Ground Reaction Forces and Soft Tissue Vibrations: Insights into the Biomechanics of Running Impacts

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Summary

Foot ground impacts and resulting soft tissue vibrations (STV) in running are frequently associated with injury risks. It has been suggested that frequency decomposition of ground reaction forces helps better identify impacts, while analyzing STV may aid in understanding shockwave propagation. This study indicates that under controlled conditions simulating running impacts, impact forces were indeed strongly correlated with STV in the Vastus Lateralis (VL) muscle, while during actual running, other factors seem to influence the observed STV in the VL.

Introduction

Running is a globally popular sport due to its accessibility, requiring only shoes and a strong sense of motivation. Yet, injury rates remain high, leading to significant health care costs. These injuries result from various factors, including biomechanics and training load. Ground reaction force (GRF) is commonly used to monitor musculoskeletal load, but its link to injury risk remains debated. Using a frequency decomposition method to separate GRF into high-frequency (HiF, impact-related) and low-frequency (LoF, active push-off-related) components [1], Malisoux et al. (2021) [2] recently associated HiF with injury risk. Some authors hypothesize that impacts generate a shockwave propagating into the leg, inducing soft tissue vibrations (STV) linked to fatigue and muscle damage, particularly in the *Vastus Lateralis* (VL) [3]. However, this relationship remains unconfirmed. Thus, this study investigates whether GRF impact-related parameters correlate with STV of VL. To isolate impact forces from active push-off, we examined this relationship using both an ergometer simulating running impacts and actual running conditions.

Methods

Twenty participants (running at least once a week) underwent simulated running impacts on an inertial ergometer and sixteen performed 15% downhill running bouts. GRF was measured using force plates and tri-axial accelerometers recorded STV of VL. GRF signals were decomposed into HiF and LoF via Discrete Fourier Transform to assess peak and loading rates of each component. STV parameters—total magnitude, amplitude, median frequency, and damping—were assessed using Continuous Wavelet Transform. Pearson's correlations evaluated relationships between GRF and STV metrics.

Results and Discussion

HiF metrics strongly correlated with STV total magnitude ($r>0.80$, $p<0.001$) on the ergometer while HiF-STV correlations were weaker when running ($r\sim0.60$, $p<0.01$) (Figure 1). Similarly, all the GRF components correlated with STV median frequency ($0.80>r>0.60$, $p<0.001$) on the ergometer but not during running. In any case, STV damping parameters showed poor correlations with GRF. Interestingly, raw GRF variables in running correlated better with STV than HiF components.

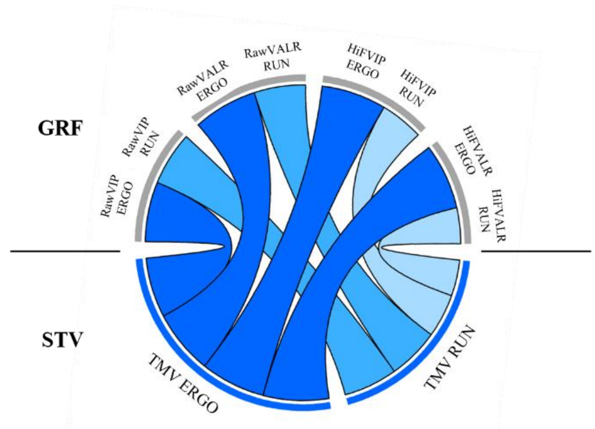

Figure 1: Correlations between total magnitude of vibration (TMV) with raw and high frequency GRF vertical impact peaks (VIP) and vertical average loading rate (VALR). Dark blue: r>0.8, blue: 0.8>r>0.6 and light blue: 0.6>r.

Under ergometer conditions, frequency decomposition effectively linked impact forces to STV magnitude and frequency. However, the weaker correlations when running suggest that STV is not solely attributable to impacts and shockwaves. Considering the higher correlations between STV and raw GRF, other biomechanical factors such as shockwave propagation direction, muscle precontraction and force transmission through rigid tissues, may influence STV during running.

Conclusions

This study demonstrates that impacts strongly relate to STV when motion artefacts are eliminated and highlights the need for further research to better understand the relative weight of biomechanical factors influencing STV when running.

References

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