# RUNNING SELF-OPTIMISATION:

# ACUTE AND SHORT-TERM ADAPTATIONS TO RUNNING MECHANICS AND RUNNING ECONOMY

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

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**Abstract**

The intuitive link between a runner's gait and their metabolic cost of running, or running economy (RE), has led to many trying to compare the running mechanics of economical runners to those of less economical runners. However using this approach has created controversy about whether running mechanics meaningfully contribute to RE. Additionally only a limited number of studies use a broad, explorative, inter-disciplinary approach, encompassing physiological parameters, flexibility, kinematics, kinetics and muscular activity. The purpose of this thesis was to primarily assess 'self-optimisation' through considering acute and short-term adaptations to running mechanics and RE. To assess the biomechanical and physiological mechanisms behind changes to RE three studies were conducted, in addition to a fourth study which investigated biomechanical familiarisation. Study one investigated whether there were any biomechanical or physiological changes in beginner runners after 10 weeks of running and whether any of these changes contributed to a change in RE. There was an 8.4% improvement in RE (224 ± 24 vs. 205 ± 27 $mL \cdot kg^{-1} \cdot min^{-1}$) and an increase in treadmill time-to-exhaustion (16.4 ± 3.2 vs. 17.3 ± 2.7 min), but no change in $\dot{V}O_{2max}$, minute ventilation or heart rate. Several kinematic, kinetic and flexibility measures were found to change over time, but joint moments and stiffness remained similar, with knee extension at toe-off, rearfoot velocity at touch down and timing of peak dorsiflexion explaining 94.3% of the variance in change in RE.

Results from study one suggested that changes in muscular activity might have contributed to kinematic differences, and subsequently an economical gait. Specifically, as joint moments were unchanged after 10 weeks it is possible that muscular coactivation may have changed since varying levels of agonist-antagonist activation can produce the same joint moment. Consequently study two examined the relationship between muscular coactivation and the metabolic cost of running, as thus far there was conflicting evidence. Results showed that in trained, recreational runners greater thigh coactivation was associated with a greater metabolic cost of running. Furthermore, the speed of running was found to affect the level of coactivation at the shank and of the flexor-flexor muscle pair, with less coactivation reported at faster submaximal speeds.

The final part of the thesis focused on a manipulation investigation into barefoot (BFT), minimalist shod (MS) and shod (SH) running. Applying the novel findings from studies one and two to this topical area would hopefully provide new insight into the

BFT running debate. Prior to applying this knowledge of kinematic and muscular activity changes in relation to RE whilst running BFT, an investigation into the time required to become familiar with barefoot treadmill running was needed. Results revealed that barefoot familiarisation was characterised by less plantarflexion and greater knee flexion at touch down, whilst stride length appeared to be adopted instantaneously. Reliability (intra-class correlations) and accuracy (standard error of mean) of the kinematic data appeared strongest once individuals had been running for 20 mins. Furthermore there were no significant differences in the kinematics after 20 mins of running.

The final study considered how changing the levels of proprioception and cushioning (BFT, MS and SH) influenced RE and the potential running mechanics that contributed to any changes in RE. The ramifications of such changes on injury risk were also considered by investigating impact accelerations, effective mass and pronation. Additionally, the effect of naturally changing stride length from a shorter BFT stride to a longer SH stride on RE were examined. Heightened proprioception and no external cushioning (BFT running) appeared to improve RE by at least 5% regardless of stride length, when compared to SH running with a SH stride length. However less proprioception and no external cushioning (MS running) only improves RE, compared to SH running with a SH stride length, when runners run with their SH stride length, rather than their shorter BFT stride length (~2.5% shorter). Improvements in RE are attributed to a lower vertical oscillation and effective mass, greater dependency on efficient, Type I muscles i.e. tibialis anterior, and less plantarflexion at toe-off. However higher impact accelerations, earlier heel off and low pronation angles, suggest there may be an increase in injury risk.

Therefore the findings from this thesis have demonstrated that runners naturally self-optimise the way they run. This is seen both as an acute (changes in footwear) and short-term (10 weeks) response to changing running gait. Study two demonstrated that economical runners appear to use different muscular strategies, with study one and four showing they also adopt specific movement patterns that may promote efficient storage and release of elastic energy. Additionally study three found that runners can become familiar with BFT treadmill running in 20 minutes. It is also important to note that economical biomechanical adjustments do not always favour a reduction in injury risk. But the thesis findings seem to suggest that perhaps performance denominates in terms of self-optimisation, rather than injury prevention.

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