

# The effects of cycling cleat position on subsequent running performance in a simulated duathlon

Carl D Paton<sup>1</sup>✉ and Timothy Jardine

## Abstract

Strategies that reduce the physiological load during the cycling phase of triathlon events may enable athletes to perform better during the subsequent running phase. The current study examines the effects of changes in shoe cleat position, during the cycling phase of a simulated duathlon, on running performance of competitive triathletes. Controlled crossover. 12 triathletes completed a simulated duathlon race using either their normal (control) cycling cleat position or an experimental mid-foot (arch) shoe cleat position. The duathlon consisted of a 30-min cycle, completed at 65% of the athlete's previously determined peak aerobic power output, followed by a self-paced maximal effort 5.5-km treadmill run. Respiratory-gas measurements were made throughout testing using an automated online metabolic system. There were only trivial differences between conditions for any metabolic variables obtained during the cycling phase of the duathlon. However run time following the mid-foot condition was 2.2% (90% CI 0.8-3.6%) shorter compared to the control condition. In addition Oxygen consumption during the run phase was greater following the mid-foot condition by 2.2% (-0.5-5.1%). We conclude that worthwhile performance gains can be achieved during the running phase of a duathlon when athletes utilize a mid-foot-cleat shoe position during the cycling phase of an event. The improvement in running performance was likely due to a reduction in the rate of plantar flexor muscle fatigue during the cycling phase of the event.

**Keywords:** triathletes, competition, arch-cleat, mid-foot

✉ **Contact email:** [cpaton@eit.ac.nz](mailto:cpaton@eit.ac.nz) (CD. Paton)

<sup>1</sup> Eastern Institute of Technology, Hawkes Bay, New Zealand

Received: 1 April 2012. Accepted: 22 June 2012.

## Introduction

Multisport events such as triathlon, duathlon and adventure racing commonly involve consecutive cycling and running phases. Reports from athletes involved in multisport competitions indicate that one of the most difficult parts of a race can be the transition from non-weight bearing cycling to weight-bearing running activities. Indeed findings from previous investigations (Millet and Vleck 2000; Heiden and Burnett 2003) have highlighted the difficulties athletes face physiologically and neuromuscularly when transitioning from cycling to running phases in triathlon events. An athlete's ability to effectively transition from cycling to running phases can therefore be critical in determining an athlete's overall race placing particularly in shorter duration triathlons that allow pack riding. As the ability to effectively transition from cycling to running phases appears so important strategies that reduce the physical load during the cycling phase of triathlon events may prove beneficial in enhancing performance during any subsequent running phase.

A strategy aimed at enhancing the cycle to run transition that has recently been adopted by some competitive triathletes involves moving the foot placement position on the bicycle pedal from a traditional forefoot position, to a more posteriorly orientated mid-foot or "arch-cleat" position (personal observation). It is postulated that the mid-foot position leads to a reduction in plantar flexor muscle activity during cycling, and that this may be of benefit during the subsequent running phase where calf fatigue can lead to a substantial reduction in running speed (Mizrahi et al. 1997). Indeed in an electromyographic investigation of the influence of pedal foot position on muscular activity in cycling, Litzemberger et al. (2008) reported that changing from the traditional forefoot to a mid-foot orientated cleat position reduced muscular activity in the calf muscle during cycling activity by up to 20%. In a subsequent follow up study from the same research group Illes et al. (2010) reported that using a mid-foot cleat position during cycling allowed subjects to better maintain their running gait in a subsequent running phase; the authors suggested that "there could be a great advantage in running for triathletes which are used to the metatarsal position".

Few studies to date have examined the effects on physiology and performance of changes in cycling shoe cleat placement. In a study investigating cleat position changes during steady state cycling, Van Sickle and



Hull (2007) reported that there were no significant changes in aerobic economy between three different cleat positions when cycling. However in their study they did note that a mid-foot orientated cleat position was associated with a reduction in plantar flexor muscle activity of a similar magnitude (~25%) to that reported by Litzenberger et al. (2008). In a more recent performance related investigation into the effects of changing cleat position Paton (2009) reported that while adopting the mid-foot cleat position lead to a small (~2%) improvement in aerobic economy the magnitude of this improvement was insufficient to impact on actual performance in a simulated cycling time trial.

While previous studies have failed to identify any direct benefits of changing foot position on actual cycling performance, to our knowledge no one has investigated the effects such a change would have on subsequent running performance during simulated competition performed at high intensity. Therefore, the primary aim of this investigation was to quantify the effects of changes in cleat orientation (to a mid-foot position) during a high-intensity cycling bout on the subsequent running performance and physiology of competitive triathletes.

### Materials and methods

Twelve trained male triathletes (Mean  $\pm$  SD, age  $37 \pm 4$  y, mass  $77 \pm 5$  kg, height  $180 \pm 4$  cm and Max  $\text{VO}_2$   $4.6 \pm 0.5$  L.min<sup>-1</sup>) gave their written informed consent to participate in this study which was approved by the Eastern Institute of Technology ethics committee. All athletes had been training for triathlon for a minimum of 2 years and were regular competitors in events ranging from short duration (sprint) to long duration (Ironman) distances. Athletes were considered to be in a well-trained state prior to commencing the study and none had previous experience using the experimental mid-foot position utilized in this study.

Each athlete completed four experimental tests within four weeks, and with at least five days between tests. Athletes initially completed two familiarization test sessions followed by two simulated duathlon races using either a control or experimental cycling shoe condition.

During the cycling phases of testing athletes 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 athletes current preferred position and in all cases was approximately beneath the head of the metatarsophalangeal joint (within  $\pm 10$ mm); the experimental (mid-foot) cleat position was set posteriorly to the control in a mid-foot position approximating a position under the individuals tarsal-metatarsal joint. In order to compensate for the effective decreased leg length during the mid-foot cleat trials the seat height was lowered, for each individual, to a position where their knee flexion angle (measured using a goniometer), at

the bottom of the pedal stroke with the foot parallel to the ground, was the same as that of the control condition. During the running phases of testing athletes used their personal choice of running shoes, which were kept constant for all test sessions.

Athletes were instructed to refrain from any hard physical activity within 24 hours of a test and present in a well-hydrated state. Additionally athletes were asked to record their dietary intake in the 24 hours pre-ceding the first test and to replicate this as closely as possible for subsequent sessions; they were also to refrain from use of any potential performance enhancing substances (e.g. caffeine). All testing sessions were performed at the same time of day for each individual in order to control for diurnal variations. Tests were performed under stable environmental conditions in a temperature controlled laboratory (~20°C, ~60% relative humidity). Athletes were not allowed to consume any products other than water in the three hours preceding testing.

All cycling tests were performed on a Velotron Pro electromagnetically-braked cycle ergometer, (RacerMate, Seattle, USA) calibrated in accordance with the manufacturers published instructions. The velotron ergometer has previously been reported to have good test re-test reliability (Sporer and McKenzie 2007). Running tests were performed on a calibrated treadmill (TechnoGym, Gambettola, Italy) set an incline of 1% in order to better simulate outdoor running conditions.

Prior to the simulated duathlons each athlete underwent a two-stage familiarization session for the cycling and running components of testing. These sessions were designed to establish the athletes' baseline physiological characteristics, determine the exercise load for the cycling stage and familiarize them with the duathlon procedures.

In the cycling familiarization session athletes initially performed a 10-minute self-selected warm-up followed by 5-minutes of steady cycling at 100 W. Thereafter athletes immediately performed an incremental ramp test, beginning at 100 W and increasing by 25 W each minute until pedal cadence dropped below 70 rpm or athletes reached volitional exhaustion. Peak aerobic power output (PPO) was calculated as the final completed stage plus the proportion of any uncompleted stage. Following the incremental test athletes completed five minutes of recovery cycling at 100 W and then 15 minutes of passive rest. Following the recovery phase athletes completed a 30 minute constant power test at a workload equivalent to 65% of their PPO achieved in the prior incremental test. The 65% power output for the steady state cycling test was selected based upon pilot testing which indicated that this intensity elicited an oxygen consumption of ~80% of maximum oxygen consumption over the 30 minutes duration in the athletes tested. In order to facilitate a smooth transition to the required cycling power output athletes completed a three minute progressive build up prior to starting the 30 minute test; this required athletes to commence at 70% of the required power and increase this by 10% each minute until they achieved

the desired load. Athletes were required to maintain a cadence of 85-100 rpm throughout the test. The familiarization cycling session was completed using the athlete's normal (control) shoe cleat position only.

In the running familiarization athletes performed a 10-minute self-selected warm-up followed by 5-minutes of running at a speed of 8 kmh<sup>-1</sup>. Thereafter athletes performed an incremental ramp test, beginning at 8 kmh<sup>-1</sup> and increasing by 1 kmh<sup>-1</sup> each minute until they reached volitional exhaustion. Following the incremental test athletes completed five minutes of recovery at 8 kmh<sup>-1</sup> and then 15 minutes of passive recovery. Following the recovery phase they completed a 5.5 km self-paced maximal intensity run. During the first 30 seconds of the running test the treadmill was set to automatically accelerate steadily from 0 to 12 kmh<sup>-1</sup>; thereafter athletes used a manual control button on the treadmill console to alter the speed of the treadmill as they desired in order to achieve the required distance in as fast a time as possible.

During all tests heart rate and oxygen uptake were continuously measured with a previously validated (Medbo et al. 2002) automated metabolic system (Cortex Metalyser 3b, Leipzig, Germany) calibrated in accordance with the manufacturer's instructions using alpha gas standards. Maximum oxygen consumption was determined as the highest 30 s average recorded during both cycling and running incremental tests.

On two further occasions athletes performed a simulated duathlon using either the control or experimental shoe condition in a randomized cross-over order. The duathlon consisted of the constant power cycling phase (65% of each athlete's PPO) immediately followed by the 5.5 km running phase from the previously described familiarization tests. Prior to the duathlon the athlete completed a warm-up consisting of 10 minutes of cycling at a self-selected intensity followed by five minutes of cycling at 50% of their prescribed test power output. The athlete then completed five minutes of passive rest and stretching before beginning the three minute ramp (previously described) leading to the start of the 30-minute constant power cycling phase. On completion of the cycling phase the athlete dismounted and undertook a 90-s transition phase. During the transition the athlete changed to their running shoes and mounted the

treadmill in preparation for the run. Athletes also consumed 200ml of plain water during the transition phase. The only information provided to athletes during the simulated duathlon was time remaining in the cycle phase and distance remaining in the run phase. Athletes were cooled throughout all trials with a large (75cm) standing floor fan. Athletes completed their second trial in the alternate condition 5-7 days later.

### Statistical analyses

We performed a magnitude based analysis of the results in accordance with the recommendations of Batterham and Hopkins (2006). The mean effects of shoe cleat position on physiological and performance variables were estimated with an excel spreadsheet (Hopkins, 2006a). Briefly, the spreadsheet utilizes the unequal-variances t statistic to compare change scores between conditions. Data were log transformed prior to analysis in order to reduce any bias arising from non-uniformity of error with effects derived by back transformation as percentage changes. In addition we used the effect size statistic (ES) to provide a measure of the magnitude of the effects and interpreted these using modified Cohen thresholds of 0.2, 0.6 and 1.2 for small moderate and large effects in accordance with the recommendations of Hopkins (Hopkins, 2006b). Uncertainties of the observed effects were expressed as ± 90% confidence intervals.

### Results

Data are presented as means ± standard deviations. The athletes achieved maximal oxygen consumptions in the incremental ramp tests of 4.4 ± 0.5 and 4.6 ± 0.5 L.min<sup>-1</sup> for cycling and running respectively. During the familiarisation trials for the cycling and running phases of the duathlon the oxygen consumption was 3.6 ± 0.4 and 4.1 ± 0.5 L.min<sup>-1</sup>; this equates to a percentage utilisation of ~81% and ~89% of the maximum oxygen consumption values for the cycling and running phases. The physiological and performance characteristics for the cycling and running phases of the duathlon are shown in Table 1. Familiarisation data are included to provide a comparative reference value. Differences in oxygen consumption across all cycling trials were trivial (ES <0.06), however there was a small observed difference (ES~0.2) for heart rate between the

**Table 1.** Comparative measures of physiology and performance between the familiarization, control and mid-foot cleat positions.

	Trial condition			Change in measure between trials		
	Famil Mean ± SD	Control Mean ± SD	MF Mean ± SD	Famil-Control % Diff ± 90%CL <sup>a</sup> (ES <sup>b</sup> )	Famil-MF % Diff ± 90%CL <sup>a</sup> (ES <sup>b</sup> )	Control-MF % Diff ± 90%CL <sup>a</sup> (ES <sup>b</sup> )
<b>Cycling</b> (30 min at 65% PPO)						
VO <sub>2</sub> (L.min <sup>-1</sup> )	3.57 ± 0.40	3.53 ± 0.29	3.55 ± 0.41	-0.7 ± 3.9 (0.05 <sup>b</sup> )	-0.8 ± 3.5 (0.06 <sup>b</sup> )	-0.0 ± 3.5 (0.01 <sup>b</sup> )
Heart rate (bpm)	162 ± 11	160 ± 12	160 ± 12	1.5 ± 1.4 (0.22 <sup>b</sup> )	1.3 ± 1.9 (0.18 <sup>b</sup> )	0.3 ± 1.4 (0.04 <sup>b</sup> )
<b>Run</b> (5.5 km)						
Time (s)	1265 ± 102	1377 ± 152	1345 ± 133	8.6 ± 2.5 (1.05 <sup>b</sup> )	6.2 ± 2.7 (0.77 <sup>b</sup> )	-2.2 ± 1.4 (0.28 <sup>b</sup> )
VO <sub>2</sub> (L.min <sup>-1</sup> )	4.11 ± 0.50	3.70 ± 0.52	3.79 ± 0.58	-10.3 ± 4.8 (0.87 <sup>b</sup> )	-8.3 ± 5.3 (0.70 <sup>b</sup> )	2.2 ± 2.8 (0.18 <sup>b</sup> )
Heart rate (bpm)	174 ± 13	168 ± 12	170 ± 12	-3.7 ± 2 (0.51 <sup>b</sup> )	-2.4 ± 1.1 (0.33 <sup>b</sup> )	1.3 ± 1.1 (0.18 <sup>b</sup> )

<sup>a</sup> ±90% CL: Add and subtract this number to the mean effect to obtain the 90% confidence limits for the true difference:

ES<sup>b</sup> Calculated Effect Size statistic for difference between trials.

familiarisation and experimental trials. The inclusion of cycling prior to the running phase had substantial effects on the run time and physiology; run time was ~7% faster in the familiarisation trial where there was no prior cycling phase. Further there was a small decrease in running time (2.2%) during the experimental trials when athletes used the mid-foot position during the cycling phase compared to the control cleat position.

The mean and individual changes in run time between the familiarisation, control and mid-foot cleat trials are shown in Figure 1.

## Discussion

The findings of the current study show that the addition of a 30-minute high-intensity cycling bout prior to a maximum effort run leads to a large (~7%) decrease in sustainable running speed. Further, changing from a traditional forefoot cleat position to a more posteriorly orientated mid-foot position during the cycling bout moderates some of the running performance decrement caused by prior cycling. The magnitude of the enhancement in run performance following the change to the mid-foot position during the cycling phase was equivalent to an increase in mean running speed of ~2% or approximately six seconds per kilometer over the 5.5 km distance ran. The faster running speed in the mid-foot trial was also accompanied by a concomitant small (~2%) increase in oxygen consumption and increase in mean heart rate.

Given that there were no substantial differences in any of the measured physiological indices during the cycling phase between trials despite the substantial change in position, the reason for the observed improvement in running speed when using the mid-foot position is unlikely to be due an actual reduction in metabolic load during cycling. We may have expected to see a small improvement in oxygen consumption when using the mid-foot position, as we have observed this in a previous study from our laboratory (Paton 2009) using a similar cycling protocol. However a reduction in oxygen consumption during the cycling phase does not appear to be responsible for the enhancement in running performance within the current study. In the absence of an improvement in cycling metabolic parameters we hypothesise that the improvement in running performance occurs because of a reduction in plantar flexor fatigue during mid-foot cycling. Several authors have previously reported that adopting a mid-foot position leads to ~20% reduction in plantar flexor activity (Van Sickle and Hull 2007; Litzenger et al., 2008). Whilst the reduced muscular activity itself may not be of direct benefit during

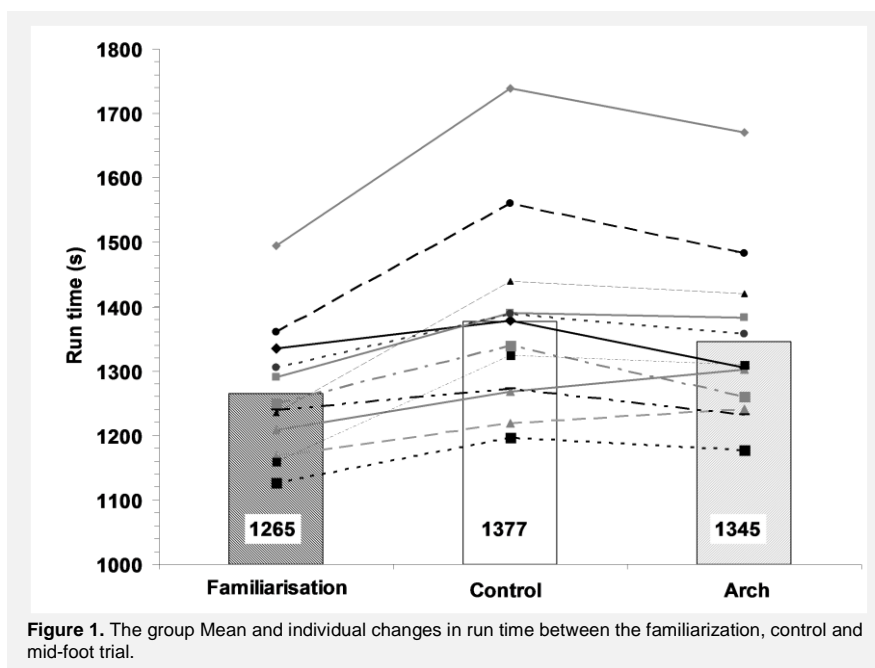


Figure 1. The group Mean and individual changes in run time between the familiarization, control and mid-foot trial.

cycling itself (as these muscles act mainly to stabilise the ankle), the reduction in fatigue in these muscle would allow athletes to perform better in a subsequent running phase. Previous authors (Kyrolainen et al., 2005) have shown that it is necessary to increase plantar flexor activity (particularly in the gastrocnemius muscles) in order to increase running speed. Indeed Mizrahi et al., (1997) has shown that as plantar flexor muscles fatigue, runners experience a reduced ability to attenuate heel strike induced shock which in turn leads to a deterioration in muscle co-ordination and running speed. It is plausible therefore that the reduced plantar flexor activity and fatigue that occurs during the mid-foot trial allows the lower leg musculature to better preserve tendomuscular stiffness therefore directly enhancing run performance. Further evidence for an enhanced running ability after using the mid-foot position is seen in a recent study by Illes et al. (2010), who reported that planter pressure (measured using pressure measuring insoles) was better maintained after cycling with the mid-foot position compared to the normal position. Whilst it was not the intention of the current study to analyse running mechanics, video recordings of athletes' running technique taken during the investigation do appear to indicate a better maintenance of running technique (personal observation) when athletes had used the mid-foot position during the cycling trials. Further, when athletes were questioned on their experience of using the mid-foot position the majority felt the change did assist their ability to transition in the early phase of the run. Unfortunately, due to technical limitations with the treadmill used it was not possible to determine whether the increase in average running speed was due to an improvement in a particular phase of the run (e.g. the early phase). However it is possible that the majority of the performance enhancement came about over the first kilometres of the run, which previous investigations (Heiden and Burnett 2003) have suggested is a crucial

phase in determining overall race placement. It is however unclear how the running performance enhancement in our investigation would manifest itself over longer duration runs.

While the magnitude of the enhancement in running performance in this study may be considered statistically small (ES 0.28) this would almost certainly be considered practically worthwhile for an athlete, especially given the small winning margins often seen in real competitions. Indeed in a study examining the reliability of elite Olympic distance triathletes over a competitive season Paton and Hopkins, (2005) estimated that the minimum worthwhile performance enhancement for well-trained triathletes would be equivalent to ~0.5% of the total event duration. However these authors' analysis indicated that such a performance enhancement would be difficult to achieve over all three disciplines in an event and that potential performance enhancement is most likely to come from improvements within a single discipline, most likely during the final run. The authors therefore estimated that an improvement in performance during the run phase of a triathlon of as little as 1.2% would provide a substantial competitive advantage. Therefore even when taking into account the likely lower ability of the athletes (and therefore potentially poorer performance reliability) used in the current study, the reported mean athlete enhancement of ~2% would likely be considered beneficial. Interestingly, a detailed analysis of the individual changes in run performance (as depicted in fig 1) in our study indicates a possible trend for the initially slower runners to gain a greater performance advantage (3-4%) when they moved to using the mid-foot position and conversely the faster runners to gain less benefit. Indeed the two runners that recorded a decrement in performance with the switch to the mid-foot position were amongst the fastest in the initial familiarisation trials. Therefore it appears possible that the change to a more posterior cycling cleat position may be best suited to slower athletes who find the transition from cycling to running problematic.

## Conclusions

We conclude that multi-sport athletes can experience worthwhile performance gains during the running phase of a duathlon when they utilize a mid-foot position during the cycling phase of the event. The faster running speed is associated with an ability to maintain higher oxygen consumption. The mechanism responsible for the improvement in running performance has yet to be identified but may be associated with reductions in plantar flexor muscle activity during the cycling phase of the event. Future studies are therefore recommended to examine how changes in muscle recruitment patterns when changing cleat position may lead to enhancements in running performance.

## Practical applications

Triathletes can make substantial gains in running performance when they utilize a mid-foot ("arch") cleat position during the cycling phase of multi-sport events.

Triathletes who run "worse of the bike" gain more advantage when using the mid-foot position.

An improvement in running performance following cycling with mid-foot is associated with an athlete's ability to maintain a higher overall oxygen consumption.

## Acknowledgment

We gratefully acknowledge the Eastern Institute of Technology for providing funding and support to complete this project and to the athletes that participated in the study for their time and considerable effort.

## References

1. Batterham AM, Hopkins WG. (2006) Making meaningful inferences about magnitudes. *International Journal of Sports Physiology and Performance* 1:(1):50-7
2. Heiden T, Burnett A (2003) Triathlon. *Sports Biomechanics* 2: (1):35-49
3. Hopkins WG (2006a) Spreadsheet for analysis of controlled trials with adjustment for a predictor. SportScience available at <http://sportsci.org/2006/wghcontrol.htm>
4. Hopkins WG (2006b) A scale of magnitudes for effect statistics. SportScience available at <http://newstats.org/effectmag.html>
5. Illes S, Hassmann M, Martin H, Ilagan R, Litzberger S, Sabo A (2010) Influence of pedaling with the metatarsus on running characteristics in triathlon competition. *Procedia Engineering* (2):3127-3131
6. Kyrolainen H, Avela J, Komi PV (2005) Changes in muscle activity with increasing running speed. *Journal of Sport Sciences* 23: (10):1101-1109
7. Litzberger S, Illes S, Hren M, Reichel M, Sabo A (2008) Influence of pedal foot position on muscular activity during ergometer cycling. *The Engineering of Sport* (7):215-222
8. Medbø JJ, Mamen A, Welde B, von Heimburg E, Stokke R. (2002) Examination of the Metamax I and II oxygen analysers during exercise studies in the laboratory. *Scandinavian journal Clinical Laboratory Investigations*: 62: 585-598.
9. Millet GP, Vleck VE (2000) Physiological and Biomechanical adaptation to the cycle to run transition in Olympic triathlon: Review and practical recommendations for training. *British journal of Sport Medicine* 34: 384-390
10. Mizrahi J, Voloshin A, Russek D, Verbitsky O, Isakau E (1997) The influence of fatigue on EMG and impact acceleration in running. *Basic and Applied Myology* 7: (2):111-118
11. Paton C, Hopkins WG (2005) Competitive performance of elite Olympic-distance triathletes: Reliability and smallest worthwhile enhancement. *SportScience* 9: 1-5 available at <http://sportsci.org/jour/05/wghtri.htm>
12. Paton C (2009) Effects of shoe cleat position on physiology and performance of competitive cyclists. *International journal of sports physiology and performance* 4: 517-523

13. Sporer BC and McKenzie DC. (2007) Reproducibility of a Laboratory Based 20-km Time Trial Evaluation in Competitive Cyclists Using the Velotron Pro Ergometer International Journal of Sports Medicine 28: (11): 940-944.
14. Van Sickle JR, Hull ML (2007) Is economy of competitive cyclists affected by the anterior- posterior foot position on the pedal? Journal of Biomechanics 40: 1262-1267