Adaptive Changes in Lower Limb Coordination Variability and Impact Shock in Marathon Runners: an Outdoor Full-Marathon Study Based on Wearable IMUs

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Summary

This study employs wearable IMUs to assess changes in lower limb intersegment coordination variability (CV) and impact shock in marathon runners. The experiment was conducted on an outdoor circular track where 23 sub-elite runners finished a full marathon with their best efforts. The runners exhibited increased CVs in sagittal motion planes but decreased CVs on non-sagittal planes as the running mileage accumulated. CVs of all coupled segments were higher on curved paths than on straight paths. Tibial and pelvic impact shocks were elevated with increasing mileage. The findings indicate that the runners adopted varying adaptive strategies in different coordination planes to balance gait stability and variability in coping with prolonged running, which appeared to affect load attenuation and may contribute to load redistribution of the lower limb.

Introduction

Intersegment coordination is a holistic measure of gait pattern that can influence the injury potential and performance of marathon runners [1]. Previous studies have documented CVs during prolonged running and linked the changes to altered shock attenuation of the lower limb [2,3]. Nevertheless, existing findings were limited by controlled laboratory conditions and mediocre running mileage. This study addresses these gaps by investigating gait adaptations during a full marathon in an outdoor setting. The study focused on the effects of running mileage and track conditions (straight vs. curved paths) on CVs and lower limb impact shocks.

Methods

Twenty-three male marathoners (running experiences: 10.90 ± 4.04 years, usual pacing: 4:46 ± 1:34 min/km) completed a full marathon on a circular asphalt track. Four 9-axis IMUs were attached to the pelvis, thigh, shank, and rearfoot of their right legs to capture segment kinematics at 120 Hz. CVs of five lower limb segment couplings and impact shocks (tibial and pelvic) were analyzed at 5-km intervals. A generalized estimating equation (GEE) assessed the effects of mileage and track conditions on these measures, controlling for confounders of age, BMI, and weekly mileage.

Results and Discussion

As the race progressed, runners demonstrated increased CVs in sagittal motion planes and decreased CVs in non-sagittal planes (Figure 1). Significant changes were observed in CVs of shank vs. rearfoot during the later stages of the marathon (Wald $\chi2$ = 4.33—7.40, p = 0.007—0.037). Comparisons between track conditions revealed that all CVs were consistently lower on curved paths than on straight paths, with a significant difference identified in the coupling of pelvis vs. thigh (Wald $\chi2$ = 24.25, $p < 0.001$). Both tibial and pelvic impact shocks increased with increasing mileage after controlling for running speed (Wald $\chi2$ = 21.99—36.17, $p < 0.005$).

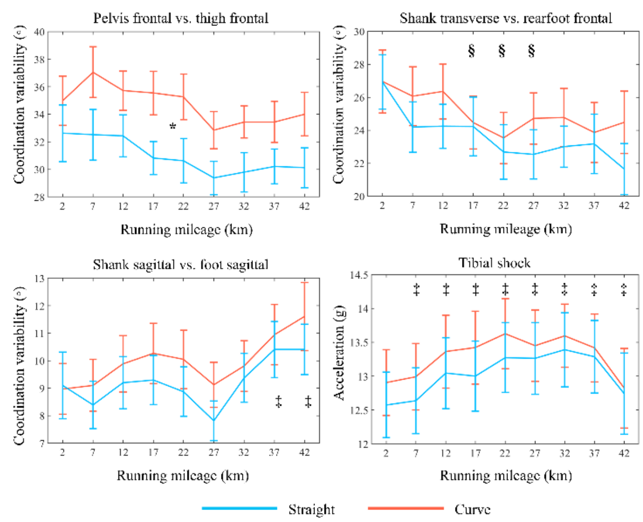

Figure 1: Changes in CVs and tibial shock during the marathon.

Conclusions

The distinct changes in lower limb CVs in different gait dimensions suggest that the human body adapted to prolonged running by balancing gait stability in the minor motion plane and greater variability in the major coordination plane. This strategy may help to tackle fatigue during repetitive exercises at the cost of disturbing load attenuation and workload distribution of the lower limb. Training protocols for marathoners can include conditioning on multiple rotational planes to improve the runner's capacity to retain the normal range of CVs.

References

[1] Hafer JF et al. (2019). *Med Sci Sports Exerc*, **51**(7):1438–1443
[2] Chen TL-W et al. (2022) *J. Sport Health Sci*, **11**(1):67–74.
[3] Reenalda J et al. (2019). *Gait Posture*, **68**:155–160.