 \ [4.8; \ 6.8]$ RRI/1000h. The runners who had received the Soft shoes had a lower RRI risk (HR [95% CI] = 0.66 [0.46; 0.93]). Furthermore, lighter runners benefitted from Soft shoes (HR [95% CI] = 0.55 [0.34; 0.92]) while heavier runners did not (HR [95% CI] = 0.81 [0.49; 1.34]).

The mean running speed during the test was 9.9 (±1.5) km/h. 325 ± 19 steps were analysed per participant. A higher Vertical Impact Peak Force (VIPF) was observed in the Soft shoe group compared to the Hard shoe group (1.53 ± 0.21 vs. 1.44 ± 0.23 BW, respectively; $p < 0.001$). However, the proportion of steps with detectable VIPF was lower in the Soft shoe group (84 vs. 97%, respectively; $p < 0.001$) and Time to VIPF was longer (47 ± 9 vs. 43 ± 7 ms, respectively; $p < 0.001$). No significant difference was observed between the two study groups for any other kinetic and spatiotemporal variable.

**Discussion and conclusion**

The overall injury risk was lower in runners who had received the shoe version with higher cushioning properties. In contrast with popular belief, only lighter runners benefitted from higher cushioning.

Runners from the Soft shoe group had greater VIPF compared to the Hard shoe group, while time to VIPF was longer and the proportion of steps with detectable VIPF was lower in participants with the Soft shoe version. These results show that the beneficial effect of greater cushioning cannot be explained by a decrease in VIPF or vertical loading rate. Taken alone, these GRF metrics are likely not appropriate markers to illustrate the relationship between shoe cushioning and injury risk, while delayed VIPF and the proportion of steps displaying a VIPF may be of relevance here.

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