Journal of Science & Cycling
Breakthroughs in Cycling & Triathlon Sciences

OPEN ACCESS

Editorial

Biology vs. Mechanics: The Missing Link Between Force Effectiveness and Performance in Road Cycling

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Received: 6 June 2024; Accepted: 27 June 2024; Published: 2 July 2024

Abstract: Training cycling technique has been popular among coaches, but limited evidence supports benefits from this practice in terms of performance. The use of pedal force effectiveness metrics is discussed, noting the limitations of these outcomes to truly reflect pedaling technique. This editorial discusses the potential discrepancies between optimal mechanics and biological constrains for cyclists to optimize pedaling technique. Current evidence on the conflicts between improved technique and performance is illustrated. Evidence on limitations from the neuromuscular system to direct forces and maximize power at the same time are discussed. Potential adaptations from key muscles to single-leg cycling and other forms of technique training are explored with acknowledgement on the current limitations from evidence in the literature, particularly around the lack of robust controlled trials. Recommendations to practitioners are provided suggesting allocating training time to other activities rather than technique for cyclists willing to improve performance.

Keywords: Bicycle; Technique Training; Biomechanics; Pedal Forces

1. Introduction

Pedaling technique has been historically analyzed using different metrics, including the index of effectiveness (LaFortune & Cavanagh, 1983) and the positive impulse proportion (PIP; García-López et al., 2016). Both methods attempt to capture the magnitude of force or impulse that drives the crank in the direction of movement. Any force or impulse that is radial to the crank or counteracts the forward rotation of the cranks is deemed as ineffective or wasted force. From a mechanical perspective, it would be ideal if cyclists directed almost all force to drive the crank in the direction of movement. However, seminal research from Coyle et al. (1991) illustrates that even highly trained cyclists do not direct all force to drive the cranks, with a proportion of the force (40-50%) generating 'ineffective force' (Bini et al., 2013).

The desire of an 'optimal pedaling technique' has created a culture among cyclists and coaches that circling the cranks is the ideal way to pedal. However, scientists involved in research on biomechanics of cycling have been discussing for a long time that this approach is not ideal or even physiologically logical.

Therefore, the purpose of this editorial paper is to enable cyclists and coaches to understand why pedaling in circles has no potential benefit in improving performance. We will acknowledge the current evidence and discuss gaps that could lead to a future change in technique training. We also acknowledge that, measurements of force effectiveness are limited because, joint angles and mechanical work can change without changes in pedal force (Bini, Hume, & Kilding, 2014). However, for simplicity purposes, we will assume that pedaling technique and force effectiveness are interchangeable terms.

2. Current evidence: technique vs. performance

Some key studies are critical to demonstrate why better pedaling technique may not lead to improved performance. The first is the work from Coyle et al. (1991), who showed that cyclists with better performance presented poorer technique. Other studies demonstrated that cyclists present better force effectiveness than non-cyclists (Mornieux et al., 2008) but triathletes were similar to road cyclists (Bini, Hume, & Kilding, 2014). More recent evidence from García-López et al. (2016) illustrated that professional cyclists produced better PIP than cyclists with lower levels of performance. However, professional cyclists presented a different bike fitting than other cyclists, which could have an influence on these results. Finally, a study mapping 100 competitive cyclists observed that, more senior cyclists (older than 23 years) presented increased pedal force effectiveness, which suggest an improved use of force to drive the cranks (Almquist et al., 2023).

It is important to note that, the only prospective study describing the influence from technique training on cycling performance was a pilot work with a small number of cyclists (Bini, Hume, & Croft, 2014). Bini et al. observed that the group of cyclists trained to improve technique (8 sessions, twice weekly) increased pedal force effectiveness but did not improve performance compared to a control group during 4-km time trials. The key message from the papers above is that, somehow cyclists are limited in circling the crank whilst producing optimal performance. Let's explore some potential reasons to explain this limitation.

3. Neuromuscular efficiency: limitations with force effectiveness

Recent research has illustrated that, when attempting to reduce radial forces, cyclists loose power and force (Kistemaker et al., 2023; Onasch & Herzog, 2024). It seems that the ability to fully recruit lower limb muscles is limited when attention is directed to improve force effectiveness (Onasch & Herzog, 2024).

One interesting example to highlight the challenge of reducing 'ineffective force' is through single leg cycling. In single leg drills, which are culturally part of technique training in cycling, it is critical to push and pull the pedals because the contralateral weight is not present to assist lifting the ipsilateral leg. Therefore, force effectiveness increases (71 ±6% vs. 54 ±3%) as a consequence with a high demand for muscles that are not commonly used during double leg cycling (Bini et al., 2015). Even though movement (i.e. angles) of the hip, knee and ankle is maintained, during single leg cycling, larger activation of biceps femoris, vastus lateralis, rectus femoris, tibialis anterior and gastrocnemius medialis is observed (Bini et al., 2015) for lower relative mechanical work produced by the hip extensors (Elmer et al., 2016). These results show that single leg cycling, and potentially any form of training to increase force effectiveness, changes the motor control and biomechanics of pedaling. A key outcome, as illustrated by Korff et al. (2007) is the increase in energy expenditure and reduced efficiency when circling (i.e. improving technique). For road cycling, this would result in premature fatigue and reduced performance.

Taken together, it is clear that the neuromuscular system struggles with the dual task of recruiting muscles properly and directing the force to circle the cranks. It is not clear yet if the limitation is at the level of the brain and other components of the central nervous system or at the muscle level. Some evidence from single leg training seems to assist in this issue.

4. Adaptations from training and muscle physiology

One key element to keep in mind is that higher percentage of type I fibers in the vastus lateralis seems to explain better performance in cycling (Coyle et al., 1991). However, later evidence suggests that fiber type does not affect performance but changes with training (Hopker et al., 2013).

Most studies though limited their histological analysis to knee extensors, without looking at other muscles in cyclists. Hamstring muscles present a balanced distribution of slow and fast twitch motor units (Evangelidis et al., 2017) and fiber type (Garrett et al., 1984) but are known for high fatigability in cycling. Biceps femoris has been show to adapt to fast twitch fibers (Dahmane et al., 2006), whilst rectus femoris also has a balanced distribution of fiber types (Garrett et al., 1984). However, data on psoas and iliacus is missing which are key muscles in the hip flexion component and highly active when cyclists attempt to improve their technique.

One potential avenue to increasing adaptations from cycling training is using reduce mass, or single leg cycling. A method involves training with single leg cycling using a counterweight attached to the contralateral side (Abbiss et al., 2011; Bini et al., 2015). This method facilitated improvements in oxidative profile for the vastus lateralis compared to double leg cycling at equivalent intensity (Heidorn et al., 2023). This finding indicates that single leg cycling and pedaling technique could lead to changes in neuromuscular physiology and force production. However, no data is available from technique training programs or even single leg cycling training showing that improvements in performance will be observed or that changes are related to improvements in the direction of pedal force. Also, it is unclear how much the muscles from hip and knee flexor groups could change their fiber type distribution to become more efficient and the time frames for these changes. In professional cyclists, PIP seems to reduce before preseason (García-López et al., 2016), which highlights a trainability component for this outcome. Future research could explore if, technique training has any potential to change efficiency at muscle level.

5. Practical Applications.

The culture of pedaling technique and cycling performance is potentially distracting cyclists and coaches from using time more wisely. Even though it is unclear how trainable cycling technique is, it seems unlikely based on current evidence that spending time training technique in cycling will produce meaningful benefits in terms of performance. However, future research with robust randomized controlled trial design could change the landscape.

6. Conclusions

There is limited evidence supporting training pedaling technique to improve cycling performance. Most evidence indicates that, attempting to increase force effectiveness actually leads to less efficiency and reduced performance.

Funding: No funding was utilized to produce this work.

Acknowledgments: La Trobe University for providing access to databases and computer resources to produce this article.

Conflicts of Interest: "The author declares no conflict of interest."

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