Biceps Femoris Long Head Dynamics During the Nordic Hamstring Exercise and High-Speed Running

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Summary

We compared hamstring dynamics (biceps femoris long head; BFLH) during the Nordic hamstring exercise (NHE) and multi-speed running using muscle-driven simulations. We found that the BFLH fiber lengthened beyond optimal length whilst running at all speeds (4-8 m/s); but was shorter than optimal throughout the NHE. In addition, the BFLH muscle-tendon unit (MTU) lengthening work was found to be greater for the NHE compared to running at between 4-7 m/s. We believe that our framework and findings can collectively contribute to understanding which mechanical stimuli promote favorable hamstring adaptations.

Introduction

The NHE and high-speed running are two training modalities that have been explored as part of training programs to prevent hamstring strains. However, it is not known how the mechanical stimuli (e.g., fiber strain, force, power, and work) differ between the two exercises. Therefore, the aim of our study was to compare the mechanical stimuli for the BLFH between NHE and running across a range of speeds.

Methods

We collected motion capture data from six athletic participants (2 females and 4 males; age: 28 ± 4 years; height: 1.77 ± 0.12 m; mass: 76.3 ± 15.9 kg) as they ran at a range of speeds and performed NHEs. We used AddBiomechanics [1] to both scale a generic musculoskeletal model [2] to the anthropometry of each participant and to compute kinematics from all the marker data captured. We used the OpenSim MATLAB (2022b) API to calculate joint moments, MTU lengths, and moment arms. We used direct collocation optimal control to solve the muscle redundancy problem, and generated simulations in MATLAB using CasADi [3]. For each participant, we calibrated the optimal fiber length, tendon slack length and maximal isometric force parameters of each Hill-type muscle (assuming limb symmetry) using an approach similar to [4]. We performed the calibration for the participant's top speed. We selected BFLH fiber length change, force, and MTU lengthening (negative) power and work for our analysis. We used linear mixed effects models for our statistical analysis.

Results and Discussion

We found that the BFLH fiber lengthened beyond optimal length for all running speeds (Figure 1A), whilst the fiber was shorter than optimal throughout the NHE, only reaching optimal at the end of the exercise. The BFLH fiber length change was greater for the NHE compared to all running speeds by 3.3 ± 0.3 cm (p<0.01). During running, the BFLH was lengthening during the first half of the flight phase, and during this period the peak force (Figure 1B) was found to be greater compared to the NHE only at 8 m/s (16.4 ± 6.0 vs. 10.1 ± 5.2 N/kg; p<0.01). For running, the magnitude of the peak BFLH MTU lengthening power was greater for even the slowest speed compared to the NHE (2.57 ± 1.45 vs. 0.41 ± 0.18 W/kg; p<0.01) (Figure 1C). Interestingly, the magnitude of the BFLH MTU lengthening work (Figure 1D) was found to be greater for the NHE for all running speeds except 8 m/s (0.32 ± 0.11 vs. 0.34 ± 0.12 J/kg; p=0.35).

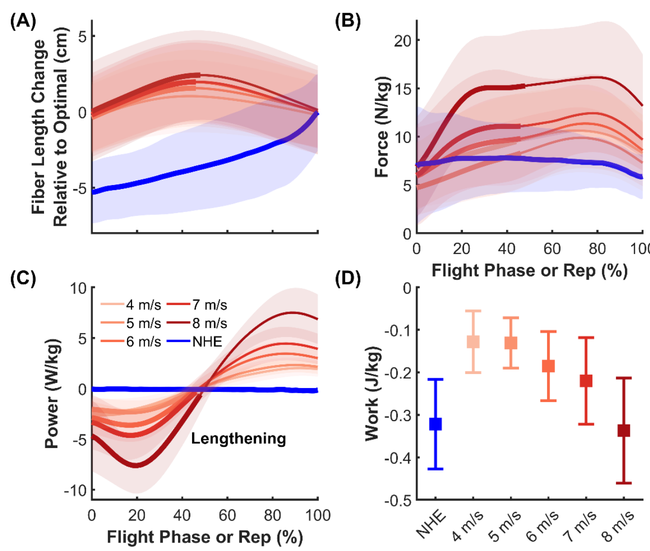

Figure 1: Mean ± SD BFLH fiber length change relative to optimal (A), force (B), MTU power (C), and MTU work (lengthening is negative) (D) for running and NHE. The period of fiber lengthening is indicated by the thicker line.

Conclusions

Our analysis has revealed key differences between the NHE and running for BFLH fiber lengths, force, and MTU power and work. This framework and analysis could be used in future studies to elucidate which mechanical stimuli—in NHE and running—promote favorable hamstring adaptations (e.g., fascicle lengthening) to prevent strains.

Acknowledgments

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References

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