Impact of Seated and Standing Bicycle Riding Position on Subsequent Running Performance

RANDALL L. JENSEN‡1, BRENDON J. EWERS†1, BRIAN CUNNIFFE*2, BRIAN PHELAN*2, ANDREW J. HARRISON‡2, and AMIR SHAFAT‡2

1Department of Health, Physical Education, and Recreation, Northern Michigan University, Marquette, MI, USA; 2Deptartment of Physical Education and Sport Sciences, University of Limerick, Limerick, IRELAND

‡Denotes professional author, †denotes graduate student author, * denotes undergraduate student author

ABSTRACT

Int J Exerc Sci 1(4) : 177-187, 2008. This study examined the effects of cycling posture on subsequent running performance similar to the transition phase of a triathlon. Experienced, non-elite triathletes completed two trials of a cycle-run transition. During the last three minutes of a 30 minute cycling bout, at power output equal to lactate threshold, subjects either remained seated (SEAT), or alternated seated and standing cycling (30 s at a time; ALT). Heart rate, RPE, minimum and maximum knee angle, stride frequency and length, and onset and duration of quadriceps and hamstrings activity were obtained at the end of a three-minute control run and at minutes 0, 2, & 4, of running after cycling transition. Repeated Measures ANOVA (condition X minute; p = 0.05) found control was significantly different than minute 0 for stride frequency and length, but not for minimum or maximum knee angle. EMG duration at minute 4 was less than all other time points for both quadriceps and hamstrings. Onset of muscle activity was not different for hamstring or quadriceps. Heart rate and RPE both increased over 15 minutes after transition and were higher for SEAT than ALT, however, there was no interaction (minute by position) for either variable. Results indicated changes in stride rate and length following cycling occur, but disappear within two minutes after the transition to running and do not differ between postures. Changes in duration of muscle activity may be related to changes in stride. Also HR and RPE differ between the SEAT and ALT cycling positions and over time.

KEY WORDS: Electromyography, kinematics, bicycling, rating of perceived exertion

INTRODUCTION

Triathletes often report “awkwardness” during the first few minutes of running following the cycle to run transition. Previous studies have shown that this is not merely a psychological feeling or imaginary effect as previous studies have demonstrated increased oxygen uptake (13) and decreased ventilatory efficiency (12, 14). Furthermore changes in muscle activity as assessed via electromyography (6, 10, 11) have been noted as well as alterations in stride length (SL) and stride frequency (SF) (1, 7, 8). Bernard and colleagues (1) have suggested that all of these factors may ultimately impact performance.

To avoid the apparently disadvantageous condition following the cycle-run transition triathletes have tried a number of different strategies. Garside and Doran (7) have suggested that alterations due to changes in body position may result in different recruitment of muscles or a better simulation of running. Li and Caldwell (15) have shown that muscle coordination of the rectus femoris and biceps femoris is altered during standing cycling. Therefore, it may be possible that the changes in body position could change recruitment of muscles resulting in their being more ready for movement and recruitment patterns more similar to running than what would be more likely following typical cycling. Cedaro (3) has advocated alternating standing and seated cycling just prior to the transition to running rather than remaining seated for the entire cycle portion of the triathlon. He suggested that this approach will allow the muscles to adapt more quickly to the movements of running. However, no data was presented to support this contention and a search of the literature provides no studies to corroborate or refute this argument. As standing cycling increases the amount of drag force (which increases power required to maintain velocity) it would seem counterproductive to perform the standing cycling for an extended period of time.

Gantner and coworkers (6) found that immediately following cycling, duration of rectus femoris and vastus medialis activity was longer than in a run condition not preceded by cycling. They suggested that the cause for the increased duration was an earlier onset and/or later offset of neuromuscular activity. Furthermore, they hypothesized that the increased quadriceps activity was most likely the cause of muscle discomfort when running was preceded by cycling exercise. It is interesting that these authors found no variation in running stride changes despite the alterations in muscle activity.

The purpose of the current paper was to examine the effect on subsequent running of alternate standing and seated cycling versus remaining in the seated position while cycling. Two studies, with separate groups of subjects, were carried out to investigate this effect.

METHOD

Subjects

All subjects were recreational or sub-elite triathletes as classified according to previously reported triathlon population data (17). 10K running time during a triathlon was 48:24 ± 6:54. Each subject provided written voluntary consent and the studies were approved by the Research Ethics Committee of the University of Limerick and the Human Subjects Research Review Committee of Northern Michigan University.

Protocol

For both studies, the exercise protocol took place on four days within a two week period; one study investigated physiological variables while the second study investigated possible biomechanical changes. On the first day subjects reported to the laboratory for a familiarization session to experience riding the cycle ergometer and running on the treadmill. For the three subsequent testing sessions subjects were asked to refrain from training for 24 hours prior to reporting for data collection and to treat the testing session as a race. Environmental conditions were held constant for all sessions for each subject.

On the first day subjects were weighed on a balance beam scale to the nearest 100 g and stature was determined by stadiometer to the nearest 5 mm. Subjects were allowed to self select the seat height of the ergometer, but once selected the same height was used for all subsequent testing. They then cycled for five minutes at a self selected workload after which they were asked to run on the treadmill at a pace that approximated their running speed for the running portion of a triathlon. The speed which the subject felt best approximated their running speed was noted and used for the running portion of the later test sessions.

On the second day of testing, following a five minute warm-up at 50 W, subjects performed a lactate threshold test using the cycle ergometer and pedaling at a cadence of 90 rpm. Initial power output was 50 W for three minutes, after which power output was increased by 25 W every three minutes until lactate threshold was achieved. Capillary blood samples were obtained from the fingertip in 50 µl heparinized capillary tubes during the last 30 sec of each stage. Blood lactate concentration was assayed with a YSI-1500 Sport Lactate Analyzer (Yellow Springs, Ohio). Lactate threshold was defined as consecutive stage increases ≥ 1 mmol $\cdot$ l^{-1} in the obtained lactate value. Power output was then determined relative to the power production at which lactate threshold was attained. This power output was maintained during each of the following cycle exercise bouts. All athletes were asked to report for testing at least three hours after eating.

On the following two days, subjects cycled for 30 minutes at the power output achieved at lactate threshold and were then asked to run at their previously self selected running pace. On one day subjects were asked to maintain cadence at 90 rpm and remain seated for the entire 30 minute cycle bout. On the other day subjects remained seated for the first 27 minutes, but for the final three minutes were required to alternate between standing and being seated (ALT) every thirty seconds, while maintaining a cadence of 90 rpm. The time of three minutes was selected to minimize the effect of additional power output required to overcome drag from an increased frontal area due to standing.

Similar cadences were maintained in both conditions to minimize differences in stride length and frequency caused by cadence fluctuations (1, 18). The order of trials (SEAT vs. ALT) was randomly assigned for each subject. Subjects were provided with verbal feedback in order to help them maintain the set cadence. For both days following the cycling portion of exercise a 30 second transition period took place, subjects then began running on a treadmill. The previously self selected running pace was reached within 30 seconds of beginning the run.

Data Collection Study 1

Eleven subjects (Mean ± SD: Age = 33.5 ± 11.0 y; Height = 172.5 ± 5.2 cm; Weight = 68.5 ± 8.7 kg; T_{LA} = 231.8 ± 39.2 W) participated in data collection of the first study. Heart rate (HR), measured via a Polar XL Heart Rate Monitor (Polar Electro

Oy; Kempele, Finland), was determined at the end of each minute for 15 minutes. Rating of perceived exertion (RPE) using the 0 to 10 scale (2) was obtained at the same time by asking the subject to rate their overall feeling of exertion.

Data Collection Study 2

In the second study, nine subjects (Mean ± SD: Age = 27.7 ± 6.0 y; Height = 168.2 ± 7.3 cm; Weight = 66.5 ± 8.5 kg; T_{LA} = 181.0 ± 26.5 W) were assessed for muscle activity of the hamstring and quadriceps and kinematic variables of the lower body for three strides. Data was collected prior to cycling (control run) and after the cycling bout at the beginning of each minute (0, 2, and 4 minutes) of running, once subjects attained the predetermined running speed. For the control run (C), subjects ran for three minutes prior to cycling with data collected for three strides at the end of the three minute control run.

Assessment of muscle activity via EMG was performed for five subjects. Surface EMG data were recorded at 1000 Hz by electrodes placed on the biceps femoris and rectus femoris. Skin preparation included shaving any hair, removing dead skin from the surface with a roughing pad, cleansing the surface with alcohol and testing for a resistance of < 5000 ohms. Three surface electrodes were used with placement according to Cram, Kasman, and Holtz (5). For the biceps femoris the first electrode was placed in the center of the thigh midway between the gluteal fold and the back of the knee; the second electrode was placed 1cm distal to, and in the same longitudinal axis, as the first electrode; the ground electrode was placed on the lateral condyle of the femur. For the quadriceps EMG (rectus femoris) the first electrode was placed in the center of the thigh midway between the inguinal fold and the patella; the second electrode was placed 1cm distal to, and in the same longitudinal axis, as the first electrode. Wires for the surface electrodes were strung under the cycling shorts of the subject and connected to an amplifier. Data was streamed continuously through an analog to digital converter (Biopac Systems, Inc. Goleta, CA) to an IBM-compatible computer. Electromyographic data were filtered with a 10-500Hz band pass filter (19) and saved with the use of computer software (Powerlab 4/25, using Chart 4. software, AD instruments, UK). Saved EMG data were processed using Root Mean Square procedures with a time constant of 20 ms.

Kinematic variables including stride length and frequency, and minimum and maximum knee angle were obtained via videotape at 50 Hz from the right side using a Panasonic AGDP800 camera to provide a 2D sagittal view of the exercise. Reflective markers were placed on the subject's right lateral malleolus, lateral epicondyle of the tibia, and the greater trochanter of the femur (see Figure 1). Kinematic analyses were performed at 50 Hz via the Peak Motus 6.0 system (Englewood, CO). Maximum and minimum knee angle were determined as the greatest and least included angle of the knee joint for three strides. Stride frequency was estimated by determining the amount of time necessary for the three strides to take place and expressing this in strides per minute. Stride length was defined as the average distance of three successive right foot contacts and determined via the following equation:

Figure 1. Subject with reflective markers performing the running portion of the triathlon transistion.

Stride length = $(V*t/3) + (FF_1-FF_4)$

Where V = velocity; t = time for the right foot to contact the treadmill surface four times; FF_1 = the horizontal location of the first right foot contact; and FF_4= the horizontal location of the fourth right foot contact.

To synchronize the kinematic and EMG data a signal pulse was generated by the Peak Motus system and sent to the Biopac system. The kinematic data was then interpolated to match the sampling rate of EMG data using a customized splining program with MatLab 7.0.

The timing of the onset of muscle activity relative to joint position was defined as the point at which the EMG increased more than two standard deviations (SD's) above baseline. Duration of muscle activity was defined as the onset of activity until the EMG returned to within two SD's of the previously determined baseline.

Statistical Analysis

Statistical analyses were performed using SPSS 13.0 for Windows. A repeated measures Analysis of Variance with cycling condition x time was used in both studies ($p = 0.05$). Dependent variables for Study 1 were heart rate and RPE; while those for Study 2 were stride length and frequency, EMG onset relative to knee angle and duration of muscle activity as assessed by EMG. Effect sizes using partial eta² (η_p^2) were also obtained for each dependent variable using the formula: $\eta_p^2 = SS_{effect} / (SS_{effect} - SS_{error})$, where SS_{effect} = effect variance and SS_{error} = error variance. Interpretation of effect size was done using a scale for effect size classification based on F-values for effect size and were converted to η_p^2 using the formula: $F = (\eta_p^2 / (1 - \eta_p^2))^{0.5}$. Consequently, the scale for classification of η_p^2 was: 0.04 = trivial, 0.041 to 0.249 = small, 0.25 to 0.549 = medium, 0.55 to 0.799 = large, and .0.8 = very large (4). If sphericity was violated a Greenhouse-Geyser correction was used. If significant differences were found, a Bonferroni's post-hoc test of pairwise comparisons was performed.

RESULTS

As shown in figure 2 heart rate values were higher for SEAT condition compared to ALT and gradually increased over the 15 minutes of running following cycling for both SEAT and ALT ($p < 0.05$; $\eta_p^2 = .533$. and $\eta_p^2 = 632$ respectively), but did not display an interaction ($p > 0.05$; $\eta_p^2 = .029$).

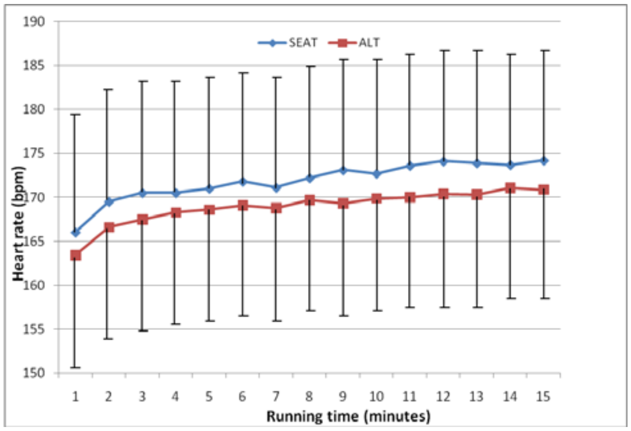

Figure 1. Mean (±SD indicated by bars; N = 11) heart rate during running following seated (SEAT = ♦) or alternate standing and seated cycling (ALT = ■).

For RPE not only did the values increase with time (see figure 3), but there was also a significant difference between the conditions with RPE during SEAT being higher than ALT ($p < 0.05$; $\eta_p^2 = .630$ and $\eta_p^2 = .673$ respectively). Cycling position did not affect the way RPE changed in time ($p > 0.05$; $\eta_p^2 = .231$). The overall mean (± SD) RPE during ALT was 5.4±2.0 and for SEAT was 6.1±1.7 ($p < 0.05$; $\eta_p^2 = .530$).

Intraclass Correlation (IC) of maximum and minimum knee angles for three strides within a condition were found to be reliable, with IC Coefficients ranging from R = 0.81 to 0.95 and no significant differences between the strides ($p > 0.05$). Thus the data of the first stride was used for all further knee angle comparisons.

Values for minimum and maximum knee angles are displayed in table 1. No significant differences were found for the minimum or maximum knee angles across cycling strategies or the time following cycle-run transition ($p > 0.05$). In addition, there were no significant interactions for either angle ($p > 0.05$; $\eta_p^2 = .030$ and $\eta_p^2 = .073$ respectively).

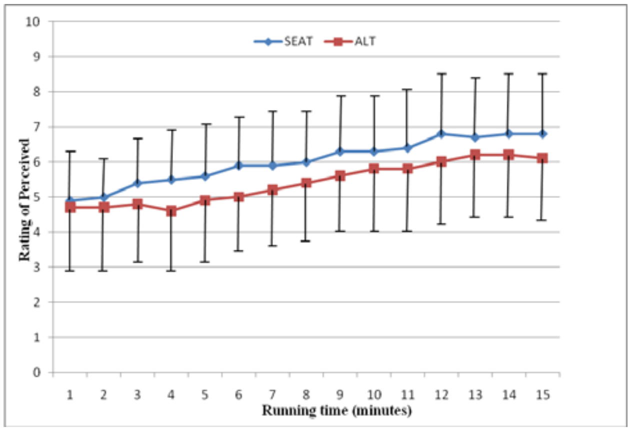

Figure 2. Mean (±SD indicated by bars; N = 11) Rating of Perceived Exertion during running following seated (SEAT = ♦) or alternate standing and seated cycling (ALT = ■). Seated condition less than alternate standing and seated cycling ($p < 0.05$).

Table 1 displays values for stride frequency and stride length. There was a difference in stride frequency for minutes ($p < 0.05$ $\eta_p^2 =$

Table 1. Means ± SD for stride frequency, stride length and knee angles during running following the transition from cycling or a control condition of just running (n=9).

Condition/Minute		Maximum Knee angle (°)	Minimum Knee angle (°)	Stride Frequency $\cdot \text{min}^{-1}$	Stride Length (m)
Control		162.6 ± 6.8	64.0 ± 9.6	80.9 ± 5.4 *	2.56 ± 0.38 *
Seated	0	164.0 ± 6.3	63.1 ± 10.9	85.2 ± 3.4	2.46 ± 0.30
	2	164.5 ± 5.2	63.6 ± 11.2	84.7 ± 5.1	2.48 ± 0.32
	4	162.4 ± 5.8	62.8 ± 11.1	84.2 ± 4.1	2.51 ± 0.33
Alternate	0	164.7 ± 5.8	61.3 ± 9.3	85.0 ± 3.7	2.46 ± 0.32
	2	164.5 ± 5.4	62.8 ± 11.5	84.2 ± 5.8	2.48 ± 0.33
	4	164.3 ± 5.9	63.5 ± 13.1	84.7 ± 6.0	2.48 ± 0.34

* Significantly different from minute 0 of both (SEAT and ALT) conditions ($p < 0.05$)

Table 2. Means ± SD for knee angle at onset of muscle activity and duration of muscle activity (n=5).

Condition/Minute		Knee angle at Quadriceps onset (°)	Knee angle at Hamstrings onset (°)	Quadriceps EMG duration (msec) *	Hamstrings EMG duration (msec) †
Control		94.6 ± 27.4	114.2 ± 33.8	242.2 ± 52.8	348.8 ± 53.7
Seated	0	91.0 ± 29.9	109.4 ± 31.7	257.0 ± 58.4	264.2 ± 41.5
	2	86.3 ± 24.3	95.1± 35.9	263.0 ± 72.7	227.4 ± 143.0
	4	98.6 ± 43.9	121.0 ± 21.5	247.6 ± 96.9	164.8 ± 97.3
Alternate	0	118.0 ± 18.8	118.2 ± 26.4	207.4 ± 85.6	398.0 ± 93.2
	2	111.5 ± 34.0	87.0 ± 40.3	311.8 ± 145.7	309.0 ± 181.2
	4	111.1 ± 27.7	117.3 ± 29.4	289.6 ± 39.5	260.6 ± 128.9

*Significant difference for minute 4 from minute 0 of both (SEAT and ALT) conditions ($p < 0.05$)

† Significant difference for minute 4 from all others for both (SEAT and ALT) conditions ($p < 0.05$)

.364), but not for the cycling position or the interaction of minute to cycling position ($p > 0.05$; $\eta_p^2 = .030$ and $\eta_p^2 = .073$ respectively). For stride length there was a difference for minutes ($p < 0.05$ $\eta_p^2 = .369$), but not for cycling position or the interaction of minute to cycling position ($p > 0.05$; $\eta_p^2 = .020$ and $\eta_p^2 = .069$ respectively).

The results of EMG assessments following the cycle transition are displayed in Table 2. There was no significant difference between the two conditions for the onset of quadriceps ($\eta_p^2 = .335$) and hamstring ($\eta_p^2 = .002$) muscle activity relative to knee angle or interaction of condition by minute ($p>0.05$; $\eta_p^2 = .484$ and $\eta_p^2 = .335$ respectively). Likewise there were no differences across the minutes of activity for quadriceps muscle activity ($p>0.05$; $\eta_p^2 = .555$). However, there was a difference across minutes for onset of hamstring activity ($p<0.05$; $\eta_p^2 = .996$). Post Hoc testing across minutes indicated that minute 4 was different than minute 2 for onset of Hamstring muscle activity (see table 2).

Similarly the duration of muscle activity was not significantly different for either muscle comparing the ALT condition to the SEAT condition (Quads $\eta_p^2 = .015$ and Hams $\eta_p^2 = .568$) or interaction of condition by minute for duration of muscle activity ($p>0.05$; $\eta_p^2 = .575$ and $\eta_p^2 = .734$ respectively). However, duration of muscle activity was significantly different across minutes for both the quadriceps and hamstring ($p<0.05$; $\eta_p^2 = .990$ and $\eta_p^2 = .995$ respectively). Post Hoc testing across minutes indicated that minute 4 was different than minute 0 for quadriceps muscle activity duration. While minute 4 duration of hamstring muscle activity was different from all other minutes (see table 2).

DISCUSSION

The findings of the current study agree with previous studies that have shown differences in running stride length and frequency following prior cycling exercise (1, 7, 8), but are in contrast to others who have found no differences (10, 12). Miller and Vleck (16) note that a poor transition phase is more common in non-elite triathletes (the level of the subjects in the current study) and this may also explain the contrast between various studies. The disagreement in prior findings probably partially explains the medium effect size for stride length and frequency in the current study, i.e. there is likely some effect, but not a very strong one. However it is also likely that changes that take place over time may result in most of the adjacent minutes being similar to one another. The data show that as time progressed, running stride length and frequency values in the current study approach that of the control condition. Indeed the difference for these variables from the control condition was only present when compared to minute 0. This is in agreement with anecdotal reports of triathletes who state that the "awkward running feeling" immediately after cycling gradually subsides over the first ten minutes of running. Furthermore, it should be noted that the changes in stride frequency and length were observed for cycling in a traditional seated position as well as for the alternating seated and standing position. Therefore it appears that the ALT method proposed by Cedaro (3) does not seem to alter stride frequency during subsequent running when compared to seated cycling.

Maximum knee angles did not differ from control running following either cycling condition. This is in agreement with Hausswirth et al. (10) who found no differences in running hip, knee, or ankle extension angles following cycling. The absence of differences in the minimum knee angles (the non-support phase) is in contrast to Hausswirth and colleagues (10) who found knee angle during an isolated run to be greater than the running portion of a simulated triathlon. It is of interest to note that while the maximum knee angles of the current study were similar to that of Hausswirth et al, 162-164° vs. 168° respectively, the minimum knee angles were significantly less in the current study (61-64° vs. 77°) (10). Furthermore, the values during the isolated run of Hausswirth and coworkers (10) were even greater (86°) than those of the current study (64°). Further flexion of the knee in the data presented here may be associated with longer activation periods of the hamstring muscle group.

Changes in muscle activity as indicated by EMG analysis may help to explain the perceived difficulty triathletes experience following the transition from cycling to running. The very large effect sizes for EMG onset and duration indicate the high degree of muscle activity change across minutes of running following cycling. Heiden and Burnett (11) stated that muscle activity changes of the quadriceps when switching from cycling to running may include an inability to extend the knee during running. This may also be related to the decreased stride length following the transition from cycling to running found in the current study. However, the difference in EMG during running after cycling was only present as the subjects moved further away from the transition time. Indeed the differences were only present once the subjects reached minute four. This change seems to support the feeling described by triathletes that the "awkwardness" following the transition from cycling to running dissipates as the running portion continues (3, 6, 16). Miller and Vleck (16, p 387) suggest that "postural compensation at the start of the cycle to run transition may be out of phase with actual neurosensory feedback." They further note that a "change from concentric muscular contraction in cycling to a stretch shortening cycle activity in running, and to an alteration in motor unit recruitment" (p 387).

Although it is difficult to explain the cause of the changes that take place in muscle activity during the transition from cycling to running; there was no significant difference between the SEAT and ALT conditions. This indicates that the change in muscle activity following the transition happened in both conditions. The lack of significant difference between conditions can probably be explained by the fact that there was a fairly large degree of variability between subjects (standard deviations ranging from 15 to 44% of the mean), which when combined with the small number of subjects, probably masked any differences.

The increase in heart rate over the 15 minutes of running following cycling was expected as many authors have found this previously (12, 13, 14, 16). The higher overall heart rate and medium effect size following the SEAT cycling position compared to ALT would indicate an increased stress on the triathlete. The cause of this difference is not clear, as Li and Caldwell (15) found that standing while cycling required a larger amount of EMG activity by the leg muscles in order to produce the same power output including opposing co-contractions of the anterior and posterior muscles of the thigh. It is possible that the alternating condition might result in a greater sharing of the cycling load across the legs, including different muscle/groups, different type of contraction, fiber type and recruitment patterns. An increase in muscle activity might also increase the required HR in order to provide metabolic support of the increased internal work. Alternatively, increased blood flow due to more dynamic movements of the entire leg complex may ultimately lessen the cardiovascular stress during the ALT condition (9). This reduced stress could then carry over to the running phase after the transition. Assessment of cardiac output and blood flow distribution during seated as opposed to standing cycling would be needed to elucidate these possibilities. The changes found in RPE mirrored those of the heart rate and may have been partially due to the differences in heart rate.

When asked which position was best for overcoming the uncomfortable feeling in the initial stages of running, in these two studies, 13 subjects preferred the alternating standing and seated positions, while five preferred the normal seated position, and two had no preference. This is likely related to the differences in RPE found in the first portion of the study. Indeed for the 11 subjects in that portion of the study, nine preferred the alternating standing condition with many stating that it allowed them to attain a “relaxed rhythm” sooner during the running portion. Based on the lack of difference found between the two conditions (SEAT vs. ALT) it appears that subjects could use whichever strategy felt most comfortable. However, of consideration might also be the fact that standing will likely increase the frontal surface area of the cyclist and thus the drag and power output required to maintain a similar speed.

Although the strategies using different body positions seem quite different, the outcome of the variables examined in the present study revealed no differences between the two positions. The changes in running stride length and cadence following 30 minutes of cycling at lactate threshold were similar to those reported by previous authors and seem to reflect the anecdotal observations of triathletes concerning “an awkwardness” in running that disappears within a few minutes of beginning the running stage. Changes in muscle activity duration are likely related to this “awkward “feeling. The lower RPE values reported during the alternate standing and seated condition by subjects of the current study suggest that there might have been less feeling of “awkwardness”, however this difference from the seated position was only manifested in the heart rate and not in any of the kinematic or EMG variables studied. The search for strategies to relieve this feeling does not appear to be complete.

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