Classification of running styles based on temporal parameters across multiple running speeds

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Summary

Running style assessment is crucial for athletic performance and injury prevention. This study aimed to classify running styles by analyzing patterns of duty factor and cadence across multiple running speeds. Two hundred and five recreational runners wore GPS-integrated inertial measurement units during running sessions, from which we extracted temporal parameters at seven different paces. Using these parameters, hierarchical cluster analysis revealed three running style clusters. Statistical analysis showed significant differences in cadence among all clusters, while duty factor showed significant differences between some cluster pairs ($p < 0.01$), supporting the importance of considering both parameters in running style classification. While theoretical frameworks suggested five possible running styles, our empirical data revealed only three naturally occurring clusters, indicating more constrained relationships than previously thought.

Introduction

Assessment of running style is essential for improving athletic performance and preventing injuries. Previous studies have characterized running styles using duty factor categorizing runners into terrestrial runner with longer ground contact time and aerial runner with longer flight time [1]. Furthermore, Dual-axis framework was proposed as a new classification framework by incorporating cadence as an additional parameter. This novel approach hypothesized the existence of five running styles [2]. However, these classifications have been limited to observations at specific running speeds, despite that both duty factor and cadence vary with running speed. Therefore, this study aimed to develop a classification for running styles by considering the patterns of change in both cadence and duty factor across multiple running speeds.

Methods

Two hundred and five recreational runners were equipped with a GPS-integrated inertial measurement unit (CMT-S20R-AS, CASIO COMPUTER Co., Ltd.) at the waist during their running sessions from August to October 2024. Running data corresponding to seven different paces (6:00, 5:40, 5:20, 5:00, 4:40, 4:20, and 4:00 min·km^{-1}) were extracted from each session, with data within ±10 seconds of each target pace being included in the pace zone. To minimize fatigue effects, only the first third of each running session was analyzed. For each pace zone, cadence and duty factor were calculated at intervals of 0.25 to 1 km using a validated algorithm. To identify running styles, hierarchical cluster analysis using Ward's method was performed on the standardized cadence and duty factor values from all pace zones. Multiple t-tests were performed for both cadence and duty factor at each pace zone to compare gait parameters between clusters. To control for multiple comparisons, Bonferroni correction was applied to the p-values Statistical significance was set at $p < 0.05$.

Results and Discussion

Hierarchical cluster analysis revealed three clusters, first separating Cluster 1 by cadence, then Clusters 2 and 3 by duty factor. Statistical analysis showed significant differences in cadence among all clusters ($p < 0.01$), while duty factor differed significantly only between Cluster 2 and others ($p < 0.01$). These differences in both parameters across multiple running speeds demonstrate that running style classification should consider not only duty factor but also cadence. While the dual-axis framework [2] theoretically proposed five running styles, our analysis revealed only three clusters, and notably we did not observe runners with the combination of low cadence and high duty factor that was defined within the framework. These findings suggest that the relationship between these parameters may be more constrained than theoretically proposed, indicating that future classification methods should consider these naturally occurring patterns.

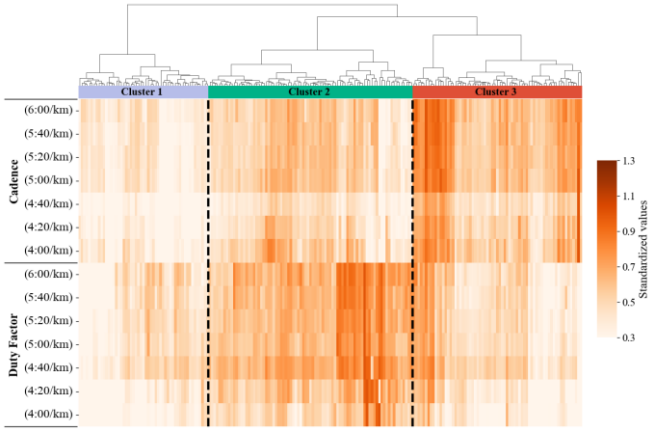

Figure 1: Comparison of temporal parameters among three clusters

Conclusions

Our findings demonstrate that running style classification should consider both cadence and duty factor, as shown by the three clusters from hierarchical cluster analysis. While the theoretical framework suggest five running styles, our empirical data revealed only three naturally occurring clusters, suggesting that the relationship between cadence and duty factor may be more constrained than previously thought. These findings indicate that future running style classification frameworks should be based on naturally occurring patterns.

References

[1] Gindre C et al. Int J Sports Med **37**: 25-29, 2016
[2] van Oeveren BT et al. Sports Biomech **23** 516-554, 2021