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Factors influencing pedaling effectiveness: A systematic review

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1 Abstract

A systematic literature review was conducted using PubMed, Scopus, SPORTDiscus, and Web of Science. The search strategy included the following terms: (technique pedaling and cyclist) OR (effectiveness and smoothness pedaling) OR (biomechanics of pedaling in cyclist) AND NOT ("rehabilitation" OR "therapy" OR "injury recovery" OR "clinical"). Studies focusing on clinical or rehabilitation contexts were excluded to maintain relevance to performance-oriented cycling.

The findings indicate that IE is not determined by a single biomechanical or physiological variable, but rather by the interaction of multiple factors. Variables such as medio-lateral force, muscle activation patterns, asymmetry, and anthropometric characteristics do not consistently influence IE across studies. In contrast, cadence and workload show more stable and predictable effects, with higher cadences generally reducing IE and increased workload tending to enhance it.

Training interventions have also demonstrated measurable effects on pedaling mechanics. A 12-week hip flexor strengthening program resulted in a reduction of negative torque (~14%) and an increase in propulsive torque (~3%) in trained cyclists. Additionally, increases in pedal force have been associated with improvements in both gross efficiency and IE, suggesting a link between force application and mechanical effectiveness.

Despite these findings, the relationship between IE and cycling performance remains inconsistent. In some cases, improvements in

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IE do not translate into meaningful performance gains, indicating that IE alone may not fully capture the complexity of pedaling efficiency. One of its main strengths lies in its ability to provide a direct mechanical description of force application; however, this reductionist approach may overlook important aspects such as coordination variability and fatigue-related changes.

Furthermore, most of the studies analyzed were conducted under controlled laboratory conditions, often using fixed workloads and constrained cadences. While this improves internal validity, it limits ecological validity and reduces the applicability of findings to real-world cycling scenarios, where conditions are highly variable.

Alternative metrics, such as pedal smoothness, have received comparatively less attention in the literature but may offer complementary insights into pedaling technique. These approaches could provide a more integrative perspective by capturing aspects of movement quality not reflected in IE alone.

In conclusion, while IE remains a useful and accessible metric for analyzing pedaling mechanics, it should not be interpreted in isolation. Future research should adopt a multidimensional approach, integrating mechanical, physiological, and performance-based variables to achieve a more comprehensive understanding of cycling performance and pedaling technique.