

Mechanical and energetic determinants of optimal cycling cadence

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Introduction: Humans prefer to maximise the economy of walking and running. At a constant velocity, humans will quickly select a combination of stride length and rate that minimises energetic cost. Deviations from the preferred movement pattern result in energetic penalties. However the neural and muscular mechanisms that influence this relationship remain minimally understood. Interestingly, cyclists pedaling at a constant power output freely select a higher cadence than that which minimises energetic cost, suggesting economy is not the only factor influencing movement preference. Studying muscle mechanics during the more constrained movement of cycling may provide insight into what factors dictate human movement preferences. Understanding muscle function at optimal cycling frequencies may also help to maximise cycling performance.

Methods: Twelve participants completed two different testing sessions. Steady state oxygen consumption was measured during cycling at a power output of 2.5 W/kg with cadences of 40, 60, 80, 100 RPM, and a preferred cadence where feedback was hidden. The same protocol was repeated while we recorded 3D kinematics and kinetics of the lower limb, ultrasonography of vastus lateralis (VL) muscle fascicles and electromyography of the thigh and calf muscles. We used an inverse dynamics analysis to calculate joint level mechanical work.

Results: Net metabolic power exhibited a J-shaped relationship with cadence, with the energetic minimum occurring at 60 RPM. Net metabolic power was significantly greater at 100RPM and lower at 60RPM compared to the preferred cadence (82 RPM). While there was no clear relationship between cadence and peak muscle activation, cumulative muscle activation was reduced at slower cadences. There was a systematic decrease in peak joint moments with increasing cadence, resulting in greater positive joint work at slower cadence. Muscle fascicle shortening increased as cadence decreased, while peak VL fascicle shortening velocity increased with increasing cadence.

Discussion: The energetic results show that humans do not immediately select the most economical cycling cadence, choosing to pedal at higher rates that cost more energy. The lower cumulative activation at 60RPM suggests a possible mechanism for the improved economy is through reduced total activation costs. Greater fascicle shortening at slow cadences indicates greater muscle work whereas higher shortening velocities at high cadence would be less economical. It may be that humans initially seek to optimise muscle power over economy for major muscles like VL, and this leads to the discrepancy between the most economical and preferred cadence.