FREQUENCY CHARACTERISTICS OF BREAST MOVEMENT: EFFECTS OF BRA AND SHOE SUPPORT

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Summary

Breast discomfort as a common symptom during running highlights the need for effective sports bra design. Time- and frequency-domain content of breast movement was analysed in 27 female runners using high- and low-support bras and shoes. Bra support significantly reduced breast acceleration, power spectral density, and attenuation in higher frequencies, with increasing effects for larger breasts, while shoe support influenced tibial accelerations.

Introduction

Sports bra design plays a critical role in running, as breast discomfort often hinders exercise participation for many women [1,2]. While breast movement has been analyzed across support levels, most studies focus on discrete time-domain variables (peak acceleration). However, impact frequency content and tissue vibrations are also key factors the body may regulate to maintain comfort and performance during running [3,4]. Therefore, both the magnitude and frequency of these impact vibrations, and their attenuation by the body, may be essential markers for evaluating sports bra and shoe design. This study examines whether changes in sports bra support and running shoe cushioning influence impact acceleration for tibia and breast in time and frequency domains, including attenuation across three frequency ranges.

Methods

Twenty-seven female runners (29 ± 8 years) were recruited from local running clubs. Data were collected across four randomized conditions, with varying bra and shoe support: high- vs. low- support bra and high- vs. low- cushion shoes. Four inertial measurement units (iMeasureU, ±16g/±200g, 1000 Hz) were attached to each tibia, directly above the ankle, and to the breasts with adhesive tape. After a standardized warm-up in their personal shoes and bra, participants completed two 400m laps in each condition at a self-selected easy pace. Peak resultant accelerations at the tibia and breast were extracted as a time-domain metric. Frequency-domain metrics were derived using power spectral density analysis to quantify acceleration signal distribution across low (L: 3-8), medium (M: 9-20), and high (H: 21-50) frequency ranges and used to calculate impact attenuation as the difference in the power spectral density between the tibia and breast. Breast size was self-reported and used to estimate breast volume. A linear mixed model was used to assess effects of bra and shoe support on peak tibia and breast acceleration, and attenuation across the frequency ranges.

Results and Discussion

Greater bra support significantly reduced peak breast acceleration ($p < 0.001$), with larger breast volumes experiencing greater reduction from low- to high-support ($p < 0.001$). Level of shoe cushioning significantly affected peak tibia acceleration ($p = 0.002$) but showed no interaction with breast volume ($p = 0.56$). Bra support also influenced frequency attenuation in the M- and H-frequency bands ($p < 0.001$). Notably, breast volume significantly moderated attenuation in the H-frequency band ($p = 0.002$), with smaller breast volumes exhibiting a reduced effect from increased support in this range (Figure 1).

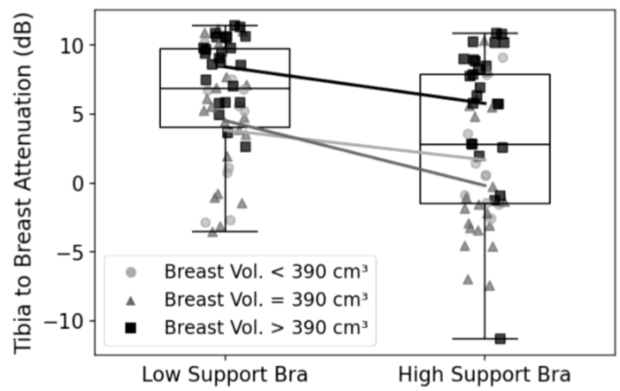

Figure 1: High freq. attenuation (dB) across bra support levels. - values indicate attenuation. Interaction shown by mean lines.

The significant effects in the H-frequency range suggest that sports bras are important for reducing rapid oscillations, especially in individuals with larger breast volumes. Moreover, H-frequency soft tissue vibrations are considered key markers regulated by the nervous system [4]. Since breast tissue lacks the active tuning ability of muscle, sports bras must provide this damping effect, not only by reducing time-domain impact peaks but also by attenuating vibrations across frequency ranges.

Conclusions

Frequency-based analysis offers valuable insight into the effectiveness of breast support and its attenuation capabilities.

Acknowledgments

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References

[1] Risius et al. (2017). *Journal of Sport Sci*, **35-9**: 842-851.
[2] Gho et al. (2010). *Supp. Care in Canc,* **18-6:** 735-741.
[3] Gruber et al. (2014). *Journal of Sp. & Hlth Sci,* **3-2**: 113-121.
[4] Nigg et al., (2001). *ESSR*, **29**(1), 37-41.