Effects of Longitudinal Bending Stiffness on Metatarsophalangeal Joint Biomechanics in Novice and Experienced Runners

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Summary

This study investigated the impact of increased longitudinal bending stiffness (LBS) in running shoes on metatarsophalangeal (MTP) joint biomechanics in novice and experienced runners. Results showed significant interactions between running experience and shoe condition were observed in ROM, angular velocity, and negative work.

Introduction

Running shoes with carbon-fiber plates have gained significant attention for enhancing LBS and influencing lower-limb biomechanics, particularly at the metatarsophalangeal joint (MTP) [1, 2]. While novice and experienced runners may exhibit differences in kinematics, kinetics, and plantar pressure [3–4], the relationship between running experience and the biomechanical response to increased LBS remains unclear. This study examines the effects of LBS on MTP joint biomechanics in novice and experienced runners. We hypothesized that experienced runners demonstrate better adaptation to increased LBS.

Methods

Twenty-eight healthy male runners participated in this study, including fourteen novice runners (height: 174.57±2.98 cm; mass: 74.36±8.54 kg) and fourteen experienced runners (height: 168.93±3.12 cm; body mass: 61.71±4.45 kg). Three shoe prototypes were tested, varying only in LSB level: low LBS (LLBS, 10.89 Nm/rad, non-plate), moderate LBS (MLBS, 17.48 Nm/rad, carbon plate), and high LBS (HLBS, 32.95 Nm/rad, carbon plate). Kinematic data were collected at 200 Hz using a 3D motion capture system (Mars 4H, Nokov), and ground reaction force data were collected at 1000 Hz using a Kistler force platform. Joint angles and work were calculated in Visual 3D. Participants performed three trials per shoe condition at 15 km/h, ensuring full right-foot placement on the platform. Two-way repeated measures ANOVA with posthoc Bonferroni corrections ($\alpha = 0.008$) were applied to analyze interactions between running experience and shoe conditions.

Results and Discussion

Novice runners exhibited greater range of motion (ROM) and angular velocity compared to experienced runners. In contrast, experienced runners demonstrated reduced ROM and peak plantar flexion velocity (P-pf-velocity) and a tendency to minimize negative work as LBS increased, though the differences between MLBS and HLBS were not statistically significant. Significant interactions between running experience and shoe condition were observed in ROM, angular velocity, and negative work. These findings highlight experienced runners may benefit from the increased LBS, whereas novice runners may not.

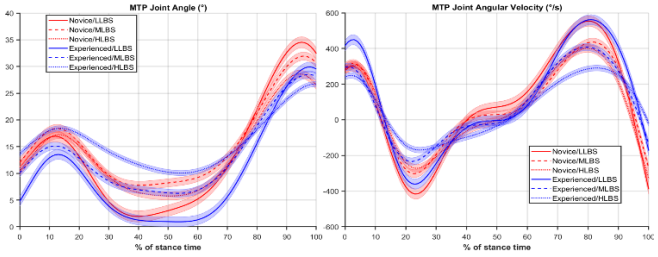

Figure 1: Group average Joint angles and joint angular velocities.

Conclusions

This study found that the biomechanical effects of shoe conditions differ between novice and experienced runners. Experienced runners may benefit more from increased LBS, as indicated by reduced ROM and angular velocities, as well as a tendency to minimize negative work.

References

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Table 1: Mean ± SD of biomechanical parameters for novice and experienced runners across three shoe conditions

Parameter	Novice/L	Novice/M	Novice/H	Exp/L	Exp/M	Exp/H	Runner	Shoe	Interact.
							Main Effect	Main Effect	Main Effect
ROM (°)^{ABCD}	32.86±4.86	25.30±3.59	24.25±5.94	30.37±2.31^{AB}	23.26±3.21^{AC}	17.71±3.68^{BC}	F=7.91 P=0.009	F=116.6; P<0.001	F=6.01 P=0.004
P-df-velocity (°/s)^{ABCD}	559.11±66.89	456.15±31.90	433.55±71.70	609.37±104.23^{AB}	440.84±58.42^{AC}	350.27±59.64^{BC}	F=1.08; P=0.309	F=59.67; P<0.001	F=6.81; P=0.002
P-pf-velocity (°/s)^{ABD}	474.00±72.62^{A}	348.37±55.61^{A}	398.06±96.74	402.59±98.12^{AB}	277.27±60.15^{AC}	220.79±81.59^{BC}	F=23.84; P<0.001	F=34.31; P<0.001	F=5.96; P=0.005
Negative work (J/Kg)^{D}	0.017±0.015	0.013±0.013	0.021±0.018	0.036±0.012^{AB}	0.029±0.015^{A}	0.024±0.014^{B}	F=8.37; P=0.008	F=2.00; P=0.145	F=4.49; P=0.016

Note: 'D' denotes a significant difference between novice and experienced runners. 'A' indicates a significant difference between LLBS and MLBS. 'B' signifies a significant difference between LLBS and HLBS. 'C' represents a significant difference between MLBS and HLBS.