Musculotendon Kinematics and Joint Mechanics during the Nordic Hamstring Exercise and Running

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Summary

The purpose of this study was to quantify mechanical loads for the Nordic hamstring exercise (NHE) and running which are used to prevent hamstring strains. We collected motion capture and force data from athletes as they ran at a range of speeds (4-8 m/s) and performed NHEs. We used musculoskeletal modeling and inverse dynamics to calculate biceps femoris long head (BFLH) muscle-tendon unit (MTU) kinematics and knee joint mechanics. While running above 65% of the average top speed resulted in greater peak knee flexion moments compared to NHE, negative knee flexion work from the NHE was comparable to near top speed running due to the longer period of BFLH lengthening (4.12 vs. 0.06 s). These results could inform training and rehab.

Introduction

Hamstring strains are the most prevalent injury in field-based sports, such as soccer [1]. Researchers have explored how the NHE and high-speed running can promote muscular adaptations to prevent hamstring injuries [2]. However, no studies have directly compared the mechanical loads imposed by the two exercises. This is necessary to compare exercise efficacy and prescribe equivalent training volumes in intervention studies. Thus, the purpose of this study is to compare mechanical loads from the NHE and running.

Methods

Fourteen athletes (8 males and 6 females; age: 26 ± 5 years; mass: 71.3 ± 11.1 kg; height: 1.75 ± 0.08 m) ran at a range of speeds and completed five NHE repetitions in a motion capture laboratory. We used AddBiomechanics [3] to scale a generic musculoskeletal model [4] to match each subject and calculate kinematics from marker trajectories. We used the OpenSim MATLAB API to perform inverse dynamics and calculate BFLH MTU kinematics. We analyzed the flight phase as the hamstrings produce the most negative work during this phase [5]. We performed ordinary least squares with bootstrapping to make statistical comparisons.

Results and Discussion

For running, the BFLH MTU was lengthening in the first half of the flight phase (Figure 1A), and this is the period where we analyzed joint moments and work. For NHEs, the BFLH MTU was lengthening throughout the exercise and over a longer period of time (mean lengthening time of 4.12 vs. 0.06 s in 8 m/s flight phase), but the lengthening velocities were nearly isometric (Figure 1B). Running resulted in comparable peak knee flexion moments to NHE for speeds between 4.3 and 5.3 m/s (Figure 1C) (NHE peak knee flexion moment of 1.52 ± 0.28 Nm/kg). Running had a larger peak knee flexion moment than the NHE at speeds above 5.3 m/s. While the knee moments are higher in running, negative knee flexion work for running (Figure 1D) was equivalent to the NHE for speeds between 6.5 and 8.0 m/s (1.33 ± 0.34 J/kg) and was lower for the slowest speeds.

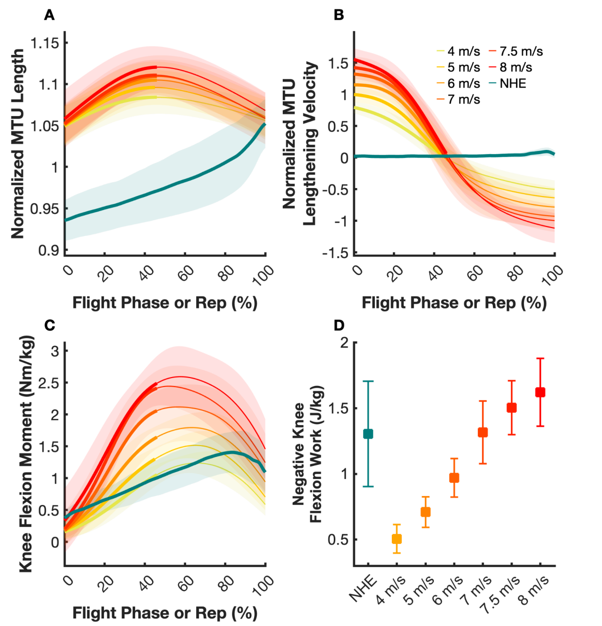

Figure 1: (A) Normalized (mean ± SD) BFLH MTU length (relative to upright posture length) (B) BFLH MTU velocity (C) knee flexion moment (D) negative knee flexion work. Five participants were able to run at 8 m/s, 11 participants ran at 7.5 m/s and all the participants ran at 7 m/s.

Conclusions

While running has greater peak BFLH MTU lengthening velocities, the NHE has a longer duration and the BFLH MTU lengthens for the entire rep. The longer duration NHE results in similar magnitudes of negative knee flexion work as one flight phase of top speed running. These results could be used to quantify the mechanical loads of training in future running and NHE studies to correlate mechanical loads with adaptation outcomes. The next step is to characterize the muscle-tendon dynamics in this same set of data.

Acknowledgments

This work was supported by the US NSF and the Wu Tsai Human Performance Alliance.

References

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