J Sci Cycling. Vol. 4(1), 14-20

RESEARCH ARTICLE **Open Access**

Impact of Cycling Intensity on Cycle-run Transition in Female Triathletes

Ryanne Carmichael[1]✉, David J Heikkinen[2] and Elaina Mertens[3]

Abstract

The purpose of the study was to determine the impact of intensity during the final km of a cycling bout on subsequent run and overall cycle-run (CR) performance. A secondary aim of the study was to examine how manipulations in cycling power affect cycle-run performance in female triathletes exclusively. Nine well-trained female triathletes participated in the study. The triathletes completed two CR sessions (20 km cycle, 5 km run). The intensity of the first 19 km of cycling was equivalent to peak power at 70% of peak oxygen consumption ($\dot{V}O_{2peak}$) and the final 1 km varied between two conditions: power achieved at 95% of $\dot{V}O_{2peak}$ (high intensity, HI) and power achieved at 50% of $\dot{V}O_{2peak}$ (low intensity, LI). The 5 km run was completed as fast as possible. Mean blood lactate concentration [La$^-$] was significantly higher during the run following the cycling bout ending with a HI rather than a LI (11.5 ± 0.64 mmol/L vs. 9.3 ± 0.72 mmol/L). Run performance was not significantly different between HI and LI (24:54 ± 02:53 min vs. 00:24:36 ± 00:03:17 min). As well, no significant differences were found between overall CR sessions (01:23:23 h ± 00:05:47 min vs. 01:23:50 h ± 00:07:01 min). Despite increases in [La$^-$], cycling intensity during the final stages of a 20 km cycling bout does not significantly impact run or CR performance in well-trained female triathletes.

Keywords: triathlon, transition, blood lactate, female athletes

✉**Contact email:** rcarmichael@plymouth.edu (R. Carmichael)

[1] *Plymouth State University, NH, United States*

[2] *Fitchburg State University, Fitchburg, MA, United States*

[3] *Loras College, Dubuque, IA, United States*

Received: 21 August 2014.Accepted. 9 March 2015.

Introduction

Triathlon is a multisport event that involves competition in consecutive swimming, cycling, and running. Although the disciplines involved in triathlon are standard; the distances within each discipline vary greatly. The shortest version of the sport, the sprint triathlon, requires participants to complete a 750 m swim, a 20 km cycle, and a 5 km run (Bentley et al. 2002). Completion of the sprint triathlon varies from under an hour to over two hours depending on individual fitness and experience. The middle distance version of the sport is also referred to as “Olympic” or “International” distance triathlon. The middle distance race requires athletes to complete distances nearly double the lengths required during a sprint effort. Specifically, participants complete a 1.5 m swim, a 40 km cycle, and a 10 km run. Athletes typically finish the race between two to four hours depending on ability level (Sleivert & Rowlands 1996). The long distance race – also called “Ironman” distance – requires participants to complete 4 km of swimming, 180 km of cycling, and 42.2 km of running. Elite athletes can complete the distance in 8 hr while non-elite athletes can take over 14 hr to complete the same course (Sleivert & Rowlands 1996).

No matter the race distance, the sport of triathlon requires participants to transition quickly from swim to cycle and from cycle to run. The transitions are part of the race and as such, the ability to move from one discipline to another effectively has been shown to predict overall triathlon performance (Hausswirth & Brisswalter 2008). Although effort exerted during the swim leg of a triathlon has been shown to negatively impact the subsequent cycle (Bentley et al. 2007; Peeling & Landers 2009), research has suggested the metabolic and biomechanical changes that occur during a run following a cycling bout have a more dramatic effect on overall triathlon performance (Bentley et al. 2002).

Various cycle-run tactical strategies designed to limit the deleterious effects of cycling on running and overall triathlon performance have been examined. These strategies include variations in biomechanics, cadence, and power (Bernard et al. 2003, 2007; Garside & Doran, 2000; Suriano and Bishop, 2010; Vercruyssen et al. 2005). Although biomechanical manipulations involving cycling posture have not been shown to affect subsequent run performance, manipulations of seat tube angle have been reported to positively affect run and cycle-run efforts (Garside & Doran 2000; Jensen et al. 2008). Garside and Doran (2000) reported that cycling with a steeper seat tube angle (81° versus 73°) resulted in faster subsequent 10 km run performances (42:55 ± 4:19 versus 46:15 ± 4:52 min) and faster overall cycle run sessions (1:45:49 ± 5:45 versus 1:50:33 ± 6:08 min). Changing cadence during a cycling bout can also affect follow up run times, but performance results appear equivocal. For example, Vercruyssen et al. (2005) showed that lower cadence during a cycling bout (freely chosen cadence -20%) led to a longer run time to fatigue (+37.3%) while Bernard et al. (2003) found that a lower cadence (60 rpm) did not lead to a faster run performance. Manipulating power output during cycling bouts also appears to have varied effects on run performance. Bernard et al. (2007) reported that high intensity cycling (92% MAP) slowed subjects' run time (-4.4%) and Suriano et al. (2007) found that lower intensity cycling (20% below LT) led to improvements in run time to exhaustion (+39.6%). Alternatively, Bonacci et al. (2011) showed no differences in neuromuscular control or running economy following a low (20 min at RPE of 14) versus a high intensity (50 min power profile test) cycling bout. When investigating the effect of cycling power output on both run and overall cycle-run performance, Suriano and Bishop (2010) found that although run performance was slower (+5%) following a high intensity cycling effort (96-100% of cycling time trial), combined cycle-run performance was enhanced following a cycling bout completed at the highest possible intensity.

Although research has been performed to identify the cycle-run transition strategies most important to overall triathlon performance, no consensus exists on the best tactic. Conventional wisdom in triathlon, including advice from coaches, physiologists, and athletes advocates a cycle-run strategy in which triathletes reduce cycling intensity prior to the run to maximize run performance. This strategy has been anecdotally reported by triathletes (Bernard et al. 2003). The intention is to rest the legs for the impending running bout – a strategy meant to allow time for the clearance of blood lactate [La^{-}] which theoretically could improve run performance (Suriano et al. 2007).

The purpose of the current research was to clarify approaches to the cycle-run transition that may improve triathlon performance. Specifically, the aim of the study was to determine if a low (LI) or a high (HI) intensity cycling effort performed during the final 1 km of a 20 km cycling bout would have an impact on subsequent 5 km run performance as well as overall cycle-run (CR) performance. The LI bout simulated a resting period prior to the run while the HI bout simulated an alternative transition tactic – an increase in power during the final leg of cycling in order to reach a better race position prior to the run (Millet & Vleck 2000).

A secondary aim of the study was to examine the usefulness of this transition tactic in female triathletes exclusively. To our knowledge, no cycle-run research investigations have examined the effect of power manipulations on performance using only female subjects. In addition to differences between male and female athletes in absolute mean power output and time to completion during triathlon and cycling races, there are differences in cycling efficiency and % $\dot{V}O_{2max}$ values at lactate threshold and at submaximal paces during endurance events (Hopker et al. 2010; Lepers et al. 2013; Maldonado-Martin et al. 2004). In addition, although time spent below, at, or above lactate threshold during cycling events and triathlon has been found to be similar between males and females, there is a paucity of research on the topic (Bernard et al. 2009; Lim et al. 2011). The physiological differences between the genders during endurance racing and the lack of previous research examining female triathletes specifically merit further investigation into how this group responds to various racing tactics.

Materials and methods

Participants

Nine female age group triathletes participated in the study (descriptive statistics for age, $\dot{V}O_{2peak}$, maximal aerobic power (MAP), body fat, weight, and height are presented in Table 1). All participants had competed in triathlon for two or more seasons (training distances per week: 5.3 ± 2.3 km for swimming, 116.1 ± 51.6 km for cycling, and 35.9 ± 13.1 km for running). All participants were volunteers and completed informed consent, medical history, and menstrual history forms prior to participation. The subjects were tested during the follicular phase of the menstrual cycle. The methods and procedures were approved by the Institutional Review Board of Springfield College.

Preliminary Testing

All testing took place in the Human Performance Laboratory at Springfield College. Participation in the study required three visits to the laboratory – an initial visit to determine $\dot{V}O_{2peak}$ via an incremental cycling protocol and two subsequent visits for the experimental CR sessions. The $\dot{V}O_{2peak}$ session was performed to assess aerobic fitness as well as to determine cycling intensity for the CR experimental conditions (~70% $\dot{V}O_{2peak}$). To ensure adequate recovery, a minimum of three days separated the $\dot{V}O_{2peak}$ sessions from the CR conditions.

The first session involved body composition assessment, height and weight measurement, and determination of aerobic fitness level ($\dot{V}O_{2peak}$). Body composition was estimated using a prediction equation previously validated for female athletes (Warner et al. 2004). Fat free mass was estimated using body mass

Table 1. Descriptive Statistics of Subjects.

Variable	Mean	*SD*
Age	34^{a}	8
VO_{2peak}	59.64^{b}	6.90
Maximal Aerobic Power	227^{c}	23
Body Fat	18^{d}	1
Weight	63.55^{e}	6.46
Height	1.64^{f}	0.07

^{a} Age = years, ^{b} VO_{2peak} = mL·kg^{-1}·min^{-1}, ^{c} Maximal Aerobic Power = Watts, ^{d} Body Fat = %, ^{e} Weight = kg, ^{f}Height = m and abdominal and thigh skinfolds measured with a Lange skinfold caliper (Beta Technology, Santa Cruz, CA). The participants were then given information about the procedures and familiarized with the equipment involved in the cycling $\dot{V}O_{2peak}$ test. Oxygen consumption ($\dot{V}O_2$), respiratory exchange ratio (RER), and $\dot{V}O_{2peak}$ were analyzed using a calibrated Physio-Dyne Max-II metabolic cart (AEI Technologies, Bastrop, TX) during a graded exercise test. The tests were performed on a Velotron cycle ergometer (RacerMate Inc., Seattle, WA). Personal cycling pedals were affixed to the cycling simulator if the subject desired. The protocol for the $\dot{V}O_{2peak}$ test began at 60W and increased by 35W every three minutes until exhaustion. Participants were instructed to keep their cadence between 75-85 RPM. Heart rate (HR) was monitored continuously and was recorded at the end of each incremental stage using a Polar Vantage XC HR monitor (Polar Electro Inc., Lake Success, NY). Rating of perceived exertion (RPE) was also assessed at the end of each incremental stage using the modified Borg 1-10 scale (Borg, 1982). The highest consecutive $\dot{V}O_2$ values in 1 min were averaged to determine $\dot{V}O_{2peak}$. The MAP was the average power in the final min of the graded exercise test.

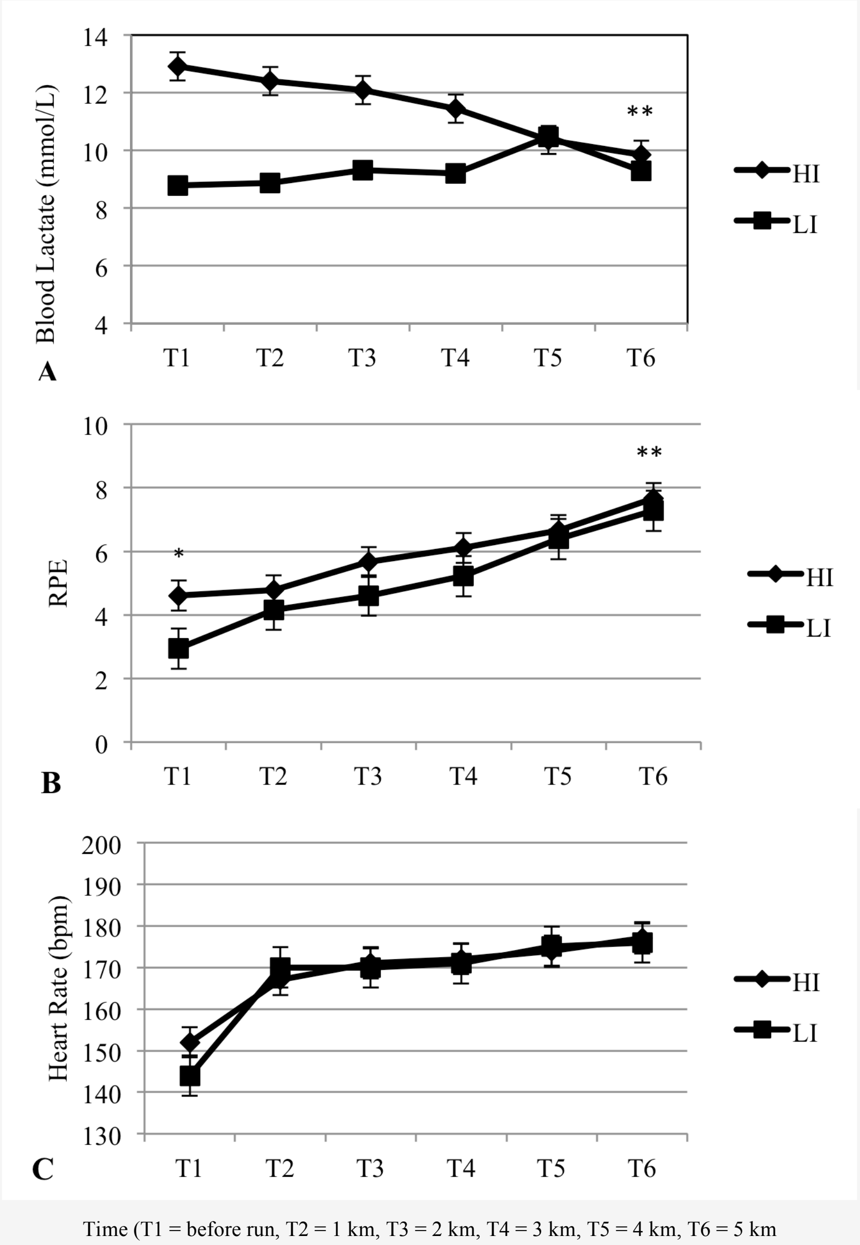

Figure 1. Trends for HR, RPE, and $[La^-]$ during 5 km run. HI = following high intensity cycle, LI = following low intensity cycle

*significantly different from LI at specific time period
**significant difference from LI throughout run bout

Cycle-run Sessions

Prior to the CR sessions, the participants were instructed to refrain from vigorous exercise for 24 hr before each bout and were told to abstain from alcohol and caffeine for 12 hr prior to testing. To control for variations in carbohydrate, protein, fat, and overall kilocalorie (kcal) intake, the participants kept a dietary record for three days prior to each CR test. The participants were told to maintain a similar diet prior to each performance and all dietary logs were analyzed to ensure compliance. All sessions were held at the same time of day and a minimum of one week separated each CR bout. The order of the CR sessions (HI or LI) was randomized.

The distances chosen for each discipline replicated the duration of a sprint triathlon – the cycle distance was 20 km and the run distance was 5 km. The participants completed the first 19 km of the cycle at an intensity corresponding to power achieved at 70% of $\dot{V}O_{2peak}$. This intensity was chosen because it corresponded to intensities used in previous cycle-run research studies (Garside & Doran 2000; Vercruyssen et al. 2002). The last 1 km of the cycle varied between tests. For the HI test, the last 1 km was completed at power corresponding to 95% of $\dot{V}O_{2peak}$ and for the LI test, the last 1 km of the cycle was completed at power corresponding to 50% of $\dot{V}O_{2peak}$. Participants were provided with an electrolyte beverage (Nuun and Company, Seattle, WA) which could be consumed ad libitum during the first CR bout. The amount consumed in the first CR bout was matched during the second trial. RPE was assessed at the end of 5, 10, 15, and 20 km. When the participants finished the cycling portion of the exercise bout, they were given 90 s to transition from the Velotron to the treadmill

(PulsarPnew-Track 28AX, Bethel, WA). The treadmill was started at a speed 30 s slower per mile than fastest self-reported triathlon 5 km run. The participants could then increase or decrease the speed as necessary but were told to complete the run as quickly as possible in each condition. Capillary blood was drawn from the fingertips of the participants and was immediately analyzed to determine [La^-] (Accutrend Lactate Analyzer, Roche Diagnostics, Basel, Switzerland). The blood samples were taken before the run (Time 1) and at the finish of each km while the participants continued running (Time 2-6). HR and RPE were also recorded Time 1-6.

Statistical analyses

A 2 X 6 repeated measures analysis of variance (ANOVA) was used to assess the effect of intensity (HI or LI) and time on [La^-], RPE, and HR during the run following the cycling bout. Statistical significance was set at $\alpha = .05$. If a significant interaction was detected, post hoc testing was done using the Bonferroni adjustment at $\alpha = 0.008$. Paired t-tests using the Bonferroni adjustment were used to assess dietary logs as well as the differences between HI and LI cycling bouts in 5 km run time, overall CR time, and RPE and HR immediately following the final 1 km of cycling ($\alpha = 0.006$). All statistical analyses were performed on SPSS software (IBM SPSS Statistics, version 21).

Results

No significant differences were found for overall fat, carbohydrate, and protein content as well as total kcals ($p > 0.006$). Thus, it was assumed dietary intake was similar in the three days preceding each CR test.

[La^-], RPE, HR

Paired t-tests with a Bonferroni adjustment revealed significant differences in both RPE and HR immediately following the final 1 km of the cycling bout. RPE was 9.3 ± .97 following the HI cycling bout and 4.8 ± 2.1 following the LI cycling bout (t (8) = 5.3, $p < 0.006$). Similarly, HR was higher post HI cycling (175.7 ± 12.9 bpm) versus LI cycling (156.6 ±12.2 bpm) (t (8) = 6.7, $p < 0.006$).

Figure 1A-C shows the trends for [La^-], RPE, and HR during the 5 km run. A significant main effect was found in blood lactate concentration between LI and HI conditions during the run [F (1, 8) = 15.61; $p < 0.05$]. Blood lactate concentration was significantly higher following the cycling bout ending with a high intensity (HI cycle: 11.5 ± 0.64 mmol/L, LI cycle: 9.3 ± 0.72 mmol/L, mean difference = 2.18 mmol/L, Figure 1A). A significant interaction was found between cycle intensity and time for RPE [F (5, 40) = 2.52; $p < 0.05$]. Pairwise comparisons revealed that RPE values were significantly higher during the run following the HI cycle for T1 only (HI cycle: 4.6 ± .74, LI cycle: 2.9 ± .65, $p < 0.008$, Figure 1B). No significant interaction or main effects for time or intensity were found in heart rate (HI: 168.9 ± 3.4 vs LI: 167.6 ± 2.6 bpm, Figure 1C) ($p > 0.05$).

Run and Cycle-run Performances

Paired t-tests with a Bonferroni adjustment were completed to examine the difference in 5 km run time and overall CR time. No significant differences existed between the two running bouts (HI cycle 24:54 ± 2:53 min, LI cycle 24:36 ± 3:17 min, mean difference = 00:00:17 sec). Also, no significant differences were found between the two overall CR sessions (HI cycle 01:23:23 hr ± 00:05:47 min, LI cycle 01:23:50 hr ± 00:07:01 min, mean difference = 00:00:27 sec) ($p > 0.006$).

Discussion

The purpose of the current research was to determine if low versus high intensity cycling during the final 1 km of a 20 km cycling bout has an impact on subsequent 5 km run performance as well as overall cycle-run performance. A secondary aim of the study was to examine how manipulations in cycling power affect cycle-run performance in female triathletes exclusively. Coaches, physiologists, and athletes commonly advocate a cycle-run strategy in which triathletes reduce cycling intensity prior to the run to maximize run performance (Bernard et al. 2003; Suriano et al. 2007). The strategy is meant to aid in recovery of the lower limbs, but comes at a cost – reduced power can equal slower overall completion time (Suriano & Bishop 2010). The main finding of the current study was that, despite the popular advice, there were no significant differences between run performances following a cycling bout ending at a low or a high intensity in trained female triathletes. In addition, no differences were found between overall CR performances between the two protocols. It is important to note that although no significant differences were found between cycling protocols for CR performance, mean CR performance was 27 s faster during the HI protocol. Such a difference may be meaningful to an athlete's race position finish in an actual competition and could be the difference between a podium finish or a win. Indeed, in the 2013 USA Triathlon (USAT) Age Group National Sprint Competition, 23 s separated the first and second place female finishers.

Blood lactate concentration and RPE were significantly different between CR sessions – higher [La^-] and RPE values were found during the run following the HI versus the LI cycling bout. Such values would indicate the potential for a decrease in performance after the HI bout as the accumulation of lactic acid contributes to muscular acidosis (Billat et al. 2003). When muscular acidosis occurs, the lower pH can impact performance by reducing muscle contractility and limiting glycolysis and adenosine triphosphate (ATP) resynthesis (Hill et al. 2001; Hollidge-Horvat et al. 1999). In addition, during self-paced exercise, increases in RPE often coincide with decreases in power output (Tucker 2009). In the current study though, run performance did not differ significantly between HI and LI despite the difference in [La^-] and RPE values. Maldonado-Martin et al. (2004) reported that while female runners have lower absolute $\dot{V}O_{2max}$ values, females run at a higher percentage of $\dot{V}O_{2max}$ than males. Specifically, at velocity at OBLA (vOBLA), velocity at lactate threshold (vLT), and at submaximal running speeds, females ran at a higher $\%\dot{V}O_{2max}$ than males. It was speculated that the power output of female runners was less impacted by steady state [La$^-$] which led them to maintain run performance. In the current study, the female triathletes may have responded similarly and thus were not significantly affected by the difference in [La$^-$] during the run performance. This is in contrast to what has been found in male subjects' performances in previous research (Etxebarria et al. 2013; Suriano et al. 2007). Etxebarria et al. (2013) examined the difference between variable (VAR, 40-140% MAP) and constant (CON, 65% MAP) cycling power variations on run performance in male triathletes. Blood lactate concentration and RPE were both higher at the end of the VAR ride and subsequent run performance was significantly slower. It was proposed that the decrement in run performance occurred due to the higher [La$^-$] and corresponding higher RPE values. Similarly, Suriano et al. (2007) examined the effect of a decrease in cycling power on run performance in male triathletes. Run time to exhaustion was improved when power was decreased in the last 5 min of a preceding cycling bout. The decreased cycling power output was associated with lower [La$^-$] which may have been one of the mechanisms related to better run performance. The fact that the run performances of the female athletes in the current study were not as significantly slowed as male athletes' performances in similar studies may mean that females respond differently under conditions of high steady state [La$^-$]. Future research should examine the gender differences in speed and power maintenance during high steady state [La$^-$] endurance performance.

Although there are aspects of lactate accumulation and the concurrent H^+ accumulation that can negatively affect exercise performance, there are certain positive aspects as well. For instance, lactate serves as a metabolic intermediate – the molecule is a substrate for oxidative metabolism in cardiac and skeletal muscle and is an important precursor for gluconeogenesis during prolonged aerobic exercise (Brooks 2000; Hashimoto & Brooks 2008). According to Brooks and Mercier (1994), carbohydrate based energy sources including glucose, glycogen, and lactate are the main fuel for exercise at moderate to high intensities. In the current study, the usefulness of lactate as a substrate to fuel exercise may well have outweighed the negative aspects of the accompanying H^+, thereby overcoming any performance decrements caused by muscular acidosis.

The fitness level of the participants is an important consideration when evaluating why the increased [La$^-$] following the HI cycle did not impede run performance. Endurance trained individuals have an enhanced ability to clear lactate and to maintain blood glucose levels via gluconeogenesis of lactate (Messonnier et al. 2013; Stallknecht et al. 1998). Of the nine participants in the current study, four were USA Age Group National qualifiers and two were World Championship qualifiers in triathlon. In addition, the mean $\dot{V}O_{2peak}$ of the participants (59.6 $mL \cdot kg^{-1} \cdot min^{-1}$ ± 6.9 $mL \cdot kg^{-1} \cdot min^{-1}$) indicated a high level of aerobic fitness. The highly trained participants in the current study may also have an increased capacity for gluconeogenesis and lactate clearance which may have offset any negative consequences of the high [La$^-$] during the run following the HI cycle.

The duration of the HI or LI portions of the cycling bouts (1 km) may also explain why no decrement was seen in run performance. While the HI effort was sufficient to elicit a significantly higher [La$^-$] during the run, the duration of the intensity may not have been long enough to elicit other mechanisms related to fatigue which could have impacted performance. Bernard et al. (2007) examined the effect of constant versus variable intensity during cycling on running performance. The participants participated in three different cycle-run combinations – a freely chosen intensity (FCI), a constant intensity (CI), and a variable intensity (VI) cycle followed by a 5 km run performance. The effort of the CI cycle corresponded to the mean power of the FCI cycle. The effort of the variable intensity ranged from 68-92% of maximal aerobic power (MAP). The last 3 km of the VI were performed at a high intensity (~92% MAP) specifically to test the conventional wisdom that holds that decreasing intensity coming into the transition is the more prudent cycle-run tactic. Run times following the VI ride were slower than run times following the CI and FCI rides. The decrement in run performance may have been related to neuromuscular factors; greater recruitment of the lower extremity muscles throughout the VI ride may have resulted in increased muscular fatigue during the run. While the HI cycle portion of the current study was similar in effort to the end of the VI ride, the duration was shorter – 1 km versus 3 km. It may be that the shorter duration of HI cycling in the current study was not long enough to elicit neuromuscular decrements which may have impacted run performance.

The fact that run performance was not significantly different between HI and LI in the current study may lead some to assume athletes should use either tactic in the approach to cycle-run transition. However, overall cycle-run performance must be considered to better understand how either approach affects triathlon performance as a whole. In an effort to determine the cycling intensity at which peak cycle-run and run performance can be achieved, Suriano and Bishop (2010) investigated the effect of four different cycling intensities on cycle-run and run performance: 81-85%, 86-90%, 91-95%, or 96-100% of cycling time trial (CTT). Although run performance was slowest following the highest intensity cycle (96-100% CTT), the effort yielded the best overall cycle-run performance. As Suriano and Bishop (2010) demonstrated, run performance following cycling is an important predictor of triathlon success, but the overall cycle-run bout must also be considered when evaluating the best tactics to maximize performance. In the current study, the difference in CR times between HI and LI did not reach statistical significance, but the difference may be practically significant to an athlete. Overall CR time was 27 s faster during the HI protocol. In actual competition, that amount of time may very well mean the difference between a medal or not.

Practical applications

The main finding of the current study was that run performance of highly trained female triathletes is not altered following a cycling bout ending at a low or high intensity despite significant differences in [La$^-$] and RPE during the run. As well, overall CR times were faster when the HI protocol was implemented. From a practical perspective, this may mean these athletes can maintain or even increase their power at the end of a cycling stage – a strategy that could improve race position and possibly improve overall cycle-run performance. It is important to note the female subjects in the current study did not respond similarly to male subjects in previous cycle-run studies with varying methodology. Given the physiological differences between males and females including variations in absolute power output and in % $\dot{V}O_{2max}$ at race pace in endurance events, future research should continue to examine how manipulations in cycling power affect run and cycle-run performance in female triathletes specifically.

Acknowledgment

The authors would like to thank Vincent Paolone, Tracey Matthews, and Brian Thompson for their support with this project. We would also like to thank the triathletes who gave their time and effort to participate in this study.

References

1. Bentley D, Libicz S, Jougla A, Coste O, Manetta J, Chamari K, Millet G (2007) The effects of exercise intensity or drafting during swimming on subsequent cycling performance in triathletes. Journal of Science and Medicine in Sport. doi: 10.1016/j.jsams.2006.05.004
2. Bentley DJ, Millet GP, Vleck VE, McNaughton LR (2002) Specific aspects of contemporary triathlon: Implications for physiological analysis and performance. Sports Medicine 32 (6): 345-359.
3. Bernard T, Vercruyssen F, Grego F, Hausswirth C, Lepers R, Vallier JM, Brisswalter J (2003) Effect of cycling cadence on subsequent 3 km running performance in well trained triathletes. British Journal of Sports Medicine. doi:10.1136/bjsm.37.2.154
4. Bernard T, Vercruyssen F, Mazure C, Gorce P, Hausswirth C, Brisswalter J (2007) Constant versus variable intensity during cycling: Effects on subsequent running performance. European Journal of Applied Physiology 99: 103-111.
5. Bernard T, Hausswirth C, Le Meur Y, Bignet F, Dorel S, Brisswalter J (2009) Distribution of power output during the cycling stage of a triathlon World Cup. Medicine and Science in Sports & Exercise. doi: 10.1249/MSS.0b013e318195a233
6. Billat VL, Sirvent P, Py G, Koralsztein J, Mercier J (2003) The concept of maximal lactate steady state: A bridge between biochemistry, physiology, and sport science. Sports Medicine 33 (6): 407-426.
7. Bonacci J, Saunders PU, Alexander M, Blanch P, Vicenzino B (2011) Neuromuscular control and running economy is preserved in elite international triathletes after cycling. Sports Biomechanics. doi: 10.1080/14763141.2010.547593
8. Borg GV (1982) Psychophysical bases of perceived exertion. Medicine and Science in Sports and Exercise 14 (5): 377-381.
9. Brooks GA, Mercier J (1994) Balance of carbohydrate and lipid utilization during exercise: the “crossover” concept. Journal of Applied Physiology 76 (6): 2253-2261.
10. Brooks GA (2000) Intra and extra cellular lactate shuttles. Medicine and Science in Sports and Exercise 32 (4): 790-799.
11. Etxebarria N, Anson JM, Pyne DB, Ferguson RA (2013) Cycling attributes that enhance running performance after the cycle section in triathlon. International Journal of Spots Physiology and Performance 8 (5): 502-509.
12. Garside I, Doran DA (2000) Effects of bicycle frame ergonomics on triathlon 10 km running performance. Journal of Sports Science 18 (10): 825-833.
13. Hashimoto T, Brooks GA (2008) Mitochondrial lactate oxidation complex and an adaptive role for lactate production. Medicine and Science in Sports and Exercise. doi: 10.1249/MSS.0b013e31815fcb04
14. Hausswirth C, Brisswalter J (2008) Strategies for improving performance in long duration events: Olympic distance triathlon. Sports Medicine. doi: 10.2165/00007256-200838110-00001
15. Hill CA, Thompson MW, Ruell PA, Thom JM, White MJ (2001) Sarcoplasmic reticulum function and muscle contractile character following fatiguing exercise in humans. The Journal of Physiology. doi: 10.1111/j.1469-7793.2001.0871h.x
16. Hollidge-Horvat MG, Parolin ML, Wong D, Jones NL, Heigenhauser GJ (1999) Effect of induced metabolic acidosis on human skeletal muscle metabolism during exercise. American Journal of Physiology 277 (4): E647-658.
17. Hopker J, Jobson S, Carter H, Passfield L (2010) Cycling efficiency in trained male and female competitive cyclists. Journal of Sports Science and Medicine 9: 332-337.
18. Jensen RL, Ewers BJ, Cunniffe B, Phelan B, Harrison AJ, Shafat A (2008) Impact of seated and standing bicycle riding position on subsequent running performance. International Journal of Exercise Science 1 (4): 177-187.
19. Lepers R, Knechtle B, Stapley PJ (2013) Trends in triathlon performance: Effects of sex and age. Sports Medicine. doi: 10.1007/s40279-013-0067-4
20. Lim AC, Peterman JE, Turner BM, Livingston LR, Byrnes WC (2011) Comparison of male and female road cyclists under identical stage race conditions. Medicine and Science in Sports & Exericse. doi: 10.1249/MSS.0b013e3181fcea8d
21. Maldonado-Martin S, Mujika I, Padilla S (2004) Physiological variables to use in the gender comparison in highly trained runners. Journal of Sports Medicine and Physical Fitness 44 (1): 8-14.
22. Messonnier LA, Emhoff CW, Fattor JA, Horning MA, Carlson TJ, Brooks GA (2013) Lactate kinetics at the lactate threshold in trained and untrained men. Journal of Applied Physiology. doi: 10.1152/japplphysiol.00043.2013
23. Millet GP, Vleck VE (2000) Physiological and biomechanical adaptations to the cycle to run transition in Olympic triathlon: Review and practical recommendations for training. British Journal of Sports Medicine. doi: 10.1136/bjsm.34.5.384
24. Peeling P, Landers G (2009) Swimming intensity during triathlon: A review of current research and strategies to enhance race performance. Journal of Sports Sciences. doi: 10.1080/02640410903081878
25. Sleivert GC, Rowlands DS (1996) Physical and physiological factors associated with success in the triathlon. Sports Medicine 1: 8-18.
26. Stallknecht B, Vissing J, Galbo H (1998) Lactate production and clearance in exercise. Effects of training. A mini review. Scandinavian Journal of Medicine and Science in Sports 8: 127-131.
27. Suriano R, Vercruyssen F, Bishop D, Brisswalter J (2007) Variable power output during cycling improves subsequent treadmill run time to exhaustion. Journal of Science and Medicine in Sport. doi: 10.1016/j.jsams.2006.06.019

28. Suriano R, Bishop D (2010) Combined cycle and run performance is maximised when the cycle is completed at the highest sustainable intensity. European Journal of Applied Physiology. doi: 10.1007/s00421-010-1547-y
29. Tucker R (2009) The anticipatory regulation of performance: the physiological basis for pacing strategies and the development of a perception-based model for exercise performance. British Journal of Sports Medicine. doi: 10.1136/bjsm.2008.050799
30. Vercruyssen F, Suriano R, Bishop D, Hausswirth C, Brisswalter J (2005) Cadence selection affects metabolic responses during cycling and subsequent running time to fatigue. British Journal of Sports Medicine. doi:10.1136/bjsm.2004.011668
31. Warner ER, Fornetti WC, Jallo JJ, Pivarnik JM (2004) A skinfold model to predict fat-free mass in female athletes. Journal of Athletic Training 39 (3): 259-262.