QUANTIFYING FATIGUE-RELATED MOVEMENT PATTERN CHANGES IN FEMALE RUNNERS

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Summary

Quantifying female-specific biomechanics in runners remains an important yet understudied area. This study applied a principal component analysis to quantify wearable sensor-derived movement pattern changes in female runners following a fatiguing 5k time trial. Results showed deviations in movement patterns during and after the time trial, with increased variability throughout the run. This approach offers a holistic method for quantifying fatigue-related biomechanics changes.

Introduction

Despite the popularity of running among women, female-specific running biomechanics remain under-researched. Anatomical differences, such as breasts, can influence running biomechanics and potentially affect performance [1]. While many studies have examined fatigue-related changes in the lower limbs, few have characterized how fatigue manifests in the upper body, particularly in understanding movement patterns in women [2]. Understanding these biomechanical adaptations in women is crucial but remains understudied. Therefore, this cross-sectional study aimed to quantify fatigue-related changes in the stride-level accelerometer patterns of recreational female runners. Specifically, it assessed overall biomechanical changes before, during, and after a fatiguing run.

Methods

As part of a larger study, 31 female runners (30 ± 8 years) were recruited from local running clubs. Data were collected on a standard 400-m outdoor track. Initial measurement units (IMeasureU Blue Trident, Vicon Ltd, Denver, CO; Fs = 1000 Hz) were placed on participants' tibiae and breasts. Runners wore their own shoes and sports bras during a 20-minute warmup at self-selected easy pace, followed by a 5k time trial to induce fatigue, and a two-lap cool-down at same easy pace.

Data from each sensor were downloaded and synchronized using the CaptureU software, then segmented into left and right strides. Resultant accelerations for the breast and ankle sensors were normalized to 0-100% of stride. Normalized strides from each sensor were concatenated into a 404xN matrix, where N is the number of strides. For each participant, a principal component analysis was applied to the middle 80% of the warm-up data to reduce dimensionality while retaining the principal components that explained 90% of the variance. The remaining data from the end of the warm-up (PRE), the 5k time trial (FTG), and the cool down (POST) were projected into the same principal component space for comparisons. The FTG time trial data were further divided into four equally spaced periods (FTG1-4).

The Euclidian distance (ED) was calculated between the baseline warm-up period centroid and each subsequent periods' centroid, as a measure of the overall change in movement pattern. Additionally, a within ED was calculated between strides and the centroid of that period to assess movement variability. A linear mixed model was used to evaluate the effects of fatigue, with separate models analyzing changes from PRE to POST (overall fatigue effects) and throughout the time trial (FTG1 to FTG4) for both the between and within ED.

Results and Discussion

Significant differences were observed between PRE and POST for between ED, but not within ED. This suggests that overall movement patterns changed following the fatiguing time trial, while the stride-to-stride variability remained consistent. During the 5km time trial, both between and within ED showed significant effects across FTG periods indicating that as the time trial progressed, movement patterns both deviated further from baseline and became more variable. These findings highlight the potential for using principal component-derived Euclidian distances to holistically measure fatigue-related differences as a measure of fatigue-related biomechanical changes. However, further analysis is needed to quantify the individual fatigue-specific alterations in running gait.

Conclusions

Principal component-derived Euclidian distances effectively quantify fatigue-related changes in movement patterns.

Acknowledgments

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References

[1] McGhee DE et al. (2020). *Physiology*. **32**, 144-156.
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Table 1: Descriptive statistics (mean (SD)) for each period and linear mixed model results. *[a]: Difference between FTG4 and FTG1.*

Variable	PRE	POST	P-value	FTG1	FTG2	FTG3	FTG4	P-value
Between ED	31.7 (12.6)	100.4 (50.1)	< 0.001*	107.3 (48.0)	104.2 (49.5)	109.5 (48.7)	117.9 (48.1)[a]	0.02*
Within ED	84.1 (20.2)	83.1 (22.4)	0.8	88.9 (19.1)	83.0 (21.3)	85.0 (20.7)	92.6 (20.0)[a]	0.001*