Carbon Fiber Insoles Enhance Foot-Ankle Leverage and Mitigate Walking Instability During Habitual Walking

Aubrey J. Gray[1], Kabir Dewan[1], Kota Z. Takahashi[2], Jason R. Franz[1]
[1]Joint Dep. of Biomedical Engineering, Univ. of North Carolina - Chapel Hill & North Carolina State Univ., Chapel Hill, NC, USA
[2]Department of Health and Kinesiology, The University of Utah, Salt Lake City, UT, USA.
Email: graaj@email.unc.edu

Summary

Older adults exhibit worse foot and ankle joint mechanical output than younger adults during functional activities such as walking. The foot in particular plays an important role not only in gait performance but also in providing mechanical leverage that may be critical for balance. We posit that carbon fiber insoles can enhance foot-ankle leverage and thereby mitigate walking instability. Independent of age, results show that carbon fiber insoles: 1) increased foot-ankle leverage and 2) decreased the ranges of 3D whole-body angular momentum (WBAM).

Introduction

Falls in older adults (≥ 65 years) are a significant public health concern that lead to a reduction in independence and quality of life. Older adults walk with deficits in foot and ankle joint function indicative of worse mechanical leverage – an outcome we posit is vital for deploying neuromuscular corrections to mitigate walking instability. Augmenting foot stiffness with carbon fiber insoles has been shown to improve foot-ankle leverage during walking [1]. We hypothesized that, compared to standard footwear, carbon fiber insoles would (i) increase peak ankle moments, (ii) increase peak external moment arms due to ground reaction forces (R_{ext}), and (iii) decrease ranges of WBAM in older and younger adults.

Methods

20 healthy younger (10F/10M, 24.8 ± 4.3 yrs, 1.72 ± 0.1m, 73.3 ± 12.5 kg) and 20 healthy older (11F/9M, 69.6 ± 4.0 yrs, 1.71 ± 0.1m, 74.0 ± 11.1 kg) participated. After providing informed, written consent, subjects were fit with a safety harness and standardized footwear (New Balance 880s). Participants walked on a dual-belt instrumented treadmill (Bertec, Corp., Columbus, OH) for a 2-minute trial at their preferred walking speed (PWS) under three different mass-matched shoe conditions in a random order: no carbon fiber insoles, 1.6-mm carbon fiber insoles, and 3.2-mm carbon fiber insoles. A 16-camera motion analysis system (Motion Analysis, Corp., Santa Rosa, CA) recorded 3D positions of a whole-body marker set in synchrony with ground reaction force data. R_{ext} [1] and WBAM [2] were calculated using previously published procedures. A two-factor repeated measures ANOVA analyzed insole and age effects on peak R_{ext}, peak ankle moments, and WBAM ranges during habitual walking

Results and Discussion

PWS was slower for older adults (1.10 m/s) compared to younger (1.33 m/s, $p<0.001$). Older adults habitually walked with 5.4% smaller peak ankle moments ($p=0.022$) and a greater frontal plane WBAM range ($p=0.015$) but not lesser R_{ext} than younger adults ($p=0.214$) when walking at preferred walking speed. During unperturbed walking, carbon fiber insoles increased peak R_{ext} (e.g., 3.2-mm: +6.8% in YA, +10.2% in OA) and peak ankle moments (e.g., 3.2-mm: +3.2% in YA, +2.3% in OA) – evidence that they enhanced foot-ankle leverage without a significant age×insole interaction. Also, during habitual walking, carbon fiber insoles increased WBAM ranges in the sagittal plane ($p<0.001$) though decreased WBAM ranges in the transverse ($p<0.001$) and frontal planes ($p<0.001$) – evidence that they mitigated walking instability in planes associated with higher requisite need for active control without a significant age×insole interaction.

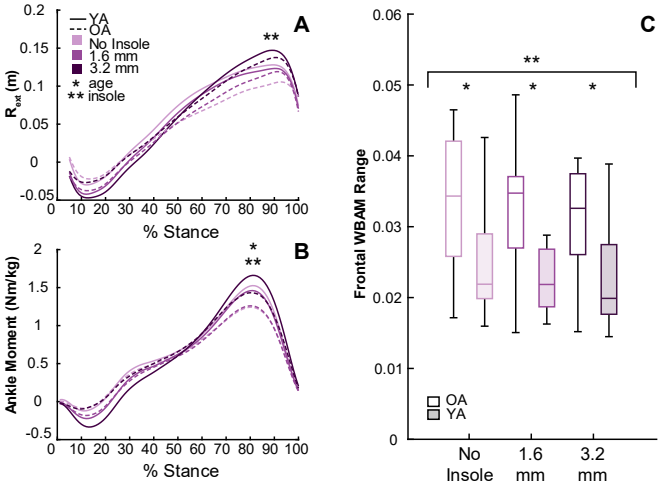

Figure 1: **A.** R_{ext} over stance for younger and older adults while wearing no carbon fiber insoles, 1.6-mm carbon fiber insoles, and 3.2-mm carbon fiber insoles while walking at PWS. **B.** Ankle moments over stance for younger adults while wearing the same shoe conditions as A and walking at PWS. **C.** Frontal plane WBAM ranges for younger and older adults while wearing the same shoe conditions as A. and B. and walking at PWS.

Conclusions

Carbon fiber insoles enhance foot-ankle mechanical leverage and convey better balance for older and younger adults during habitual/unperturbed walking.

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References

[1] Takahashi, KZ, et. Al. (2016). *Sci Rep*. **6**(1): 29870

[2] Silverman, AK, et. Al. (2012). *J Biomech*, **45**(6): 965-71