Effects of Shoe Cleat Position on Physiology and Performance of Competitive Cyclists

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Purpose: Aerobic economy is an important factor that affects the performance of competitive cyclists. It has been suggested that placing the foot more anteriorly on the bicycle pedals may improve economy over the traditional foot position by improving pedaling efficiency. The current study examines the effects of changing the anterior-posterior pedal foot position on the physiology and performance of well-trained cyclists. Methods: In a crossover study, 10 competitive cyclists completed two maximal incremental and two submaximal tests in either their preferred (control) or a forward (arch) foot position. Maximum oxygen consumption and peak power output were determined from the incremental tests for both foot positions. On two further occasions, cyclists also completed a two-part 60-min submaximal test that required them to maintain a constant power output (equivalent to 60% of their incremental peak power) for 30 min, during which respiratory and blood lactate samples were taken at predetermined intervals. Thereafter, subjects completed a 30-min self-paced maximal effort time trial. Results: Relative to the control, the mean changes (±90% confidence limits) in the arch condition were as follows: maximum oxygen consumption, −0.5% (±2.0%); incremental peak power output, −0.8% (±1.3%); steady-state oxygen consumption at 60%, −2.4% (±1.1%); steady-state heart rate 60%, 0.4% (±1.7%); lactate concentration 60%, 8.7% (±14.4%); and mean time trial power, −1.5% (±2.9%). Conclusions: We conclude that there was no substantial physiological or performance advantage in this group using an arch-cleat shoe position in comparison with a cyclist’s normal preferred condition.

Keywords: arch cleat, economy, time trial

A cyclist’s ability to produce power in endurance cycling events is dependent upon their maximum oxygen consumption (VO_{2max}), the fraction of maximum oxygen consumption that can be maintained during the event (anaerobic threshold), and the rider’s aerobic economy.1 Previous studies have reported that pedaling technique is a factor that can affect aerobic economy by influencing a rider’s gross mechanical efficiency.2,3 Recently, some competitive cyclists and triathletes have

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been attempting to influence their pedaling technique and improve performance by moving the position of the foot on the bicycle pedal much further forward (by moving the shoe cleat posteriorly) than has been traditionally used. Indeed, custom-made shoes and components that enable cyclists to achieve what has been termed the arch-cleat position are commonly available from cycling product manufacturers (e.g., http://biomac.webstudios.at/). Proponents of the arch-cleat position suggest that cycling performance may be enhanced owing to a potentially more powerful downward stroke on the pedal, a more even distribution of force through the pedaling cycle, and a reduced requirement for ankle stabilizing by the plantar flexor musculature (personal communication).

The only previous study examining the effects of moving the anterior-posterior foot position on physiological variables was published recently by Van Sickle and Hull. These authors investigated the effect of using three different foot positions on the aerobic economy of exercise while cyclists rode at a fixed submaximal (~90% of ventilatory threshold power) intensity. These authors proposed that moving the shoe cleat posteriorly might reduce the force moment developed by the pedal reaction load about the ankle joint and in doing so translate into an increase in pedaling efficiency and an improved aerobic economy. Even though the authors did report a significant reduction in plantar flexor activation (recorded by electromyography) as the cleats were moved more posteriorly, this did not lead to any significant improvement in aerobic economy during exercise.

Whereas the Van Sickle and Hulls study addresses the question of whether moving the shoes’ cleats posteriorly would benefit a cyclist in terms of aerobic economy, it did not address any benefit in terms of actual performance. In addition, these authors did not examine the effects of moving the cleat position on the two other important physiological aspects associated with aerobic competition, namely, maximum oxygen consumption and lactic acid production.

Therefore the aim of the current study was to investigate the effects of adjusting the anterior-posterior foot position on maximal aerobic exercise intensity and simulated time trial performance and associated physiological measures with competitive cyclists.

Methods

Design

The study was a partially randomized crossover design in which subjects completed a set of exercise tests in either an experimental or control condition. The study was performed over a 4-wk period immediately before the cyclists’ main competitive season. All cyclists in the study were familiar with general laboratory testing procedures, having completed exercise tests on previous occasions.

Subjects

Ten well-trained male cyclists (mean ± SD, age 37 ± 4 y, mass 77 ± 5 kg, height 180 ± 4 cm) were recruited from the local cycling community. All subjects had a minimum of 3 y of competitive experience and had completed 6 to 10 wk of base training before commencing the study. None of the subjects in the study had
previous experience of using the arch-cleat shoe position. All cyclists gave their written informed consent to participate, in accordance with the institute’s ethics committee guidelines.

**Experimental Procedures**

Each cyclist used identical but individually sized cycling shoes (Exustar Enterprise Co., Taichung, Taiwan) fitted to “SPD”-style cleat pedals. The cycling cleats were mounted in two different anterior-posterior positions on the shoe. The *control* cleat position was set to replicate the cyclists’ current preferred position and in all cases was approximately beneath the head of the phalanges/metatarsal joint (within ±10 mm); the experimental (arch) cleat position was set posteriorly to the control (~50 mm) in a midsole position approximating a position under the individuals’ tarsal/metatarsal joint. To compensate for the effective decreased leg length during the arch-cleat trials, the seat height was lowered, for each individual, to a position where their knee flexion angle, at the bottom of the pedal stroke with the foot parallel to the ground, was the same as that of the control condition. Lowering the seat height also had the effect of moving the seat forward by 3 mm for each 10-mm drop.

Each cyclist completed two maximal incremental and submaximal performance tests within 4 wk and with at least 5 d between tests. Cyclists initially completed (in a fixed order) the incremental tests, beginning with the cleat in the *control* position. The arch-cleat shoe position was set up on completion of the first incremental test session, and cyclists were required to complete a minimum of 3 × 1-h training sessions in the arch position before completing the arch-cleat trials. Cyclists completed the submaximal tests in a balanced randomized order.

Cyclists were instructed to refrain from any hard physical activity within 24 h of a testing session. In addition, cyclists were asked to record their dietary intake in the 24 h preceding a test and to replicate this as closely as possible for subsequent tests. All testing sessions were performed at a similar time of day to control for diurnal variations.

All testing was performed on a Velotron electromagnetically braked cycle ergometer (RacerMate, Seattle, USA) calibrated in accordance with the manufacturer’s published instructions. Tests were performed under stable environmental conditions in a temperature-controlled laboratory (~20°C, ~60% relative humidity). For the incremental tests, cyclists initially performed a 10-min self-selected warm-up followed by 5 min of steady cycling at 150 W. Thereafter, cyclists performed an incremental ramp test, beginning at 150 W and increasing by 25 W each minute until reaching volitional exhaustion. For the incremental test, subjects were instructed to maintain a pedaling cadence within the range 90 to 100 revolutions per minute (RPM). During the incremental test, heart rate and oxygen uptake were continuously measured with a precalibrated Metalyser 3b metabolic cart (Cortex, Leipzig, Germany). Peak aerobic power output (PPO) was calculated as the final completed stage plus the proportion of any uncompleted stage multiplied by 25 W. Maximum oxygen consumption was determined as the highest 30-s average recorded during the incremental test.

On two further occasions, cyclists performed two submaximal tests in a randomized order. Each submaximal test consisted of two segments separated by 5 min of passive recovery. Warm-up for the test consisted of 10 min of self-selected intensity
exercise followed by 5 min of directed intensity exercise. The 5 min of directed intensity was aimed at preparing the cyclist for the subsequent ride and consisted of five 1-min stages commencing at 40% of their predetermined control trial PPO and increasing by 4% each minute up to 60% of their preferred cleat position PPO. Immediately on completion of this warm-up, riders commenced a 30-min period of steady-state exercise fixed at 60% (~73% maximum oxygen uptake) of their control cleat position PPO. For the steady-state trials, cyclists were once again required to maintain a pedaling cadence between 90 to 100 RPM to control for possible variations in aerobic economy resulting from differences in cadence. During steady-state exercise, oxygen consumption was recorded at intervals of 5 to 10, 15 to 20, and 25 to 30 min using the metabolic system previously described; additionally, finger tip blood samples were taken at 10, 20, and 30 min and immediately analyzed for lactate concentration using the Lactate Scout portable device (EKF Diagnostic, Magdeburg, Germany). Following 5 min of passive recovery, subjects then completed a self-paced maximal effort 30-min time trial. For the time trials, the cyclists were required to ride the same preselected gearing for both experimental and control trials. During the time trial, the cyclists received no encouragement and the only information available was time remaining. Cyclists were cooled throughout all trials with standing floor fans, and water was allowed ad libitum.

**Statistical Analysis**

Data are presented as means ± standard deviations. The mean effects of shoe cleat position on physiological and performance variables (and their 90% confidence limits) were estimated with a spreadsheet. Briefly, the spreadsheet utilizes the unequal-variances $t$ statistic to compare change scores between control and experimental conditions. Data were log transformed before analysis to reduce any bias arising from nonuniformity of error. Statistical significance was set at an $\alpha$-level of 0.05. In addition, I used the effect size (ES) statistic to provide a measure of the magnitude of the effects and interpreted these in accordance with the recommendations of Cohen.

**Results**

Power in the steady-state tests was 258 ± 17 W. Pedaling cadence was not significantly different ($P > .05$) between control and experimental conditions in either the steady-state (93 ± 6 vs 93 ± 4 RPM) or time trial (95 ± 5 vs 95 ± 4 RPM) tests.

Table 1 shows the mean ± SD results for both physiological and performance measures and the percentage differences between control and experimental conditions. There were no significant differences in any physiological or performance variables in the tests, aside from oxygen uptake at 60% of PPO, which was significantly lower in the arch-cleat trials ($P < .01$). The magnitude of the difference (ES 0.27) between oxygen uptakes at 60% of PPO equated to only a small effect as defined by Cohen.

**Discussion**

The major finding in this study is that moving the foot forward over the pedal axle has little effect on maximal and submaximal measures of performance or physiological characteristics of trained cyclists. Analysis of the magnitude of difference between the
Table 1  Comparative measures of performance and physiology in the control and arch-cleat positions

<table>
<thead>
<tr>
<th></th>
<th>Control mean ± SD</th>
<th>Arch mean ± SD</th>
<th>Control−Arch % Difference ± 90% CL†</th>
<th>Effect Size</th>
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</thead>
<tbody>
<tr>
<td><strong>Incremental Test</strong></td>
<td></td>
<td></td>
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<td></td>
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<tr>
<td>Maximum oxygen uptake (L·min⁻¹)</td>
<td>4.39 ± 0.35</td>
<td>4.37 ± 0.41</td>
<td>-0.5 ± 2.0</td>
<td>0.06</td>
</tr>
<tr>
<td>Peak incremental power (W)</td>
<td>430 ± 32</td>
<td>426 ± 27</td>
<td>-0.8 ± 1.3</td>
<td>0.13</td>
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<tr>
<td><strong>Submaximal Test</strong></td>
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<td></td>
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<tr>
<td>Oxygen uptake at 60% of peak power (L·min⁻¹)</td>
<td>3.26 ± 0.29</td>
<td>3.18 ± 0.29</td>
<td>-2.4 ± 1.1</td>
<td>0.27*</td>
</tr>
<tr>
<td>Lactate at 60% of peak power (mmol)</td>
<td>2.8 ± 1.0</td>
<td>3.1 ± 1.3</td>
<td>8.7 ± 14.4</td>
<td>0.17</td>
</tr>
<tr>
<td>Heart rate 60% of peak power (bpm)</td>
<td>147 ± 11</td>
<td>148 ± 12</td>
<td>0.4 ± 1.7</td>
<td>0.04</td>
</tr>
<tr>
<td>Time trial mean power (W)</td>
<td>304 ± 33</td>
<td>299 ± 19</td>
<td>-1.5 ± 2.9</td>
<td>0.17</td>
</tr>
</tbody>
</table>

† ±90% CL: Add and subtract this number to the mean effect to obtain the 90% confidence limits for the true difference.
*Small effect in accordance with guidelines of Cohen.³
two cleat positions revealed trivial differences for all but one measured variable—that being the oxygen cost of exercise at a steady-state intensity of 60% of peak power output.

The reason for the significant improvement in aerobic economy when using the arch-cleat position is unclear but may be related to a reduction in muscle activation of the ankle plantar flexors during the pedal cycle. As the foot position moves forward over the pedal axle, less muscular activity, by the ankle stabilizers, would be required to equilibrate the torque moment created by the pedal reaction forces. Interestingly, Van Sickle and Hull have previously reported a significant reduction in muscle plantar flexor activity as the shoe cleat was moved posteriorly but found that this did not lead to an improved aerobic economy. Another possible explanation for the improved economy, when using the arch-cleat position, is a change in the active muscles responsible for generating power. If the ankle plantar flexors actually aid in force production during the normal pedaling cycle, then reducing their activity will presumably require a compensatory increase in recruitment of other muscles that act upon the hip and knee. It is possible that these compensatory muscles are more aerobically efficient and this may have led to the reduced oxygen consumption in this study. However, despite the reported improvement in aerobic economy, this did not appear to translate into an improved competitive performance. The failure to enhance performance is substantiated by the lack of improvement in the time trial simulation despite the mean workload being only ~14% greater than that in the steady-state tests during which oxygen cost was measured. Therefore, it appears that although the arch-cleat position may reduce the submaximal oxygen cost, the magnitude of the gain in aerobic economy (~2.5%) is insufficient to have any substantially worthwhile effect on cycling performance. Given that the cyclists in the study were experienced and had received limited habituation to the arch-cleat position, it might be considered surprising that their performance did not deteriorate with the novel arch-cleat position. A possible explanation for the lack of difference in performance between cleat positions is that the neuromuscular system can operate over a wide “bandwidth” and is capable of dealing with, and adjusting to, even quite large variations from a cyclist’s normal riding position. Indeed Korff et al. state that even large variations in pedaling technique do not result in significant changes in efficiency relative to a preferred pedaling style, unless the rider is instructed to pull up actively on the pedal. Similar findings have also been reported with runners who have been shown to rapidly adjust their running gait in response to substantial variations in shoe design. It is, however, possible that given a longer habituation period the cyclists might adapt physiologically as well as neurologically and eventually perform better once the muscles contributing to power development have adapted to the arch-cleat position. Although using the arch-cleat position did not lead to any significant improvement or reduction in performance under the conditions used in this study, it is unclear how performance would be affected in more stochastic cycling activities. During mass start competitions, cyclists are frequently called upon to perform short-term anaerobic efforts when climbing and sprinting. It is possible that using the arch-cleat position has the potential to substantially decrease power production by reducing the activity of muscles that span the ankle during high-intensity efforts. In addition, the arch-cleat position, when used with the current standard bicycle geometry, leads to a substantial front wheel/foot overlap, which would limit its use when riding in mass start cycling races requiring frequent cornering or rapid maneuvers.
Practical Applications and Conclusion

In summary, moving the cycling shoe cleat posteriorly to achieve an arch-cleat position did not lead to any substantial difference in performance despite an apparent improvement in aerobic economy with this group of well-trained cyclists. Further studies are needed to investigate the effects of long-term habituation to the arch-cleat position and to determine potential performance effects during non-steady-state and high-intensity activity.

Acknowledgments

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References