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Pedaling force symmetry during 4-km cycling time trial

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SUMMARY
Existing research suggests that differences in bilateral pedal force application during cycling ranges between 5-20% for uninjured cyclists. However, limited evidence has been provided during different racing type efforts. The aim of this study was to assess asymmetry in pedal forces during a 4-km cycling time trial. Ten athletes with competitive experience in either cycling and/or triathlon races were assessed to determine their maximal workload level (session 1) and their maximal performance during a 4-km cycling time-trial (session 2). Bilateral pedal forces were acquired at eight sections of 500 m of the time trial to compute the total force applied to the pedals. Asymmetry indexes were computed following equation from Robinson et al. [1]. Differences in total force between pedals were rated using effect sizes (ES). Differences in bilateral total force were small comparing right to left pedals throughout the trial (3-10%, ES: 0.03-0.1). The high intensity/short distance in 4 km time trials may not elicit asymmetries such as previously reported for lower intensity/longer distances.

INTRODUCTION
Bilateral cycling motion has usually been assessed assuming symmetry in force production and kinematics of lower limbs. However, differences in power output, and mechanical work of the legs ranged from 5% to 20% in uninjured cyclists and non-cyclists [2]. Conflicting results were reported comparing cyclists [3-6] and non-cyclists [7] without clear relationships between pedaling cadence [4] and workload level [7] in bilateral symmetry. During a race, power output fluctuates according to travelling distance and to fatigue state of the cyclist [8, 9]. During 40 km time trial it was suggested that exercise intensity may increase asymmetry in peak crank torque. Due to high intensity exercise level observed during a 4-km time trial, maximum aerobic effort would be expected along with greater pedal force application. Therefore, large asymmetries in pedal force application would lead to greater fluctuations in travelling speed and potential reductions in performance. The aim of this study was to assess asymmetry in pedal forces during a 4-km cycling time trial.

METHODS
Ten athletes with competitive experience in either cycling and/or triathlon races participated in the study. (mean ±SD: age, 32 ±10 years; height, 180 ±13 cm; body mass, 71.2 ±14 kg; maximal aerobic power output, 377 ±88 W; VO_{2max}, 62 ±6 $ml \cdot kg^{-1} \cdot min^{-1}$).

Cyclists/triathletes performed an incremental cycling exercise on the cycle ergometer with three minutes of warm-up at 100 W and pedaling cadence visually controlled at 90 ±2 rpm (session 1). Workload was then increased to 150 W and remained increasing in a step profile of 25 W/min until cyclists' exhaustion [10] to determined maximal aerobic power output. After 10 minutes of rest, a familiarization with the 4-km time trial test was performed by the participants, at a self-selected gear-ratio and pedaling cadence.

During the 4-km time trial (session 2), normal and anterior-posterior forces were measured using a pair of strain gauge instrumented pedals [11], with pedal-to-crank angle measured using angular potentiometers. A reed switch attached to the bicycle frame detected the position of the crank in relation to the pedal revolution and computed pedaling cadence. Gas exchanges were continuously sampled using a metabolic cart (TrueOne 2400, Parvo Medics, Salt Lake City, UT, USA).

All analogue data were acquired using an analogue to digital board PCI-MIO-16XE-50 (National Instruments, USA) at 600 Hz, with a custom Matlab (Mathworks Inc, MA) data acquisition script. Analogue data were acquired for 10 s, every 500 m of the time trial, apart from the last stage when data was collected at 3.8 km to enable sufficient time to collect 10 s of data before the end of the time trial. Average resultant (total) force applied to the pedals was averaged for five revolutions of the crank for each stage of 500 m of the 4-km time trial then averages were computed for the start (0.5-1km), mid (2-2.5km) and end of the test (3.5-3.8 km).

Asymmetry index (AI%) was calculated as outlined by Robinson et al. [1] and differences in total force between pedals were rated using effect sizes (ES). Cohen's effect sizes (ES) were computed for the analysis of magnitude of the differences between means and were rated as trivial (<0.25), small (0.25-0.5), moderate (0.5-1.0), and large (>1.0) [12]. We chose large effect sizes for discussion of results to ascertain non-overlap between mean scores greater than 55% [13].

RESULTS AND DISCUSSION

Oxygen uptake ranged from 86% of maximal at the start of the test to 97% of maximal in the end of the test, highlighting a very high intensity effort level during the 4-km time trial.

Total pedal force application and asymmetry indexes for the right and left pedals are presented in Figure 1.

Differences between right and left total pedal force were of 3% (ES: 0.03) for the start of the test, 7% (ES: 0.07) for the mid of the test and 10% (ES: 0.1) for the end of the test.

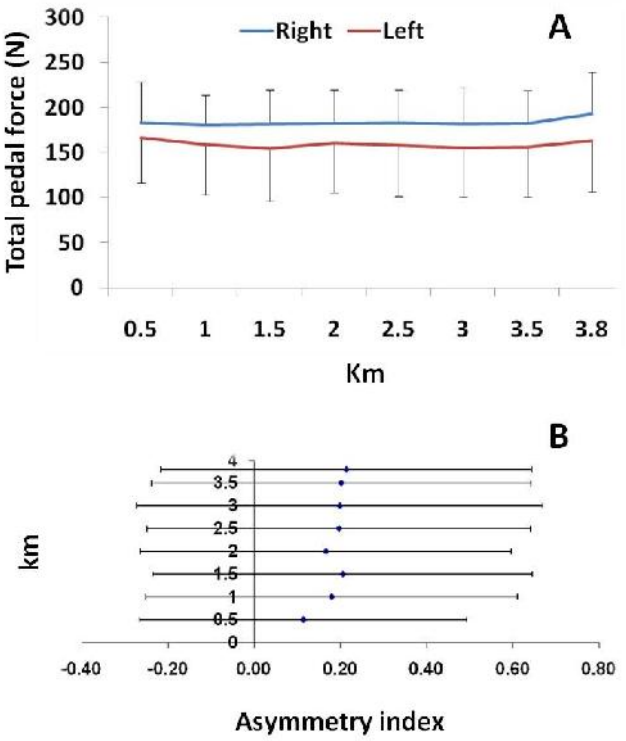

Figure 1: Total pedal force during the 4-km time trial (A) and asymmetry indices taken from right and left total forces (B). Positive asymmetry indices indicate greater force for the right pedal.

Pedal force asymmetries were similar to observed in previous studies [2, 5, 6] suggesting that differences in right to left pedal forces would be smaller than 10% in uninjured cyclists. Asymmetries indexes showed large variation as previously stated in previous research [4, 7] indicating that individual asymmetries may be linked to varying determinants. Potential reductions in individual asymmetries for performance optimization are unknown. The long term effect of right to left leg asymmetry in potential overuse injuries requires additional studies.

CONCLUSIONS

Pedal force asymmetries of cyclists performing maximal effort exercise are within the ranges observed in previous studies for uninjured cyclists. A threshold of 10% of bilateral differences in total pedal force may be suggested from our findings. Large variability in asymmetry indexes suggests an enhanced between-subjects variation for pedal force application. Rather than effects on performance, asymmetries require further studies related to risk of overuse injury.

REFERENCES

1. Robinson, R.O., W. Herzog, and B.M. Nigg, *Use of force platform variables to quantify the effects of chiropractic manipulation on gait symmetry.* Journal of Manipulative and Physiological Therapeutics, 1987. **10**(4): p. 172-176.
2. Carpes, F.P., C.B. Mota, and I.E. Faria, *On the bilateral asymmetry during running and cycling - A review considering leg preference.* Physical Therapy in Sport, 2010. **11**(4): p. 136-142.
3. Carpes, F.P., et al., *Influence of exercise intensity on bilateral pedaling symmetry.* Progress in motor control IV, 2007. **11**: p. S54-S55.
4. Smak, W., R.R. Neptune, and M.L. Hull, *The influence of pedaling rate on bilateral asymmetry in cycling.* Journal of Biomechanics, 1999. **32**(9): p. 899-906.
5. Carpes, F.P., et al., *Bilateral pedaling asymmetry during a simulated 40-km cycling time-trial.* Journal of Sports Medicine and Physical Fitness, 2007. **47**(1): p. 51-57.
6. Bini, R.R., et al., *External work bilateral symmetry during incremental cycling exercise*, in *25 International Symposium on Biomechanics in Sports*, H.-J. Menzel and M.H. Chagas, Editors. 2007, International Society of Biomechanics in Sports: Ouro Preto, Brazil. p. 168-171.
7. Daly, D.J. and P.R. Cavanagh, *Asymmetry in bicycle ergometer pedalling.* Medicine and Science in Sports and Exercise, 1976. **8**(3): p. 204-208.
8. Abbiss, C.R., et al., *Dynamic pacing strategies during the cycle phase of an ironman triathlon.* Medicine and Science in Sports and Exercise, 2006. **38**(4): p. 726-734.
9. Abbiss, C.R. and P.B. Laursen, *Models to explain fatigue during prolonged endurance cycling.* Sports Medicine, 2005. **35**(10): p. 865-898.
10. Lucía, A., et al., *Inverse relationship between VO2max and economy/efficiency in world-class cyclists.* Medicine and Science in Sports and Exercise, 2002. **34**(12): p. 2079-2084.
11. Candotti, C.T., et al., *Effective force and economy of triathletes and cyclists.* Sports Biomechanics, 2007. **6**(1): p. 31-43.
12. Rhea, M.R., *Determining the magnitude of treatment effects in strength training research through the use of the effect size.* Journal of Strength and Conditioning Research, 2004. **18**(4): p. 918-920.
13. Cohen, J., *Statistical power analysis for the behavioral sciences*. 2nd ed ed. 1988, Hillsdale, NJ: Lawrence Earlbaum Associates.