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Title: Quasi-Isometric Cycling: A Case Study Investigation of a Novel Method to Augment Peak Power Output in Sprint Cycling

Mehdi Kordi[1], Martin Evans[2], Glyn Howatson[1,3]

[1]Department of Sport Exercise and Rehabilitation, Faculty of Health and Life Sciences, Northumbria University, Newcastle-Upon-Tyne, UK

[2]The FA, St George's Park, Burton-on-Trent, Staffordshire, UK

[3]Water Research Group, School of Environmental Sciences and Development, Northwest University, Potchefstroom, South Africa

Corresponding author:

Dr. Mehdi Kordi
Department of Sport Exercise and Rehabilitation
Faculty of Health and Life Sciences
Northumbria University
Newcastle-Upon-Tyne
UK
Tel: +44 772 591 7358
Email: mehdi.kordi@hotmail.co.uk

Submission type: Case study

Preferred running head: Quasi-Isometric Cycling increases Peak Power

Abstract word count: 250
Text only word count: 1580
Number of figures: 2
Number of tables: Zero

I had full access to all of the data in this study and take full responsibility for their integrity and analysis

Abstract

Purpose: Peak power output (PPO) is a determinant of sprint cycling performance and can be enhanced by resistance exercise that targets maximum strength. Conventional resistance training is not always suitable for elite cyclists because of chronic spinal issues, therefore alternative methods to improve strength, that concurrently reduces injury risk are welcome. In this case study, quasi-isometric cycling (QIC), a novel task-specific resistance training method designed to improve PPO without the use of transitional resistance training was investigated. **Methods:** A highly-trained sprint track cyclist (10.401 s for 200 m) completed a 5-week training block followed by a second 5-week block that replaced conventional resistance training with the novel QIC training method. The replacement training method required the cyclist to maximally drive the crank of a modified cycle ergometer for 5 seconds as it passed though ~100° range (starting at 45° from top dead centre) at a constant angular velocity. Each session consisted of 3 sets of 6 repetitions on each leg. In the saddle (ITS) and out of saddle (OOS) lab PPO was recorded. **Results:** Conventional training did not alter sprinting ability, however the intervention improved OOS PPO by 100 W (from 1,751 W to 1,851 W), whilst in ITS PPO increased by 57 W from 1,671W to 1,728W. **Conclusion:** QIC increased PPO in a highly-trained, national-level sprint cyclist that could be translated to improvements in performance on the track. Furthermore, QIC provides a simple, but nonetheless effective, alternative for sprint track cyclists who have compromised function to perform traditional strength training.

Introduction

Peak power output during cycling (PPO) is the maximum power output over a single crank revolution during a short (usually <10s) period of time. [1,2] The PPO during cycling in a laboratory environment can be accurately measured and is comparable to maximal sprints on the track. [3] Specifically, it has been well-established that PPO during sprint cycling can be used to predict performance [1,4,5] and is the biggest physiological predictor of flying 200 m performance in sprint track cycling. [1] It has also been established that maximum strength heavily influences the ability to generate PPO in elite cyclists. [6–9] However, little research has been conducted to investigate interventions that could increase maximum strength and hence PPO [7–9], and in particular, using highly-trained or elite level track sprint cyclists.

Despite the obvious benefits of maximising strength to influence PPO, there are many challenges that prevent sprint cyclists from engaging in traditional, systematic resistance training and hence reduce the potential to develop maximum strength. These challenges are largely attributable to chronic back injuries [10], whereby traditional multi-joint gym-based exercises such as back squat, deadlifts and other Olympic-style lifting is compromised due to the inability to put high axial loading through the spine; consequently, these training modes are contraindicated by science and medicine teams. Therefore, any alternative method to provide a stimulus for increasing maximum strength (and hence translate to PPO) that concurrently reduces the aforementioned issues would be well received to support athlete development and potentially extend athletic careers.

We have developed a novel, safe and task specific method (quasi-isometric cycling; QIC) for those who have compromised gym training. The QIC method requires the athlete to pedal with maximal intent with acceleration of the crank minimised, thereby minimising any segmental dynamics (such as momentum and centripetal force) that attenuate torque as velocity (cadence) builds. [11] In contrast, riding a bicycle with maximum intent with a large gear ratio reduces time under tension of the muscle groups due to segmental dynamics. This is demonstrated in Figure 1. Accordingly, the aim of this case study was to examine the efficacy of a 5-week QIC intervention to improve PPO in a highly strength trained, sprint cyclist.

[Insert Figure 1 about here]

Methods

Subject

The rider was a highly trained, national level track sprint cyclist (age 30 y, height 182 cm, body mass 88.7 kg) with a personal best 200 m time trial performance of 10.401 s; at the time of data collection, it was 6.2% from the sea-level World Record; and 0.7% from the 30 – 34 yr age category best performance. The athlete had over 5 years of systematic strength training and track sprint cycling experience and no underlying health conditions or chronic injuries.

Intervention

The intervention assessed the changes in PPO by substituting QIC for traditional resistance training sessions. The rider's body mass was 88.2 kg when reporting to the lab for post-intervention testing. Prior to the intervention, the rider had completed a five-week block, which included three track sessions, two gym sessions, one low-intensity 90 min road ride per week and one PPO laboratory testing session. The exact same five-week block was repeated with the only difference being the introduction of QIC sessions instead of the two gym sessions.

The QIC was performed on a custom-made ergometer (BAE Systems, United Kingdom) that was built to replicate the kinematic profile of sprint cycling. The inertial-load of the ergometer was increased by building it with a double-geared drive-train, specially-cast flywheel that was almost identical to the one that has been previously described. [12] To perform the QIC, the ergometer flywheel was brought to a standstill and acceleration of the wheel was minimised by having a cable tie partially brake the flywheel to ensure speed of the flywheel is constant and acceleration is minimised. The rider was instructed to have the lead crank at 45° from top dead centre and try to pedal the lead crank down to 150° from top, dead centre as 'with maximal intent' using both legs. The duration of each repetition was aimed to be approximately 5 s (around 20°/s). The practitioner positioned at the cast flywheel had real-time feedback with a digital inclinometer that was stuck on the lead crank and could judge how much extra pressure needed to be applied throughout the individual effort. The ergometer was instrumented with cranks (BF1 Factor cranks, Diss, United Kingdom) that was sampling torque of each crank at 200Hz. The cyclist performed 3 sets of 6 reps for each QIC session and was told to try to "pedal the cranks forward with both legs as hard and fast as possible". This replaced the cyclist's gym sessions which centred around back squats, deadlifts and single leg press (along with auxiliary upper body and core strength exercises). In the 5-weeks preceding the intervention, the main aforementioned exercises were progressed in load and lowered in volume starting with 5 reps and 5 sets to 3 reps and 3 sets (with the exception of a 'deload' week on week 3). The 5-week time period was what the cyclists used for his standard training 'macro-cycle' and therefore, it would make it more suitable to fit his schedule.

Assessment of Peak Power Output

The ergometer was set up as per riders racing bike geometry and performed the QIC on the drops, in the saddle (ITS). An isoinertial-load method was performed to measure PPO as described by Martin et al. [2] This was performed on a SRM Ergometer which was fitted with a dynamically calibrated scientific SRM power meter. Prior to each PPO test, the SRM power meter was zeroed according to manufacturer's instructions and sampling rate was set at 5Hz. The PPO lab tests were performed subsequent to a complete rest day. After a 15 minute self-prescribed warm-up. The rider performed four 6 s PPO tests: the first two ITS and the final two out of the saddle (OOS) with 5 minutes rest between each effort. The best PPO from the ITS and OOS protocol was used. In addition, cadence at PPO (C_{opt}) was used as a crude, functional marker for changes co-ordination. The coefficient of variation for PPO the test was calculated to be 2.9% and C_{opt} was 3.5% for ITS PPO [13]. For OOS PPO, the coefficient of variation was 2.5% and 2.2% for C_{opt} (unpublished).

Results

The participant's body mass at the post testing session was 88.2 kg (reduction of 0.5 kg from baseline). The four PPO lab assessments prior to the 5-week QIC intervention were similar (mean OOS PPO 1,740 ± 6 W; mean ITS PPO 1,680 ± 10 W) (Figure 2a). Following 5-week QIC intervention, OOS improved by 100 W (5.7%) from 1,751 W to 1,851 W whilst in ITS PPO increased by 57 W (3.4%) from 1,671W to 1,728W (Figure 2b). The torque traces of the QIC in comparison to the maximal pedalling with only the flywheel as resistance is presented in Figure 2. Pre- and post-intervention did not show any change in C_{opt} both ITS (119 vs. 118 RPM; -0.8%) and OTS (120 vs. 118 RPM; -1.7%).

[Insert Figure 2 about here]

Discussion

Over a 5-week period, replacing two gym sessions with a QIC session showed meaningful increases in PPO in a strength trained, national level track sprint cyclist. The reason why QIC has shown more efficacy to improve power at higher cadences could be either, or a combination of the following: a) the cadence of QIC is approximately 5 RPM which would result in an increase in time-under-tension for the targeted cycling muscles that are consequently at a similar joint-angle and force-length properties as those when cycling, and hence there is a great deal of task specificity; b) The segmental dynamics are minimised (such as momentum and centripetal force), which means there is no acceleration *per se* (even throughout the revolution) and therefore any torque that is applied to move the cranks/flywheel (without acceleration) removes the need for co-ordination. This is in contrast to the isokinetic cycling, where QIC increases the need for neuromuscular system to move the crank arm rather than simply pedal maximally at low cadences and only focuses on a specific part of the pedal stroke. No changes in (ITS or OTS) PPO were seen during the 5-weeks habitual training. It is plausible that one of the following, or combination thereof could explain this, 1) The training stimulus from the gym training performed with maximum intent, but was not sufficient to provide an additional stimulus; 2) The potential for further habitual gym training could have been attenuated from 5-years of similar training [14] and/or; 3) The lack of specificity to cycling could mean that any improvement in strength (or power) was yet to be translated. [15]

It has previously been suggested that maximal effort, low cadence isokinetic cycling impairs stroke efficiency and thereby reduces the increase in maximal power output during pedalling at higher cadences. In this intervention, no change in C_{opt} was seen, which suggests at least from a functional aspect, QIC did not affect co-ordination.

Practical Application

QIC can be used as a cycling specific training tool that can be used as an alternative to or in conjunction with traditional gym-based training in order to improve PPO in trained sprint cyclists.

Conclusion

This case study showed that QIC resulted in a marked increase in cycling PPO performance and should be considered as an adjunct tool to support the strength training programme for elite sprint cyclists, or as suitable alternative to those who have compromised ability to engage with traditional strength training sessions.

References

1. Dorel S, Hautier CA, Rambaud O, et al. Torque and power-velocity relationships in cycling: relevance to track sprint performance in world-class cyclists. *Int J Sports Med*. 2005;26(9):739-746. doi:10.1055/s-2004-830493

2. Martin JC, Wagner BM, Coyle EF. Inertial-load method determines maximal cycling power in a single exercise bout. *Med Sci Sports Exerc*. 1997;29(11):1505-1512.

3. Gardner AS, Martin JC, Martin DT, Barras M, Jenkins DG. Maximal torque- and power-pedaling rate relationships for elite sprint cyclists in laboratory and field tests. *Eur J Appl Physiol*. 2007;101(3):287-292. doi:10.1007/s00421-007-0498-4

4. Martin JC, Davidson CJ, Pardyjak ER. Understanding sprint-cycling performance: the integration of muscle power, resistance, and modeling. *Int J Sports Physiol Perform*. 2007;2(1):5-21.

5. Martin JC, Gardner AS, Barras M, Martin DT. Modeling sprint cycling using field-derived parameters and forward integration. *Med Sci Sports Exerc*. 2006;38(3):592-597. doi:10.1249/01.mss.0000193560.34022.04

6. Kordi M, Folland J, Goodall S, et al. Mechanical and morphological determinants of peak power output in elite cyclists. *Scand J Med Sci Sports*. 2020;30(2):227-237. doi:10.1111/sms.13570

7. Leong CH, McDermott WJ, Elmer SJ, Martin JC. Chronic eccentric cycling improves quadriceps muscle structure and maximum cycling power. *Int J Sports Med*. 2014;35(7):559-565. doi:10.1055/s-0033-1358471

8. Rønnestad BR, Hansen EA, Raastad T. Effect of heavy strength training on thigh muscle cross-sectional area, performance determinants, and performance in well-trained cyclists. *Eur J Appl Physiol*. 2010;108(5):965-975. doi:10.1007/s00421-009-1307-z

9. Rønnestad BR, Hansen J, Hollan I, Ellefsen S. Strength training improves performance and pedaling characteristics in elite cyclists: Strength training in elite cyclists. *Scand J Med Sci Sports*. 2015;25(1):e89-e98. doi:10.1111/sms.12257

10. Callaghan MJ, Jarvis C. Evaluation of elite British cyclists: the role of the squad medical. *Br J Sports Med*. 1996;30(4):349-353. doi:10.1136/bjsm.30.4.349

11. Bobbert MF. Why is the force-velocity relationship in leg press tasks quasi-linear rather than hyperbolic? *J Appl Physiol*. 2012;112(12):1975-1983. doi:10.1152/japplphysiol.00787.2011

12. Munro LA, Stannard SR, Fink PW, Foskett A. Potentiation of sprint cycling performance: the effects of a high-inertia ergometer warm-up. *J Sports Sci*. 2017;35(14):1442-1450. doi:10.1080/02640414.2016.1215492

13. Kordi M, Folland J, Goodall S, Barratt P, Howatson G. Isovelocity vs. Isoinertial Sprint Cycling Tests for Power- and Torque-cadence Relationships. *Int J Sports Med*. 2019;40(14):897-902. doi:10.1055/a-0989-2387

14. Ahtiainen JP, Pakarinen A, Alen M, Kraemer WJ, H□kkinen K. Muscle hypertrophy, hormonal adaptations and strength development during strength training in strength-trained and untrained men. *Eur J Appl Physiol*. 2003;89(6):555-563. doi:10.1007/s00421-003-0833-3

15. Kordi M, Goodall S, Barratt P, Rowley N, Leeder J, Howatson G. Relation between Peak Power Output in Sprint Cycling and Maximum Voluntary Isometric Torque Production. *J Electromyogr Kinesiol Off J Int Soc Electrophysiol Kinesiol*. 2017;35:95-99. doi:10.1016/j.jelekin.2017.06.003

Acknowledgements:

The authors would like to thank the cyclist who volunteered to take part in this study.

Conflicts of Interest:

The results of the current study do not constitute endorsement of the product by the authors or the journal. The authors declare no know conflicts of interest

Figure 1 (a) Longitudinal track of out of saddle (OOS) and in the saddle (ITS) peak power output (PPO) in the five weeks prior and subsequent to the intervention; (b) shows the power-cadence relationship of the OOS PPO pre- and post-Quasi-isometric cycling (QIC) intervention. Post intervention, PPO increased by 100W OOS and 57W ITS.

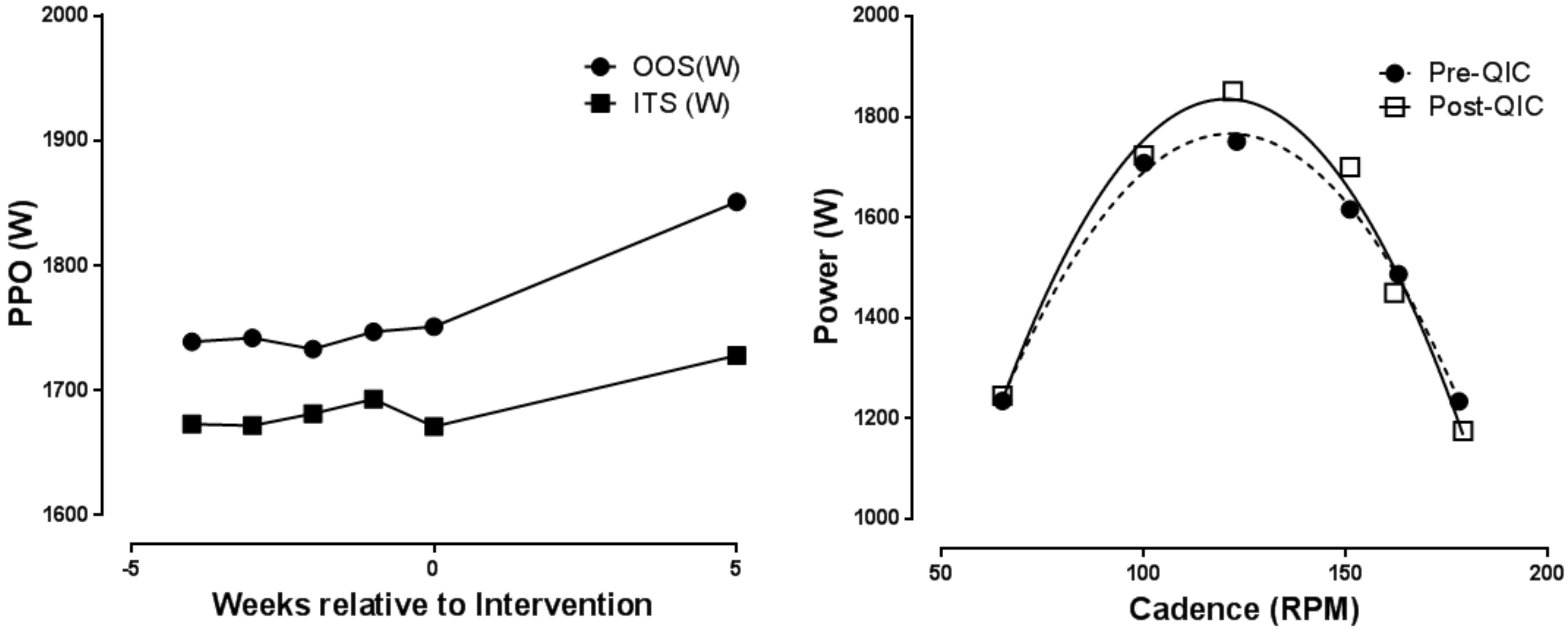

Figure 2: Typical torque traces of two quasi-isometric contractions (above) in comparison to standard maximal pedalling. All contractions are from stationary starts to bottom, dead centre (BDC). Both axis are matched in terms