Effects of speed and performance level on lower extremity coordination during running

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Summary

This study investigated the effects of speed and performance level on lower-extremity coordination during running. Twelve male university track athletes (middle- and long-distance runners) were divided into higher- and lower-performance groups (HP and LP) and ran on a treadmill at five speeds (180–300 m/min). The continuous relative phase (CRP) and its variability in the lower-limb segments were calculated using marker-less motion capture and motion analysis software. The results showed that CRP variability decreased as speed increased. Thigh-shank CRP during the swing phase decreased with increasing velocity. The inter-limb thigh CRP showed distinct patterns, with LP demonstrating closer to opposite phases at higher speeds. These findings indicate that running speed affects lower-limb coordination. This suggests that lower performance corresponds to greater phase variability and opposed phasing during intense running.

Introduction

Humans encounter locomotor challenges by modifying the frequency, amplitude, and segment interactions of rhythmic flexion/extension patterns [1]. Modern approaches to locomotor control analysis employ the continuous relative phase (CRP) of the limbs to study coordination and changes in disease, injury, and skill [2]. Most studies have been conducted in walking, jogging, and clinical settings, but the relationship between coordination and motor skills while running at high speeds has not been explored. This study aimed to examine the effects of speed and performance level on lower extremity coordination during running.

Methods

Twelve male middle- and long-distance runners aged 18–23, belonging to a university track and field team, participated in the experiment. They were divided into two groups depending on their performance (six in the higher-performance group: HP and six in the lower-performance group: LP) based on the WA scoring table. The participants ran on a treadmill for 3 min at 5 running speeds (180, 210, 240, 270, and 300 m/min). The 30 seconds from 2 min after the start of each trial were used as the measurement interval, and a marker-less motion capture system was used to capture 3D movements of the lower limb segments during running at a sampling frequency of 100 Hz. A rotary encoder was set on the treadmill to measure the belt speed during the run at a sampling frequency of 1000 Hz. Data from ten consecutive cycles of the right leg, starting from the right foot strike, were extracted from the measured interval and included in the analysis. The skeleton of the participant was automatically recognized from the video images using a skeletal recognition software (Theia3D, Theia Markerless Inc.), and the angles and angular velocities of the pelvis and lower limb segments (thigh, shank, and foot) in the sagittal plane were calculated using 3D motion analysis software (Visual3D, C-Motion Inc.). The CRP was calculated from the segment angles in the sagittal plane using the Hilbert transform [3].

Results and Discussion

Intra- and inter-limb CRP levels and their variability were calculated by dividing the phases into stance and swing phases. For the intralimb CRP, the thigh-shank CRP decreased with increasing velocity during the swing phase. With increasing speed, the phase lead of the shank occurred earlier during the swing phase. Figure 1 shows the results of the thigh–thigh CRP by group. For the interlimb CRP, both thigh phases showed opposite phases with increasing velocity. At low speeds, the phase advance of the grounded foot tended to occur later. The interaction between speed and performance level was also significant, with LP exhibiting more anti-phase behavior at higher speeds. The CRP of the thigh is thought to be closer to the opposite phase when running without margins. The main effect of speed on CRP variability was significant for all variables, both intra- and inter-limb, and the variability decreased with increasing speed.

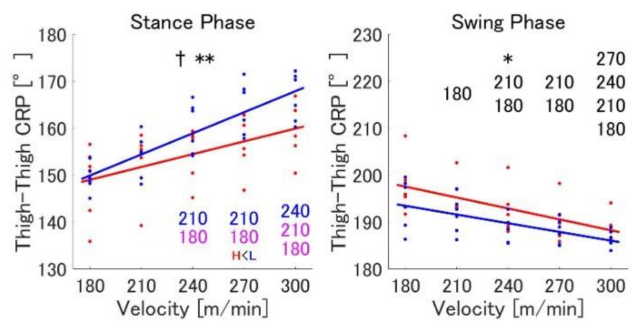

Figure 1: Thigh-Thigh CRP
(red: Higher performance group, bule: Lower performance group)

Conclusions

These results indicate that running speed affects lower-limb coordination. The lower performance suggests that the thigh-thigh CRP was closer to the opposite phase at high velocities. The results also suggest that the variability in lower limb coordination decreased with increasing speed.

Reference

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[2] Hu, M et al. (2021) *Gait Posture*; 215-233.
[3] Lamb, P et al. (2014). *Clinical Biomechanics*; **29**: 484-493.