Effect of Fatigue on Running Kinematics During a High Intensity Constant-Speed 30-Minute Run

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Summary

This study investigates fatigue-induced changes in lower limb kinematics and physiological responses during a 30-minute treadmill run at 85% VO2max. Knee and hip joint angles were assessed at pre-, mid-, and post-exercise intervals. Significant fatigue-related changes were observed in left and right knee extension at toe-off ($p<0.01$), and knee flexion at heel strike ($p<0.05$). When it came to the metabolic fatigue metrics evaluated, Heart rate (HR) and perceived exertion (Borg) increased significantly ($p<0.001$). These results confirm the presence of fatigue, altering biomechanics. Understanding these adaptations can aid in developing training strategies to mitigate fatigue-related inefficiencies and potentially reduce risk of injury.

Introduction

Fatigue is known to alter running biomechanics, potentially increasing injury risk [1]. Previous research has shown that prolonged running leads to increased joint loading and changes in movement patterns, potentially affecting efficiency and stability [2]. Understanding how lower limb kinematics evolve during prolonged exercise can inform training strategies to mitigate these risks. Fatigue-related alterations in running mechanics may result in inefficient movement patterns, leading to overuse injuries [3]. This study evaluates the effects of fatigue on ankle, knee and hip kinematics over a 30-minute constant-speed treadmill run and examines physiological markers such as HR, VO2max, and Respiratory Quotient (RQ) to confirm the presence of fatigue.

Methods

Eleven participants (age = 23.46 ± 3.08 years, height = 174.17 ± 12.44 cm, mass = 75.03 ± 10.59 kg, BMI = 24.75 ± 2.64) completed a 30-minute treadmill run at 85% VO2max on an instrumented treadmill (HP Cosmos, Germany) set to a 1% incline to simulate outdoor running. Borg, HR, VO2max, RQ, and marker trajectory were recorded at pre-, mid-, and post-exercise intervals. Kinematic data were collected via QTM (Qualisys, Gothenburg, Sweden) motion capture using the Qualisys Sports marker set at 100Hz and filtered using a 4th order low-pass Butterworth filter. Metabolic data were collected using the Cosmed K5 (COSMED, Rome, Italy). The analyzed kinematic metrics included max knee flexion, extension, range of motion (ROM), heel strike and toe-off angles, max ankle plantarflexion and dorsiflexion, max ankle abduction and adduction, max ankle rotation and its respective ROMs, max hip flexion and extension, max hip abduction and adduction, hip rotation and ROM, as well as max angular asymmetry. Data were collected for 30 seconds at each time condition. Statistical analysis was conducted using repeated measures ANOVA to determine significant differences across time points.

Results and Discussion

Significant changes in knee and hip kinematics were observed over time. Knee extension at toe-off increased significantly on the left limb from 5.04±6.45° to 6.98±6.60°, $p<0.01$, with a similar increase on the right limb from 14.28±7.82° to 15.81±7.24°, $p<0.05$. Knee flexion at heel strike also showed a significant increase from 5.05±6.48° to 6.97±6.61°, $p<0.01$ for the left leg, while the right knee flexion increased from 14.31±7.80° to 15.82±7.26°, $p<0.05$.

While hip extension did not show significant changes over time ($p>0.05$), hip ROM on the left leg trended toward an increase from 23.71±6.27° to 25.70±4.86°, $p = 0.056$. Furthermore, hip minimum rotation decreased significantly on the left from 18.52±6.28° to 16.79±5.58°, $p<0.01$.

Physiological data further support these kinematic changes. HR increased significantly across time points, rising from 163.25±7.48 bpm pre-exercise to 179.13±8.44 bpm mid-exercise and 188.25±7.23 bpm post-exercise ($p<0.001$), confirming the cardiovascular demand of prolonged exercise. RQ (1.02±0.09 to 1.05±0.09, $p=0.15$) and VO2max (42.8±7.46 to 45.4±6.924 VO2/kg, $p=0.246$) remained relatively stable, suggesting a sustained high aerobic metabolism. Borg scale demonstrated a substantial increase from 11±1.85 pre-exercise to 16.5±1.77 post-exercise ($p<0.001$), reinforcing subjective fatigue perception.

Conclusions

Fatigue-induced changes in knee and hip mechanics during prolonged running may reflect both an adaptive strategy to sustained high-intensity loading and a potential risk for overuse injuries. The increases in HR and perceived exertion confirm the physiological stress over time. Future research should focus on training interventions to enhance fatigue resistance while maintaining efficient running mechanics. Additionally, investigating neuromuscular activity could provide insights into muscle activation patterns and fatigue-related adaptations.

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References

[1] Derrick T.R. et al,. (2002) *Med. & Science in Sport & Exercise Musculoskeletal*, **34**:(5):765-71.
[2] Abt J.P. et al,. (2011) *J. Strength & Cond. Research*, **25**:(6):1479-85.
[3] Heiderscheit B.C. et al,. (2011) *Med. & Science in Sport & Exercise*, **43**:(2):296-302.