# Association Between Positive Joint Work Distribution and Cost of Transport During a Fatiguing 10-km Run – A Pilot Study

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## Summary

This study examines the association between positive joint work distribution and cost of transport (CoT) during a fatiguing 10-km run. Recreational runners completed a 10-km treadmill run with near-maximal effort while motion capture, ground reaction forces and metabolic gas-exchange data were collected. From 1 to 10 km, positive joint work distribution shifted progressively from the ankle (44% to 35% total joint work) to the hip (39% to 48%), while knee contribution remained constant (17%). Simultaneously, CoT increased continuously, with a total increase of 1.8% from 1 to 10 km. This shift to a greater reliance on proximal muscles with less energy storage and return capacity and longer muscle fibers for propulsion may be one potential factor influencing the increase of CoT. Further research is needed to better understand this association and thus improve running performance.

## Introduction

A fatiguing run increases energy costs [1] and shifts positive joint work from distal to proximal joints [2], changing the main propulsion from the energy-efficient muscle-tendon unit at the ankle to the larger muscle groups at the knee and hip. However, it remains unclear whether the increase in energy cost is linked to the joint work shift. This study investigates this association by looking at the increase in CoT and the shift in positive joint work distribution of the ankle, knee and hip during a fatiguing 10-km run.

## Methods

Recreational runners (n = 3) ran 10 km on an instrumented treadmill with near-maximal effort (5% slower than their personal best time over 10 km (44 min 0 s ± 5 min 21 s), running velocity of 3.64 ± 0.42 m/s). We recorded motion capture data of the lower body (200 Hz) and ground reaction forces (2000 Hz) for 30 s at the beginning of each kilometer and for the last 30 s of the run, while measuring breath-by-breath metabolic gas-exchange data during the whole run. Perceived exertion (Borg CR-10) and blood lactate samples were collected pre- and post-run, the latter also 2 min post-run. Positive joint work in the sagittal plane was calculated for the ankle, knee and hip of the right leg over the first 30 steps of each measurement (0 km to 10 km). CoT was determined over the first minute of each kilometer and the last minute of the run (except 0 km to ensure steady-state conditions).

## Results and Discussion

The 10-km run was fatiguing as perceived exertion changed from 3.7 ± 0.6 pre-run (after a 5 min warm-up) to 8.7 ± 0.6 post-run. Blood lactate concentrations increased moderately from 1.6 ± 0.1 mmol/L pre-run to 3.75 ± 1.2 mmol/L post- run and decreased to 2.7 ± 0.0 mmol/L 2 min post-run. Additionally, gas-exchange data showed a respiratory exchange ratio < 1 for all participants throughout the run, indicating a predominantly aerobic metabolism. CoT increased continuously over the run, resulting in a total increase of 1.8% ± 1.1% (△ 0.14 ± 0.02 J/kg·m) from 1 km to 10 km (Figure 1).

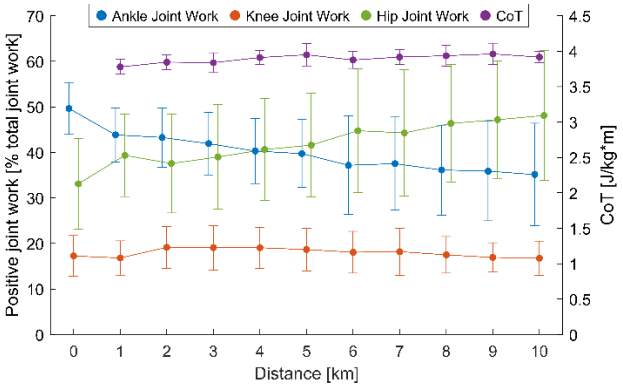


**Figure 1**: Relative positive joint work of ankle, knee and hip and CoT over a fatiguing 10-km run (mean ± standard deviation).

Simultaneously, positive joint work distribution shifted continuously during the run from the ankle to the hip (Figure 1), with the ankle changing from 44 ± 6% of the total joint work at 1 km to 35 ± 11% at 10 km (△ -9 ± 9%) and the hip from 39 ± 9% to 48 ± 14% (△ +9 ± 11%), while the knee joint work remained constant (△ 0 ± 3%) at 17 ± 4%. This shift potentially leads to a greater reliance on proximal muscles with less energy storage and return capacity and longer muscle fibers for propulsion, which may produce greater metabolic costs. Consequently, the joint work redistribution may be one potential factor influencing the increase of CoT. Statistical analysis of larger sample sizes is required (and will be presented at the conference) to quantify the association between joint work distribution and CoT.

## Conclusions

The progressive shift of positive joint work from the ankle to the hip during a fatiguing 10-km run, accompanied by a continuous increase in CoT, suggests that greater reliance on larger proximal muscles for propulsion may lead to increased metabolic costs, potentially impacting running performance.

## References

[1] Fletscher and MacIntosh (2018). *PLoS One*, **13**(8): e0202026.

[2] Sanno et al. (2018). *Med. Sci. Sports Exerc.*, **50**(12): 2507-2517.