Does one single most economical running technique exist? Some preliminary results

Adrian R. Rivadulla[1], Xi Chen[2], Dario Cazzola[1], Grant Trewartha[1], Ezio Preatoni[1]
[1]Department for Health, University of Bath, Bath, UK
[2]Department of Computer Science, University of Bath, Bath, UK
Email: arr43@bath.ac.uk

Introduction

Running economy is a critical factor in running performance and the search for the most economical running technique has received great attention in running biomechanics research. The challenge is that running technique is highly individual, making it difficult to extend the results of a study to the wider population, which may explain why there have been contrasting findings in the literature [1]. Recent studies using unsupervised learning have identified clusters of runners with a similar running technique and have shown how these clusters responded in different ways to shoe types [2] or exercise-based physiotherapeutic treatment [3]. From these results, it follows that there may not be a single most economical running technique which applies to everyone. However, running clustering studies to date have focused on describing the biomechanical differences between clusters and have not included running energetics in their analyses.

We used hierarchical clustering to identify groups of runners with similar technique and then compared energy expenditure between clusters.

Methods

Thirty-one competitive long-distance male runners (height: 1.79±0.06 m, body mass: 72.7±7 kg, lactate threshold: 14.4+1 km/h) completed a four-minute run at 12 km/h on a treadmill at 1% gradient. Full body kinematics and gas exchange were collected using motion capture (Oqus, Qualysis, Gothenberg, Sweden) and a metabolic system (K5, COSMED, Rome, Italy). Mean trunk-to-pelvis, hip, knee and ankle sagittal plane angles, centre of mass vertical displacement normalised by leg length (time-continuous variables), stride frequency and duty factor (discrete variables) were calculated to characterise running technique [1]. Energy expenditure was estimated using indirect calorimetry.

To reduce the dimensionality of our data, time-continuous variables were modelled as Fourier series with the minimum number of harmonics required to reconstruct angular and translational signals with an error <2° and <5 mm, respectively [4]. Principal component analysis was then applied on the standardised Fourier coefficients and discrete variables, and as many principal component scores as needed to capture 99% of the variance in the original space were retained and used as input to hierarchical clustering.

Hierarchical agglomerative clustering (similarity metric: Euclidian distance, linkage criteria: Ward) was then implemented. The number of clusters (n=2) was selected based upon the largest distance between clusters. Parametric/non-parametric SPM 1-D or discrete methods were used to compare both clusters according to the nature of the variable and distribution characteristics and Cohen's effect size (d) was calculated for the energy expenditure comparison.

Results

Cluster 1 (n=21) exhibited a less extended hip and knee and less plantar flexed ankle towards the end of stance phase, greater vertical centre of mass displacement during flight phase and higher duty factor compared to Cluster 2 (n=10). However, no significant differences in energy expenditure were found (p=0.15, d=-0.54, Figure 1).

Discussion

These preliminary results indicate that runners used different motor solutions yet with similar energetic requirements to complete the run. Thus, a one single most economical running technical model may not exist. In future work we will increase our dataset, include females, different speeds, and variability as part of our definition of running technique.

References

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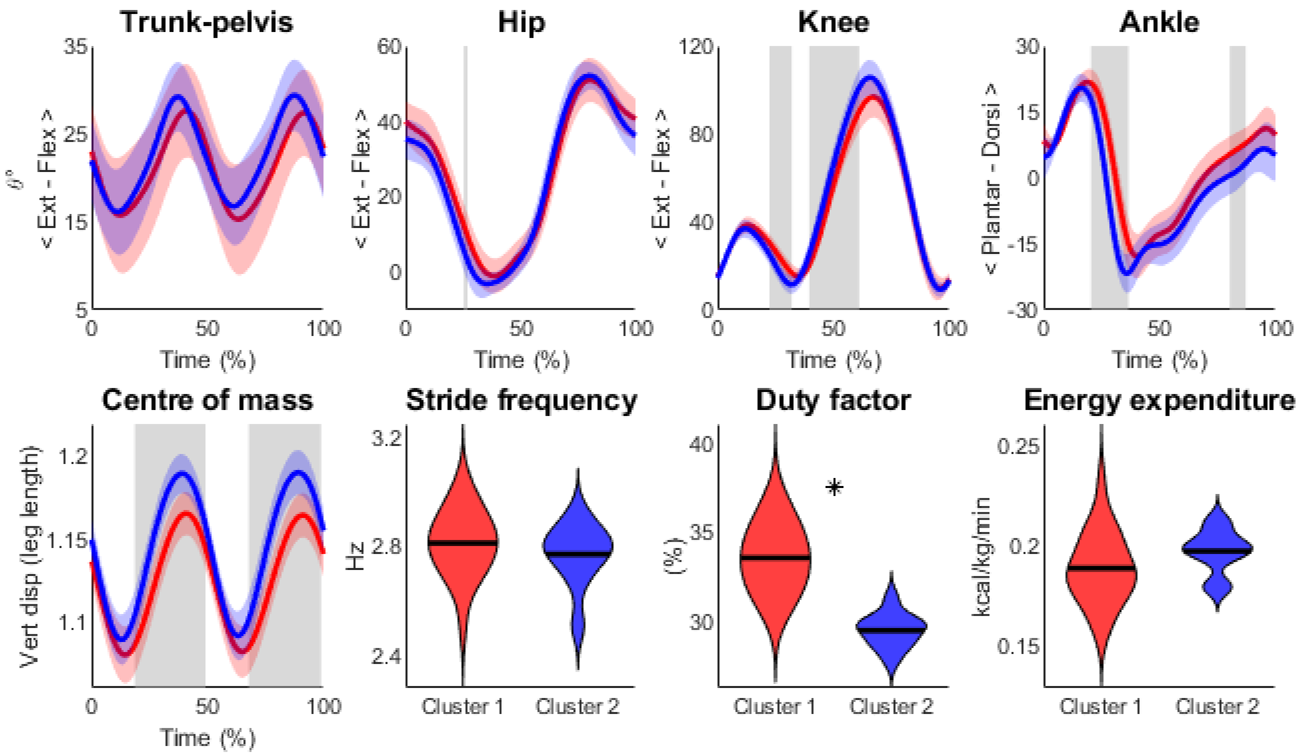

Figure 1. Mean time-continuous kinematic variables (top row and bottom left; mean curve and standard deviation clouds) throughout the stride cycle (foot contact to foot contact) and violin plots for discrete variables (bottom row; horizontal black line indicates the mean) for clusters 1 (red) and 2 (blue). Grey patches in the time-continuous plots indicate phases of the gait cycle in which significant differences were found by the SPM analysis. * = significantly different (p < 0.001).