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ABSTRACT				
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KEY WORDS	
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TEXT				
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2	Left	32	“repeated measures”	“cross sectional”
4	Left	10	“indexes”	“indices”
6	Left	9	“indexes”	“indices”
6	Left	40	“Quite the contrary”	“In contrary”
6	Left	45		Add reference “21” after “leg”.

REFERENCES		
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FOOTNOTES ON THE LAST PAGE	
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Relationship between pedal force asymmetry and performance in cycling time trial

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Aim. **It remains unclear if cyclists with better performance have less asymmetry. Therefore, this study aimed at assessing the relationship between cycling time trial performance and bilateral asymmetries in pedal forces.**

Methods. **Ten cyclists/triathletes performed an incremental cycling test to exhaustion to measure maximal oxygen uptake and power output. In a second session, bilateral pedal forces were acquired during a 4-km cycling time trial on the stationary cycle ergometer. Resultant and effective forces were computed along with the index of effectiveness at 500 m sections of the time trial using instrumented pedals. Intra-limb variability and the asymmetry index were calculated for each force variable.**

Results. **Multivariate analysis assessed bilateral differences in pedal forces accounting for power output, pedalling cadence and oxygen uptake of each cyclist. Force variables did not change throughout the test (effective – P=0.98, resultant – P=0.90 and index of effectiveness – P=0.99) with larger force applied by the dominant limb (11-21%). The relationship between asymmetries and performances was strong for the effective force (r=-0.72) but weak for the resultant force (r = 0.01) and for the index of effectiveness (r=-0.29). Substantial asymmetries were observed for the effective force (36-54%), resultant force (11-21%) and for the index of effectiveness (21-32%) at greater range than intra-limb variability (effective force =8-22%, resultant force =5-10% and index of effectiveness =1-3%).**

Conclusion. **Larger asymmetries in effective force were related to better performances during the 4-km time trial with low intra-limb variability for force measures suggesting consistence in asymmetries for individual cyclists.**

Key Words: Athletic performance - Kinetics - Exercise test.

Cycling has been considered a constrained motion given cranks and pedals follow a consistent path around the bottom bracket. For that reason, it has been assumed that forces applied to the pedals and transferred to the cranks are symmetrical comparing right to left lower limbs.[1] In a recent review [2] asymmetries in bilateral force production have been suggested to limit cycling performance and to anticipate fatigue effects. However, only one study assessed asymmetries in peak crank torque during cycling time trial performed on the laboratory.[3] Unfortunately, the reduced number of cyclists in this study (*i.e.* six cyclists) limited any potential assessment of relationships between exercise intensity and bilateral asymmetries. Therefore, it remains unclear if cyclists with better performance have less asymmetry.

Studies looking at asymmetries in cyclists were mostly limited to measurements of peak crank torque [3, 4] or external mechanical work.[5] These are limited measurements of the force produced by the lower limbs, as the percentage of pedal forces that result in crank torque is usually 40-60%.[6, 7] Therefore, existing evidence on bilateral asymmetries in cycling may be affected by a contribution of muscle force production and cyclists' ability to drive forces perpendicular to the crank. With that in mind, measurements of bilateral asymmetries using total force applied to the pedals should be contrasted to asymmetries in effective force, which is analogue to crank torque.

Previous studies suggested that a threshold for

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bilateral asymmetry in uninjured cyclists would be 5-20%.[3, 4] However, lower (~3%)[5] and greater (23-30%)[4] levels of asymmetry have been observed. Others have also suggested that asymmetries would be varied among cyclists.[8, 9] However, only one study assessed asymmetries in cyclists during racing, with limitations on measuring only peak torque (not pedal forces). It is then important to explore asymmetries looking at pedal forces with focus on providing normative data for cyclists who intend to use upcoming commercial pedal force systems during training (*e.g.* Garmin-Vector® [Schaffhausen, Switzerland], Look-Polar® [Kempele, Finland] and others). Indeed, it would be critical to assure that upcoming pedal force systems enable users to compute their individual levels of asymmetry to provide data for training interventions.

Assuming that commercial pedal force systems will enable cyclists to continuously assess force related measures for each pedal, it is important to investigate if better performance could be closely linked to lower asymmetries in pedal forces. To provide evidence on that, this study aimed at assessing the relationship between cycling time trial performance and bilateral asymmetries in pedal forces.

Materials and methods

Participants

A quantitative repeated measures experimental design was used to collect data. Ten cyclists with competitive experience in cycling and triathlon were invited to participate in the study. Cyclists' (mean and standard deviation was 32±10 years, 71±14 kg, 180±13 cm, 62±6.3 $ml\cdot kg^{-1}\cdot min^{-1}$ maximal oxygen uptake, 377±88 W peak power output, and 5.3±0.8 $W\cdot kg^{-1}$ peak power per body mass) signed an informed consent form in agreement with the committee of ethics in research of the institution where this study was conducted. No cyclist/triathlete had an injury that would impact on test performance at the time of data collection.

Testing protocol and instruments

At their first session, body mass and height were measured from cyclists/triathletes according to ISAK protocols.[10] Cyclists/triathletes completed the Waterloo inventory to allow the determination of lower limb dominance.[11] Cyclists/triathletes' bicycle saddle height and horizontal position were measured to set-up the stationary cycle ergometer (Velotron, Racermate, Inc, Seattle, WA, USA). They 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. Workload was then increased to 150 W and remained increasing in a step profile of 25 W/min until cyclists' exhaustion.[12] A script was configured in the Velotron CS2008 software (Velotron, Racermate, Inc, Seattle, WA, USA) for automatic control of the constant workload mode with cycle ergometer resistance constantly changing to balance for fluctuations in pedalling cadence. Gas exchanges were continuously sampled from a mixing chamber where samples were drawn into the oxygen and carbon dioxide analyzers for continuous measurement using a metabolic cart (TrueOne 2400, Parvo Medics, Salt Lake City, UT, USA). Analyzers for oxygen and carbon dioxide were calibrated according to manufacturer recommendations. Maximal aerobic workload and maximal oxygen uptake were defined as the highest workload measured during the test and as the highest oxygen uptake value computed over a 15 s average of the data, respectively. After 30 minutes of rest, cyclists were prepared in the cycle ergometer to familiarise with the 4-km time trial test. They were instructed to perform maximally with full control for gear ratio and pedalling cadence. The second session of testing was conducted where there was similar training load prior to the first testing session, in order to try to ensure that the pre-test conditions were similar in terms of physical rest and preparedness for the testing sessions. After two to seven days from the first testing session, cyclists/triathletes returned to the laboratory at the approximate same time of the day to perform the 4-km time trial test following the same procedures described for the familiarisation session.

Normal and anterior-posterior forces were measured using a pair of strain gauge instrumented pedals,[13] with pedal-to-crank angle measured using angular potentiometers attached to the pedal spindle. The pedal force system enabled normal and anterior-posterior force measurements using strain gauges with cyclists/triathletes using cycling shoes with

Look® Delta cleats. Pedal force data passed through an amplifier (RM04, Applied Measurements, Oakleigh, Australia) and, along with potentiometers and reed switch signals, were recorded using an analogue to digital board (PCI-MIO-16XE-50, National Instruments, Austin, TX, USA) at 600 Hz per channel using a custom made script in Matlab (Mathworks Inc, Natick, MA, USA). Analogue data (force and pedal-to-crank angles) were acquired for 30 seconds at 500 metres intervals of the test (apart from the 3.8 km data acquisition to eliminate drops in force after the 4 km mark) while oxygen uptake was taken continuously during the 4-km time trial tests.

Data analysis

Pedal-to-crank angle measured by the potentiometers were converted into sine and cosine to compute tangential and radial forces on the cranks. Low pass zero lag Butterworth digital filter with cut of frequency of 10 Hz was applied to the sine and cosine data from potentiometers to attenuate signal noise from gap in potentiometer voltage readings.[14]

A reed switch attached to the bicycle frame detected the position of the crank in relation to the pedal revolution and enabled to separate pedal force data into every crank revolution. Average resultant (total) force applied on the sagittal plane of the pedal surface was calculated from full crank cycle, whilst pedal force effectiveness was assessed by the index of effectiveness computed as the ratio between the angular impulse of the tangential force on the crank (effective force) and the linear impulse of the total force applied on the pedal.[15] Average pedalling cadence was computed from timing of the reed switch sensor,[16] whilst average power output of each crank cycle was determined from the product of crank torque (computed from right and left effective forces and crank-arm length) to the average crank angular velocity taken from average pedalling cadence.[16] Forces variables and power output were averaged for each cyclist/triathlete across five revolutions of the crank for each 500 metres section of the 4-km time trial test. Intra-limb variability [17] was computed for force variables as the average coefficient of variance for the groups of cyclists. All force processing were conducted using a custom made script in Matlab (Mathworks Inc, Natick, MA, USA).

Asymmetry index (AI%) was calculated as outlined by Robinson *et al.* [18] for average total pedal force, effective force and index of effectiveness, defining positive asymmetry whenever the dominant limb presented larger force measures than the non-dominant limb. Oxygen uptake was averaged for each 500 m section of the 4-km time trial test in order to illustrate exercise intensity during the 4-km time trial tests.

Statistical analysis

Right and left pedal measures of resultant pedal force, index of effectiveness and effective force were converted into measures for dominant and non-dominant limbs, given results from the Waterloo inventory (*i.e.* more than 60% of preference for a given limb). Along with force variables, power output and pedalling cadence were log transformed in order to reduce the non-uniformity in data distribution. A multivariate ANOVA was performed in order to assess differences in force variables between each 500 metres section of the time trial and between dominant and non-dominant limbs, using SPSS for Windows 16.0 that included power output, pedalling cadence and oxygen uptake as covariates. *Post hoc* correction of Sidak was used for pairwise multiple comparisons. Correlations between asymmetry index of each force measure and performance time was computed via Pearson correlations in Matlab, assuming strong relationships for $r=0.7$-1.0, moderate when $r=0.4$-0.69 and weak relationship when $r<0.1$-0.39.[19] Significant differences were assumed when $P<0.05$ and observed power >0.8, and substantial asymmetries were considered for bilateral differences greater than 10%.[3, 4, 20]

Results

Measures of power output, pedalling cadence, oxygen uptake, effective force, resultant force and index of effectiveness taken during the 4-km time trial are shown in Figure 1.

Effects from power output were found in effective force ($P<0.01$ and observed power $=1.0$) and index of effectiveness ($P<0.01$ and observed power $=0.99$). Cadence affected effective force ($p<0.01$ and observed power $=0.99$) and resultant force ($P<0.01$ and observed power $=0.97$). No effects from oxygen up-

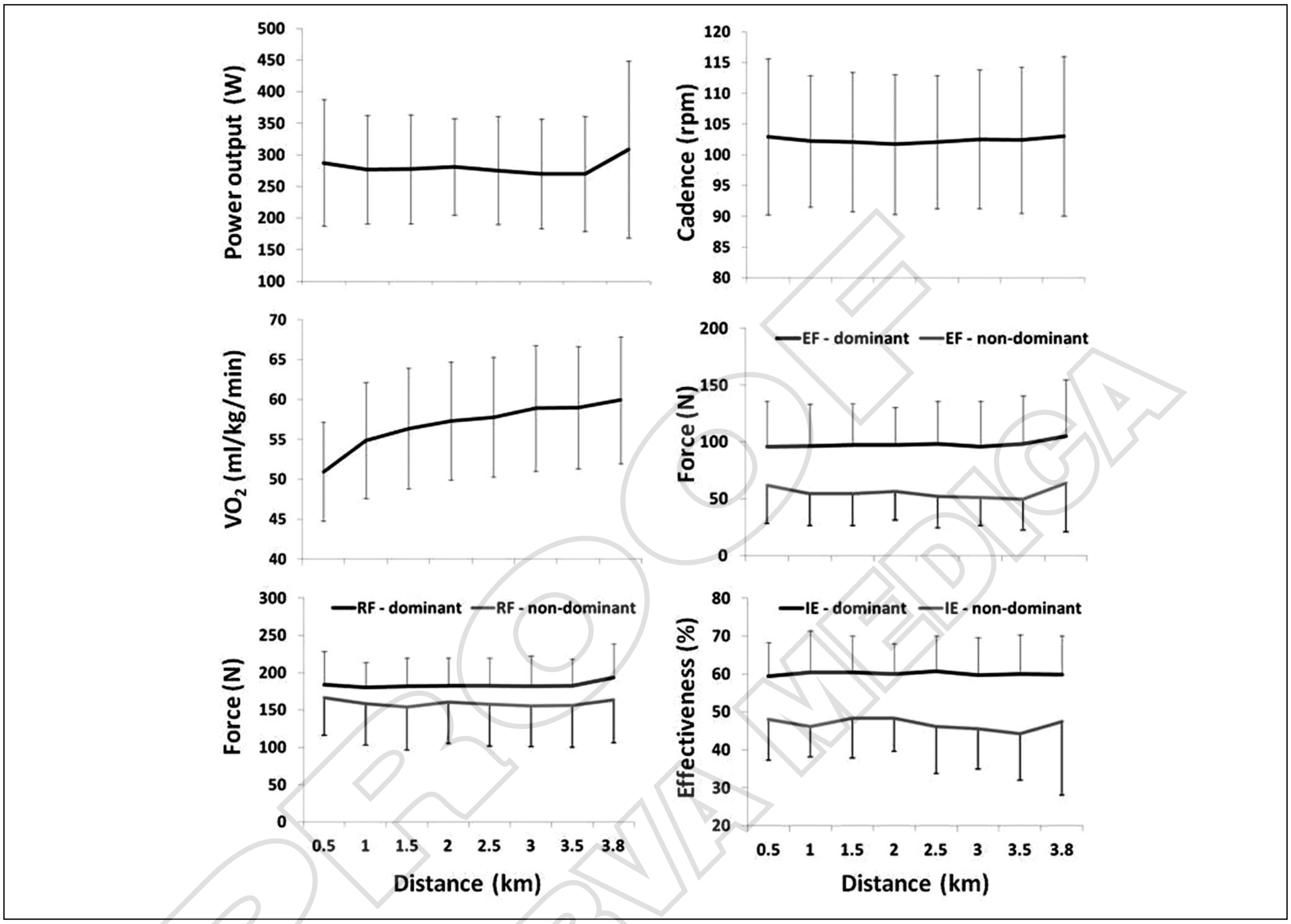

Figure 1.—Power output, pedalling cadence, oxygen uptake (VO_2), effective force (EF), resultant force (RF) and index of effectiveness (IE) taken at each 500 metres section of a 4-km time trial. N.=10.

take were found in any of the force measures. Likewise, force variables did not change throughout the test (effective – P=0.98, resultant – P=0.90 and index of effectiveness – P=0.99).

Differences between dominant and non-dominant limbs were found for effective force (P<0.01 and observed power =1.0), resultant force (P<0.01 and observed power =0.98) and index of effectiveness (P<0.01 and observed power =1.0). The asymmetry indexes and intra-limb variability are shown in Table I to highlight greater force production for the dominant than the non-dominant limb.

The relationship between asymmetries and performances was strong for the effective force (r=-0.72, P=0.03) but weak for resultant force (r=0.01, P=0.98) and for the index of effectiveness (r=-0.29, P=0.42), which are illustrated in Figure 2.

Discussion

This study assessed the relationship between bilateral asymmetries in pedal forces and performance of cyclists during a 4-km cycling time trial. Substantial asymmetries were observed for the effective force (36-54%), resultant force (11-21%) and for the index of effectiveness (21-32%), which are larger than another study assessing cyclists during a 40-km time trial (<1-17%).[3] Along these lines, larger asymmetries in effective force were related to better per-

TABLE I.—*Intra-limb variability (CV%) and asymmetry indexes (%) for each section of the 4-km time trial computed for effective force, resultant force and index of effectiveness.*

		0.5 km	1 km	1.5 km	2 km	2.5 km	3 km	3.5 km	3.8 km
Effective force	Dominant	8%	9%	8%	10%	10%	9%	8%	9%
	Non-dominant	20%	20%	22%	18%	21%	21%	27%	21%
	Asymmetry index	36 ±33%	46 ±31%	45 ±32%	45 ±26%	51 ±33%	48 ±36%	54 ±34%	39 ±31%
Resultant force	Dominant	5%	6%	5%	6%	5%	6%	5%	6%
	Non-dominant	9%	9%	9%	8%	9%	8%	10%	10%
	Asymmetry index	11 ±38%	18 ±43%	21 ±44%	17 ±43%	20 ±44%	20 ±47%	20 ±44%	21 ±43%
Index of effectiveness	Dominant	1%	1%	1%	1%	2%	2%	1%	1%
	Non-dominant	1%	1%	1%	1%	1%	2%	3%	2%
	Asymmetry index	21 ±26%	26 ±23%	23 ±28%	22 ±22%	29 ±32%	27 ±30%	32 ±34%	28 ±44%

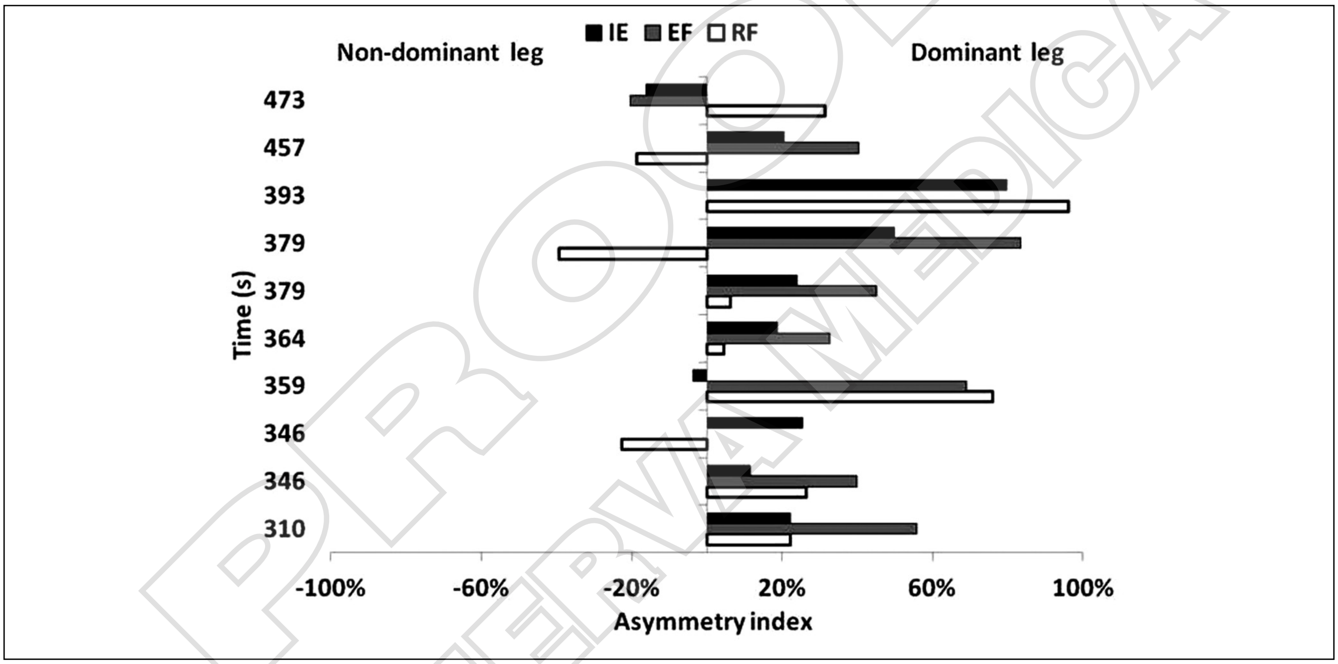

Figure 2.—Average asymmetry indexes for the effective force (EF), resultant force (RF) and index of effectiveness (IE) taken during the 4-km time trial ordered by performance time (s). N.= 10.

formances during the 4-km time trial, in contrary to observations in the referred study.[3]

Assuming that during time trials, the central nervous system optimizes neural drive to muscles in order to postpone fatigue, asymmetries could be affected by particular changes in fatigue state for a given limb. Reductions in asymmetries in crank torque at higher exercise intensities have been hypothesized due to a potential increased bilateral neural input by inter-hemispheric cortical communication to facilitate the excitability of both legs.[2] However, studies assessing muscle activation in cyclists during bilateral cycling exercise at increasing power outputs did not report differences in lower limb muscle activation comparing both legs.[11] Muscle activation during single leg cycling did not differ when cyclists dominant and non-dominant legs were compared,[21] which suggests that lower limb neural drive may not differ between legs. Therefore, further research should shed light on why some cyclists present larger asymmetries than others.

Upcoming commercial pedal force systems enable cyclists to monitor bilateral pedal power, which have been raising the question of how much asymmetry should uninjured cyclists present. Although ranges from 5-20% [3, 4] have been suggested, arbitrary threshold of 10% [3, 20, 22] should be questioned, as cyclists present either higher (23-30%) [4] or lower asymmetries (~3%).[5] The present study assessed effective force, which is an analogue of crank torque and pedal power, to approximate the measurements taken in previous studies.[3, 4] Indeed, we showed that asymmetry indexes can be smaller for the resultant (total) force applied to the pedal compared to other force variables. This may be due to the coupling between kinetics and kinematics in measures of the effective force, which does not happen for the resultant force or for the peak crank torque (used in previous studies). Therefore, a range of normative asymmetries is still to be determined given the outcome measure and workload [3, 4] can largely affect asymmetries in cycling. However, it is clearly shown that injured cyclists could present asymmetries ranging at ~400%.[23, 24] Therefore, further research is needed to: 1) define an optimal measure for assessment of asymmetries; and 2) define a range of acceptable asymmetries in uninjured cyclists.

Individual responses in asymmetry for the varying measures were observed in this study. For example, in Figure 2, the athlete who gets the fourth best performance 4km (359 seconds) has asymmetry values of <70%% for effective and resultant forces, and 4% for the index of effectiveness. On the contrary, the athlete with the eighth best time (393 seconds) has asymmetry of ~96% for effective and resultant forces, which are much closer to the asymmetry for the index of effectiveness. The reason for these observations could be that cyclists of similar performance largely differ in terms of pedal force measures, which can be observed in Figure 1. This is in agreement to findings from Bini and Hume [25] who found technical errors of measurement for the index of effectiveness ranging from 10-14% comparing measures taken at separate days. Quite the contrary, the resultant force had errors of measurement ranging between 5-11%. For both measures, the non-dominant limb always presented larger between-day variability, which could lend support to the hypothesis of larger variability to the non-dominant leg.

Lower asymmetries for resultant pedal force potentially highlighted that kinetics and kinematics could be coupled in increasing (or decreasing) asymmetry in cyclists. In this study, effective force and the index of effectiveness were affected by pedal kinematics. Earlier findings suggest that trained cyclists could reduce asymmetries in ankle joint towards greater workloads,[26] therefore, adding a confounding effect in effective force and index of effectiveness. In the present study, cyclists may have had greater effect from kinematics in their bilateral asymmetries due to large asymmetry indices for the effective force and index of effectiveness compared to the resultant force. Exercise intensity (measured from oxygen uptake) ranged from 83±6% (at 500 metres) to 97±7% (at 4-km) in the present study. Assessment of these force measures is needed at various workloads in order to ascertain if exercise intensity could affect similarly resultant and effective pedal forces.

Variability in asymmetries were shown to affect measures taken in different days.[9] Along with that, intra-limb variability has been recently suggested to play a role on bilateral asymmetries in running.[17] With that in mind, the present study showed that intra-limb variability was smaller than the range of asymmetries, which enforces that consistence in movement pattern is high, and differences between limbs were large. Interestingly, for the effective force, intra-limb variability was large for the non-dominant compared to the dominant limb throughout the time trial (20-22% *vs.* 8-10%). This difference could be linked to greater consistence for kinematics of the dominant limb,[26] although that have not been reflected in the index of effectiveness. Further research is needed to address if greater asymmetries in pedal force could be related to bilateral differences in joint kinematics. Along these lines, given changes in kinematics affects the force-length-velocity relationship of individual muscles, it would be valuable to assess bilateral joint motion throughout the crank cycle to ascertain on the muscles groups that could potentially be leading bilateral asymmetries. Variability in pedal forces measured in different days was shown to be trivial (5-11% for resultant force and 10-14% for index of effectiveness),[25] suggesting that asymmetries could be sustained across many days if training program is not changed.

Conclusions

Asymmetries were observed for the effective force (36-54%), resultant force (11-21%) and for the index of effectiveness (21-32%) with an inverse relationship between asymmetries in effective force and 4-km cycling time trial performance. Intra-limb variability in pedal forces were generally smaller than bilateral differences in pedal forces, suggesting that bilateral differences in pedal forces is greater than consistence in movement pattern of cyclists.

References

1. Kautz S, Feltner ME, Coyle EF, Bailey MP. The pedaling technique of elite endurance cyclists: changes with increasing workload at constant cadence. Int J Sports Biomech 1991;7:29-53.
2. Carpes FP, Mota CB, Faria IE. On the bilateral asymmetry during running and cycling - A review considering leg preference. Phys Ther Sport 2010;11:136-42.
3. Carpes FP, Rossato M, Faria IE, Mota CB. Bilateral pedaling asymmetry during a simulated 40-km cycling time-trial. J Sports Med Phys Fit 2007;47:51-7.
4. Bertucci WM, Arfaoui A, Polidori G. Analysis of the pedaling biomechanics of master's cyclists: A preliminary study. J Sci Cycling 2012;1:42-6.
5. Bini RR, Diefenthaeler F, Carpes FP, Mota CB. External work bilateral symmetry during incremental cycling exercise. In: Menzel H-J, Chagas MH, editors. 25 International Symposium on Biomechanics in Sports. Ouro Preto, Brazil: International Society of Biomechanics in Sports; 2007. p. 168-71.
6. Bini R, Hume P, Kilding A. Saddle height effects on pedal forces, joint mechanical work and kinematics of cyclists and triathletes. Eur J Sport Sci 2014;14:44-52.
7. Arkesteijn M, Hopker J, Jobson SA, Passfield L. The Effect of Turbo Trainer Cycling on Pedalling Technique and Cycling Efficiency. Int J Sports Med 2013;34:520-5
8. Smak W, Neptune RR, Hull ML. The influence of pedaling rate on bilateral asymmetry in cycling. J Biomech 1999;32:899-906.
9. Daly DJ, Cavanagh PR. Asymmetry in bicycle ergometer pedalling. Med Sci Sports Exerc 1976;8:204-8.
10. Marfell-Jones M, Olds T, Stewart A, Carter L. International standards for anthropometric assessment. Kineanthropometry ISfAo, editor. Potchefstroom, South Africa: ISAK; 2006.
11. Carpes FP, Diefenthaeler F, Bini RR, Stefanyshyn DJ, Faria IE, Mota CB. Influence of leg preference on bilateral muscle activation during cycling. J Sports Sci 2011;29:151-9.
12. Lucía A, Hoyos J, Pérez M, Santalla A, Chicharro JL. Inverse relationship between VO2max and economy/efficiency in world-class cyclists. Med Sci Sports Exerc 2002;34:2079-84.
13. Candotti CT, Ribeiro J, Soares DP, de Oliveira AR, Loss JF, Guimarães ACS. Effective force and economy of triathletes and cyclists. Sports Biomech 2007;6:31-43.
14. Hull ML, Davis RR. Measurement of pedal loading in bicycling: I. Instrumentation. J Biomech. 1981;14:843-56.
15. Rossato M, Bini RR, Carpes FP, Diefenthaeler F, Moro ARP. Cadence and workload effects on pedaling technique of well-trained cyclists. Int J Sports Med 2008;29:746-52.
16. Bini RR, Carpes FP, Diefenthaeler F, Mota CB, Guimarães ACS. Physiological and electromyographic responses during 40-km cycling time trial: Relationship to muscle coordination and performance. J Sci Med Sport 2008;11:363-70.
17. Exell TA, Irwin G, Gittoes MJR, Kerwin DG. Implications of intra-limb variability on asymmetry analyses. J Sports Sci 2012;30:403-9.
18. Robinson RO, Herzog W, Nigg BM. Use of force platform variables to quantify the effects of chiropractic manipulation on gait symmetry. J Manipul Physiol Ther 1987;10:172-6.
19. Dancey CP, Reidy J. Statistics Without Maths for Psychology: Using SPSS for Windows TM. Edinburgh: Pearson/Prentice Hall; 2004.
20. Carpes FP, Rossato M, Faria IE, Mota CB. Influence of exercise intensity on bilateral pedaling symmetry. Progress in motor control IV 2007;11:S54-S5.
21. Carpes FP, Diefenthaeler F, Bini RR, Stefanyshyn D, Faria IE, Mota CB. Does leg preference affect muscle activation and efficiency? J Electromyogr Kinesiol 2010;20:1230-6.
22. Carpes FP, Bini RR, Mota CB. Training level, perception and bilateral asymmetry during multi-joint leg-press exercise. Braz J Biomotr 2008;2:51-62.
23. Hunt MA, Sanderson DJ, Moffet H, Inglis JT. Interlimb asymmetry in persons with and without an anterior cruciate ligament deficiency during stationary cycling. Arch Phys Med Rehabil 2004;85:1475-8.
24. Hunt MA, Sanderson DJ, Moffet H, Inglis JT. Biomechanical changes elicited by an anterior cruciate ligament deficiency during steady rate cycling. Clin Biomech 2003;18:393-400.
25. Bini RR, Hume PA. Between-day reliability of pedal forces for cyclists during an incremental cycling test to exhaustion. Isokin Exerc Sci 2013;21:203-9.
26. Edeline O, Polin D, Tourny-Chollet C, Weber J. Effect of workload on bilateral pedaling kinematics in non-trained cyclists. J Hum Mov Stud 2004;46:493-517.

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