2010

The Influence of Elliptical Chainrings on 10 km Cycling Time Trial Performance

Jeremiah Peiffer
Edith Cowan University

Christopher Abbiss
Edith Cowan University

10.1123/ijspp.5.4.459

International Journal of Sports Physiology and Performance, 2010, 5, 459-468

The Influence of Elliptical Chainrings on 10 km Cycling Time Trial Performance

Jeremiah J. Peiffer and Chris R. Abbiss

The use of elliptical chainrings (also called chainwheels or sprockets) has gained considerable interest in the amateur and professional cycling community. Nevertheless, we are unaware of any scientific studies that have examined the performance benefits of using elliptical chainrings during an actual performance trial. Therefore, this study examined the influence of elliptical chainring use on physiological and performance parameters during a 10 km cycling time trial. Nine male cyclists completed, in a counterbalanced order, three 10 km cycling time trials using either a standard chainring or an elliptical chainring at two distinct settings. An attempt was made to blind the cyclists to the type of chainring used until the completion of the study. During the 10 km time trial, power output and heart rate were recorded at a frequency of 1 Hz and RPE was measured at 3, 6, and 8.5 km. Total power output was not different (P = .40) between the circular (340 ± 30 W) or either elliptical chainring condition (342 ± 29 W and 341 ± 31 W). Similarly, no differences (P = .73) in 2 km mean power output were observed between conditions. Further, no differences in RPE were observed between conditions measured at 3, 6, and 8.5 km. Heart rate was significantly greater (P = .02) using the less aggressive elliptical setting (174 ± 10 bpm) compared with the circular setting (171 ± 9 bpm). Elliptical chainrings do not appear to provide a performance benefit over traditional circular chainrings during a mid-distance time trial.

Keywords: cycling, performance, cadence, testing

Advancements in cycling equipment can have major implications for overall cycling performance. For instance, the progression from single and double speed bicycles to the multigeared bicycles of the present have allowed greater speeds and the ability to transverse terrains that were once impassable. With the evolution of composite materials, lighter and more aerodynamic bicycles provide performance advancements irrespective of a cyclist's ability.[1,2] Nevertheless, beyond a greater selection of gear ratios, changes to the drive train of the bicycle (chain, gears, and

Jeremiah J. Peiffer is with the School of Chiropractic and Sports Science, Murdoch University, Murdoch, WA, Australia, and the School of Exercise, Biomedical, and Health Sciences, Edith Cowan University, Joondalup, WA, Australia. Chris R. Abbiss is with the School of Exercise, Biomedical, and Health Sciences, Edith Cowan University, Joondalup, WA, Australia; the Department of Physiology, Australian Institute of Sport, Belconnen, ACT, Australia; and the Division of Materials Science and Engineering, Commonwealth Scientific and Industrial Research Organisation, Belmont, VIC, Australia.

crank) have be relatively nonexistent, despite the presences of biomechanically measured "dead" spots within the normal pedal stroke.[3] For example, during the normal pedal stroke the majority of torque is produced with the crank parallel to the ground (90°) with very low or zero forces produced at crank positions of top-dead-center (0°) and bottom-dead-center (180°).[3]

One such attempt to reduce the time spent at top- and bottom-dead-center and increase the time in the downstroke has involved the use of elliptical chainrings (also called chainwheels or sprockets). Elliptical chainring configurations provide a greater effective ring diameter during the down stroke, theoretically resulting in greater power production during this period of the pedal stroke.[4–7] Indeed, in vitro calculations by Rankin and Neptune[6] suggest that elliptical chainrings can increase cycling power, by approximately 2.9%, over a range of cadences (60, 90, and 120 rpm). The physiological assessment of elliptical chainrings has primarily focused on cycling economy, with no differences observed between circular and elliptical chainrings in trained[4,7] or highly trained[5] cyclists. To date, no study has examined the influence of elliptical chainrings on performance in trained or untrained individuals using actual performance testing; thus, providing the need for research in this area. Therefore, the purpose of this study was to examine the submaximal physiological parameters and 10 km cycling time trial performance of cyclists while cycling with both circular and elliptical chainrings. Based on a theoretical increase in power production of 2.9%[6] we hypothesized that the use of elliptical chainrings would increase cycling performance.

Methods

Participants

Nine trained male cyclists (age: 31 ± 6 y; body mass: 78.6 ± 4.8 kg; VO_2max: 64.1 ± 4.4 $mL \cdot kg^{-1} \cdot min^{-1}$; peak power: 450 ± 34 W) volunteered to participate in this study. Participants were required to complete four 10 km cycling time trials separated by no less than five and no greater than 10 d. Participants were asked to avoid strenuous physical activity in the 24 h before the trial and to consume a similar diet the day before and day of testing. The possible risks and benefits of participation in this study were explained to each participant and written consent was obtained before data collection. Approval from the necessary institution's Human Ethics Research Committee was obtained before the commencement of this study.

10 km Time Trials

Participants were required to complete four 10 km cycling time trials using one of three chainring configurations (standard, elipitcal$_1$, and eliptical$_2$). All time trials were conducted on the Velotron cycle ergometer (Racermate, Seattle, USA) in an environmental chamber maintained at 24°C and 40% relative humidity. A large fan providing a wind speed of 32 $km \cdot h^{-1}$ was placed directly in front (approx. 1 m) of the subjects, to provide an accurate simulation of wind speed and was started upon commencement of each trial. Before the start of each time trial participants completed a standardized 10 minute warm-up (5 min at 150 W followed by 5 min at 200 W) at a fixed cadence (90 rpm). During the warm-up expired gases were collected, each second, using a metabolic cart (Parvo TrueOne, Utah, USA). The average oxygen consumption for the final 2 min of each stage were recorded and used to calculate the participants' cycling economy ($W \cdot L^{-1} O_2$).[8] This method of assessment was selected as this measure is consistent with a lower coefficient of variability (3.3%) compared with measures of gross (4.2%) and delta efficiency (6.7%).[8] In addition, heart rate was recorded at 30 s intervals and ratings of perceived exertion (RPE) were obtained at 5 min and 10 min during the warm-up. At the completion of the warm-up, participants were allowed 5 min of recovery before the start of the 10 km time trial.

Information regarding the chainring use and performance times for the 10 km time trials were withheld from the participants until the completion of all four trials. In addition, a guard was affixed to the cycle ergometer that did not allow the participants to see the chainring during the time trials (Figure 1). All time trials were started from a standing start at a fixed gear ratio (53 × 16) and participants were instructed to finish the time trial in the shortest time possible. Participants were not provided feedback except the distance completed. During the time trials, ratings of perceived exertion were recorded at 3, 6, and 8.5 km using visual analog scales.[9]

The initial 10 km time trial was completed using a standard circular chainring (53 tooth; Durace, Shimano, Japan) and was used for familiarization purposes; therefore, this data was not included in the analysis. The remaining three time trials were conducted in a counterbalanced order using one of three chainring configurations (normal, $elliptical_1$, or $elliptical_2$; Figure 1). The elliptical chainring used during

Figure 1 — Guard used to limit participant visibility of chainring (top-right and top-left) and orientation of the elliptical chainring in the $elliptical_1$ (bottom-left) and $elliptical_2$ (bottom-right) settings.

this study (Q-rings, Rotor-Cranks, Spain) were selected as their use has gained acceptance in the amateur and professional cycling community. The design of the elliptical chainrings provided for multiple positioning of the rings and a constant eccentricity (ratio major to minor axis) of 1.10. During the trial in the $elliptical_1$ setting, the major axis of the chainring was offset 110° counter clockwise to the crank arm. While during the $elliptical_2$ trial, the major axis of the chainring was offset 100° counter clockwise to the crank arm.

Data Processing

During the time trial, power output (Velotron Coaching software, Racermate, USA) and heart rate (810i, Polar, Finland) were recorded at a frequency of 1 Hz. For comparison purposes, raw power output and heart rate data were converted to 2.0 km averages. Further, the mean power output for the entire 10 km time trial was recorded for analysis.

Statistical Analysis

Differences in the 2.0 km average power output, heart rate and the RPE measures at 3, 6, and 8.5 km between conditions were analyzed using a two-way ANOVA with repeated measures. Significant main effects or interactions were analyzed using Tukey's HSD post hoc test. In addition, differences between the submaximal variables collected during the warm-up (economy, heart rate, and RPE) were analyzed between conditions 150 W and 200 W using a two-way ANOVA. Further, the percent change in performance between the standard circular chainrings and the two elliptical chainrings were compared with the smallest worthwhile change in performance (1%), calculated from previously published coefficient of variation measurements of sustainable power during a time trial using the Velotron cycle ergometer,[10,11] as outlined by Hopkins et al.[12] All statistics were completed using Statistica (Version 7; StatSoft, USA) with the level of significance set to $P < .05$. Data are presented as means ± standard deviations unless otherwise noted.

Results

Submaximal Performance

The differences in cycling economy, heart rate and RPE recorded at 150 W and 200 W are presented in Table 1. No differences were observed for cycling economy ($P = .26$), heart rate ($P = .75$) or RPE ($P = .42$) between the three conditions at either 150 W or 200 W.

10 km Time Trial Performance

No differences in the mean power output ($P = .40$) were observed between conditions (Table 2). In addition, neither cycling with $Elliptical_1$ or $Elliptical_2$ improved performance beyond the smallest worthwhile change in performance (1.0%). A significant main effect for time was observed for the 2.0 km average power measures ($P = .001$), with greater power recorded in the first 2.0 km compared with all

Table 1 Cycling economy, heart rate, and ratings of perceived exertion (RPE) measured during submaximal exercise at 150 W and 200 W using circular, elliptical$_1$ (offset 110°), and elliptical$_2$ (offset 100°) chainrings

	Circular		Elliptical$_1$		Elliptical$_2$	
	150 W	**200 W**	**150 W**	**200 W**	**150 W**	**200 W**
Economy ($W \cdot L^{-1} O_2$)	67.8 ± 3.2	73.0 ± 3.5	67.0 ± 2.5	72.5 ± 2.4	67.0 ± 2.4	73.0 ± 2.7
Heart Rate (bpm)	117 ± 12	132 ± 12	119 ± 12	134 ± 14	117 ± 12	132 ± 14
RPE	7.7 ± 1.7	8.8 ± 2.1	7.4 ± 1.7	9.1 ± 2.4	7.8 ± 1.8	9.0 ± 2.0

Table 2 Sustainable power output and completion time measured during a 10 km cycling time trial using circular, elliptical$_1$ (offset 110°), and elliptical$_2$ (offset 100°) chainrings

	Circular	Elliptical$_1$	Elliptical$_2$	$\%\Delta_{C\text{-}E1}$	$\%\Delta_{C\text{-}E2}$
Power Output (W)	340 ± 30	342 ± 29	341 ± 31	0.67 ± 0.01	0.40 ± 0.02

Note. %Δ = Percent change; C-E1 = Circular vs. Elliptical$_1$; C-E2 = Circular vs. Elliptical$_2$.

other time points (Figure 2). The analysis of the 2.0 km average cadence produced a significant main effect for time ($P = .001$). Cadence was significantly greater at 2 km and 4 km compared with all other time points (Figure 2). Significant main effects for time ($P = .001$) and chainrings ($P = .02$) were observed for the 2.0 km average heart rate values. During cycling with the Elliptical$_1$ chainring, the average heart rate was significantly greater (174 ± 10 bpm) compared with the circular chainring condition (171 ± 9 bpm). Further, in all conditions the 2.0 km average heart rate was significantly less in the first 2.0 km compared with all other time points (Figure 2). No differences in the ratings of perceived exertion were observed between conditions; however, a main effect for time was observed ($P = .001$) with greater RPE values measured at 6 km (16.7 ± 1.7) compared with 3 km (14.9 ± 2.1), and greater RPE values at 8.5 km (18.0 ± 1.8) compared both the 6 km and 3 km measurement points.

The individual percent change in power output between the elliptical chainrings and the normal chainring are presented in Figure 3. A performance enhancement was observed for most participants when using an elliptical chainring compared with the circular chainring. Nevertheless, only four of the nine participants increased performance beyond the smallest worthwhile performance change (1%).

Discussion

The purposes of this study were to examine the influence of elliptical chainrings on submaximal physiological responses to cycling and cycling performance during a 10 km time trial. The major findings from this study were: 1) average power output over the entire 10 km time trial was not different between chainring configurations, 2)

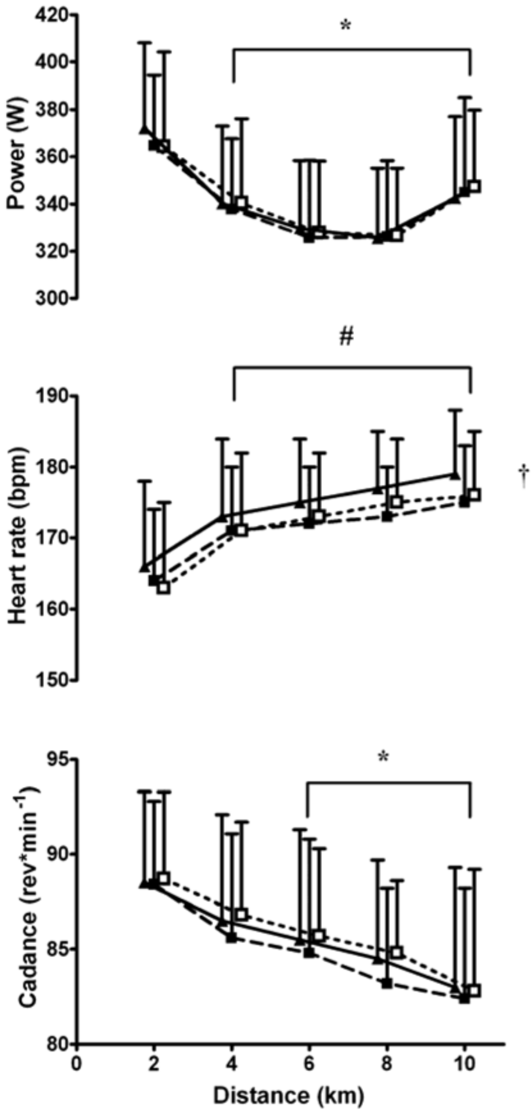

Figure 2 — Average 2 km power output, heart rate, and cadence measured during a 10 km cycling time trial using circular (■), elliptical$_1$ (▲; offset 110°) and elliptical$_2$ (□; offset 100°) chainrings. *Main effect for time, values less than all preceding; # main effect for time, values greater than all preceding; † main effect for condition, elliptical$_1$ > circular.

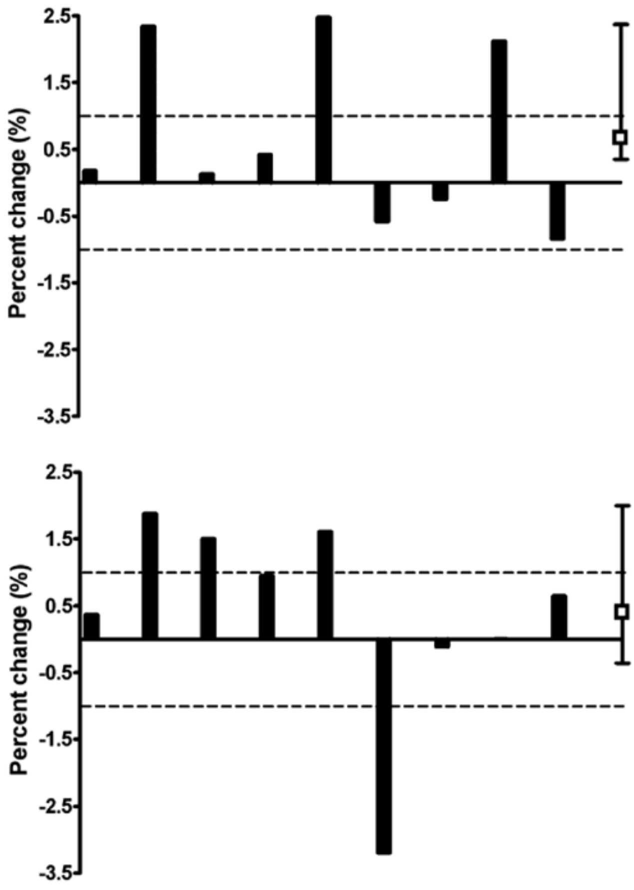

Figure 3 — Individual percent change in sustainable power between circular and elliptical$_1$ (top) and circular and elliptical$_2$ (bottom) chainrings. Dash line = smallest worthwhile change to provide a performance enhancement; box and whiskers = mean percent change ± 95% confidence interval.

heart rate was greater during the 10 km time trial with elliptical$_1$ setting, compared with the circular condition, and 3) when examining the smallest worthwhile change in performance a high between subject variability was observed when using elliptical chainrings.

Previous elliptical chainring studies have focus primarily on the submaximal benefits associated with the use of these devices.[4,5,7] Similar to past research,[4,5,7] this study examined the submaximal benefits of elliptical chainrings and observed no differenced in heart rate, cycling economy or RPE when using elliptical compared with circular chainrings (Table 1). In addition to measuring the submaximal influences of elliptical chainrings, we also examined the performance benefits of using elliptical chainrings during a 10 km cycling time trial. Our data indicates that elliptical chainrings provide no benefits to cycling performance over existing circular chainrings during a 10 km time trial. In this study we observed similar sustainable power output and completion times for the 10 km time trial during all trials (Table 2). In addition, when compared with the smallest worthwhile performance enhancing change in sustainable power,[12] neither elliptical chainring provided benefits. It is possible that our results were influenced by our selection of elliptical chainrings. Rankin and Neptune[6] modeled the performance benefits of using elliptical compared with circular chainrings at 60, 90, and 120 rpm and observed a significant increase in power of 2.9% when using the elliptical chainrings. Further, Rankin and Neptune[6] determined the most optimal elliptical chainring shape to have an eccentricity of 1.29. In the present study, we used commercially manufactured elliptical chainrings with a predetermined eccentricity of 1.10. It is possible that the eccentricity of our elliptical chainring was too small and therefore responsible for the lack of differences in sustainable power output observed between the three conditions.

While no differences in sustainable power output (Table 2), 2 km average power output (Figure 2) or RPE was observed between conditions, significantly higher heart rates were recorded during the elliptical$_1$ trial when compared with the circular trial (Figure 2). This finding indicates a greater cardiovascular strain when using the elliptical$_1$ setting.[13] We speculate that the positioning of the chainrings major axis (110° counter clockwise to crank arm) might have been responsible for the increase in heart rate. During the elliptical$_1$ setting, the influence of the major axis would have occurred later within the greatest power producing zone of the pedal stroke (90–180°), possibly requiring greater muscle activation,[6] thus promoting a higher heart rate.[14] Nevertheless, we did not measure muscle activity and therefore cannot confirm or deny this hypothesis. Further, we did not measure hydration status before each time trial; therefore, we cannot deny that a greater level of pretrial hypohydration was present which could have influenced heart rate.

Although we did not observe a statistical increase in performance during cycling with either the elliptical$_1$ or elliptical$_2$ setting, we cannot entirely refute the efficacy of the chainrings. Analysis of the individual changes in sustainable power between the two elliptical chainrings and the circular chainring indicate a highly variable performance effect (Figure 3). For instance, four of the nine participants recorded a performance enhancement greater than the smallest worthwhile change in sustainable power[12] needed to enhance performance when using at least one of the elliptical chainrings. Further, only two individuals did not demonstrate a positive change in sustainable power when using at least one of the elliptical chainrings. For this reason, we suggest that the influence of elliptical chainrings on cycling performance is dependent on the individual and further studies are needed to highlight the interpersonal differences that can influence the effectiveness of elliptical chainrings.

Conclusion

In conclusion, we demonstrated that the use of elliptical chainrings does not increase sustainable power during a 10 km cycling time trial in a group of trained male cyclists. Further, no noticeable differences were observed in cycling economy or heart rate at two submaximal workloads. Nevertheless, considerable variability in the percent change of sustainable power for the elliptical and circular chainring settings was observed between participants. These findings indicate that the use of elliptical chainrings do not enhance cycling performance; however, this should be determined on a cyclist to cyclist basis.

Practical Application

The margin for victory in professional and amateur cycling can often be measured in seconds. For this reason, specialized equipment that has the potential to improve performance should be a welcomed addition to both athletes and coaches. Although the use of elliptical chainrings did not enhance 10 km cycling performance in our group of trained cyclists, the between subject variability in performance should be considered by those interested in using this device. Therefore, we suggest that cyclists should individually assess the efficacy of using elliptical chainrings to enhance their cycling performance.

References

1. Faria EW, Parker DL, Faria IE. The science of cycling: factors affecting performance - part 2. *Sports Med*. 2005;35:313–337.
2. Jeukendrup AE, Martin J. Improving cycling performance: how should we spend our time and money. *Sports Med*. 2001;31:559–569.
3. Rossato M, Bini RR, Carpes FP, Diefenthaeler F, Moro AR. Cadence and workload effects on pedaling technique of well-trained cyclists. *Int J Sports Med*. 2008;29:746–752.
4. Hull ML, Williams M, Williams K, Kautz S. Physiological response to cycling with both circular and noncircular chainrings. *Med Sci Sports Exerc*. 1992;24:1114–1122.
5. Cullen LK, Andrew K, Lair KR, Widger MJ, Timson BF. Efficiency of trained cyclists using circular and noncircular chainrings. *Int J Sports Med*. 1992;13:264–269.
6. Rankin JW, Neptune RR. A theoretical analysis of an optimal chainring shape to maximize crank power during isokinetic pedaling. *J Biomech*. 2008;41:1494–1502.
7. Ratel S, Duche P, Hautier CA, Williams CA, Bedu M. Physiological responses during cycling with noncircular "Harmonic" and circular chainrings. *Eur J Appl Physiol*. 2004;91:100–104.
8. Peiffer JJ, Abbiss CR, Chapman D, Laursen PB, Parker DL. Physiological characteristics of masters-level cyclists. *J Strength Cond Res*. 2008;22:1434–1440.
9. Borg GA. Psycholphysical bases of perceived exertion. *Med Sci Sports Exerc*. 1982;14:377–381.
10. Abbiss CR, Levin G, McGuigan MR, Laursen PB. Reliability of power output during dynamic cycling. *Int J Sports Med*. 2008;29:574–578.

11. Sporer BC, McKenzie DC. Reproducibility of a laboratory based 20-km time trial evaluation in competitive cyclists using the Velotron Pro ergometer. *Int J Sports Med*. 2007;28:940–944.
12. Hopkins WG, Hawley JA, Burke LM. Design and analysis of research on sport performance enhancement. *Med Sci Sports Exerc*. 1999;31:472–485.
13. Earnest CP, Jurca R, Church TS, Chicharro JL, Hoyos J, Lucia A. Relation between physical exertion and heart rate variability characteristics in professional cyclists during the Tour of Spain. *Br J Sports Med*. 2004;38:568–575.
14. Taylor JA, Chase PB, Enoka RM, Seals DR. Cardiovascular adjustments to rhythmic handgrip exercise: relationship to electromyographic activity and post-exercise hyperemia. *Eur J Appl Physiol Occup Physiol*. 1988;58:32–38.