How different shoe conditions influence the frequency components of ground reaction forces during walking

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Summary

The human foot has evolved to meet the demands of bipedal locomotion, providing effective sensory feedback [1,2]. Modern shoes, particularly cushioning running shoes, may influence this feedback [3]. This study examines the effects of barefoot, minimal footwear, and running shoe conditions on vertical ground reaction forces (vGRF) during walking using a Morlet wavelet transformation. Results indicate that running shoes dampen high amplitudes, whereas minimal footwear preserve a frequency spectrum similar to barefoot walking. These findings highlight the importance of minimal footwear in maintaining sensory feedback and have potential implications for individuals with reduced sensory perception [4].

Introduction

Since the development of bipedal gait, for most of the time humans have walked barefoot [2,3]. The interplay of forces between the ground and the foot is perceived by mechanoreceptors in the skin of the foot sole [1,5]. Fast adaptive mechanoreceptors provide important sensory information about initial contact (IC) [5]. While barefoot walkers develop natural protective mechanisms like calluses, which preserve sensory feedback, modern running shoes significantly influence this feedback [2,3], raising biomechanical questions regarding shoe design. A frequency analysis of the vGRF in different shoe conditions can help to determine the relationship between the impact frequencies occurring during walking and the optimal perception spectrum of the mechanoreceptors.

Methods

41 subjects participated in this study (15m/26f; 26.1±8.7 yrs, 1.74±0.08 m, 67.7±10.2 kg). A force plate (9287 BA, 1000 Hz, Kistler, Winterthur, Switzerland) was used to investigate the impact frequencies during walking. After familiarization with the measurement setup, five repeated walking trials for the left foot were recorded in each condition: barefoot, minimal footwear and running shoe (walking speed: 1.5 ± 0.1 m/s).

Results and Discussion

A Morlet wavelet transformation of the vGRF shows a gradient of damping properties across the conditions (Figure 1). It is known that different shoe conditions influence vGRF at heel contact [3] and can dampen high frequency components [6]. Interestingly, minimal footwear appears to have relatively little influence on ground vibrations during walking compared to running shoes (Figure 1). The damping of high-frequency vibration components and their amplitudes could have an effect on the sensory input during IC. In silicio, models show a high level of activity of rapidly adapting Pacinian corpuscles during IC [7]. Less high frequency components and damped amplitudes could limit the important sensory input from the Pacinian corpuscles during IC, which may change gait behavior. Therefore, the influence of different shoe conditions on vibration sensitivity should be specifically investigated and included in further studies.

Conclusions

Minimal footwear maintains a similar frequency profile to natural barefoot walking and may support sensory feedback better than cushioning shoes. This could be a biomechanical advantage for individuals with reduced sensory perception. Future studies could investigate how frequency behavior during gait interacts with sensory perception to propose specific shoe sole mechanical properties for individuals with reduced sensory perception [4].

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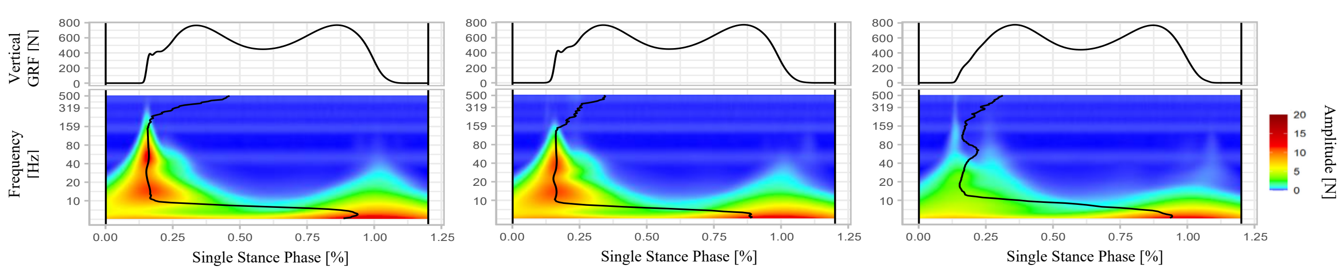

Figure 1: Morlet wavelet transformation of vertical ground reaction forces (GRF): barefoot (left), minimal footwear (mid), running shoe (right).