The effects of three varied cycle leg protocols on self-paced run time trial performance.

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In the past, the cycling portion of an Olympic Distance Triathlon (ODT) was typically performed at steady state power outputs. However, with the advent of drafting and the inclusion of smaller spectator friendly bike courses, the demands of the cycle leg have changed. The purpose of this research was to investigate the effect of three varied cycle leg protocols on self-paced run time trial performance. Subjects (n=4) completed an initial phase of testing to determine baseline information. A 7.5 km run time trial on the treadmill (RTT) was followed by progressive maximal run (RT) and cycle tests (CT) 72 hours later. The best run performance was established using the RTT, whilst the individual anaerobic threshold (IAT), maximal power and VO$_{2max}$ was recorded from the maximal tests. The subjects then completed three cycle leg protocols each of 45 minutes in duration, followed immediately by another 7.5km run time trial, with a minimum of 72 hours recovery between testing protocols. This bike-run combination is referred to as a BRICK. The three protocols were conducted in a randomised counter-balanced manner and included: a simulated draft time trial (BRICK^{DRT}), a self paced steady state time trial (BRICK^{ITT}) and a variable power output time trial (BRICK^{ITU}). Compared to the control RTT, the results demonstrated for all BRICK running protocols significantly lower ($p<0.005$) mid and end oxygen consumption (VO$_2$) values, BRICK^{ITT} (3.61 ± .15**,** 3.73 ± .24), BRICK^{DRT} (3.67 ± .24, 3.70 ± .24) and BRICK^{ITU} (3.54 ± .22, 3.66 ± .15) v's RT (3.90 ± .39, 3.95 ± .28). No significant differences were recorded between the RTT and the BRICK protocols for the measures of heart rate (HR), bicarbonate ion concentration (HCO3), lactate (HLa), pH, perceived exertion (RPE) and 7.5km run times. This research demonstrated a decrease in VO$_2$ during the run leg of all BRICK protocols and indicated limitations in run pacing and velocity of competitive triathletes.

Of significant importance to coaches in the development of effective training programmes, is an understanding of the primary physiological and psychological characteristics that contribute to successful sporting performance (Craig *et al*., 1993). With respect to physiological characteristics, coaches and sports scientists commonly seek an understanding of the various metabolic components and their respective contributions to success in that sport or event.

The Olympic Distance Triathlon (ODT) involves swimming (1.5 km), cycling (40 km), running (10 km) and transition skills. In the past, the cycling portion of the ODT was typically performed at steady state power outputs. However, with the advent of draft legal events and the inclusion of smaller spectator friendly bike courses, the demands of the cycle leg have changed.

Recent data suggests that power output and the energy systems utilised during draft legal and tight street circuits are vastly different to the steady state time trial (Smith *et al*., 1997; Hausswirth *et al*., 1999). Hence, the effects of these changes on subsequent run performance are still not fully understood.

The cycle leg, represents the largest proportion of the total race duration of the ODT (>50%). With regard to draft legal events, anecdotally the effect appears to have reduced the importance of the cycle leg in the outcome. The draft legal ODT has been described as a 'wet run,' de-emphasising the place of the cycle leg. The inclusion of tight street circuits has also changed the nature of the conventional cycle leg. Recent data collected from the International Triathlon Union race over the proposed Sydney 2000 Olympic course, reveals large variations in power output, more in line with criterium massed start cycle events (Smith et al. 1997).

In contrast, the traditional 40 km individual time trial (ITT) event requires a steady state power output. Power at anaerobic threshold (AT) and maximum power, obtained from an incremental cycle test, are positively correlated to 40 km ITT time (Coyle *et al*., 1991; Hawley and Noakes, 1997).

The effect of drafting on cycling performance has been assessed by Palmer *et al*., (1997). They compared the time to ride a 20 km ITT following a 150 minute ride which was either at a constant load (58% of peak power output), representing a draft ride, or a variable power output ride (mean power of 58% of peak power varying by ± 12%). Despite similar total work and heart rates, the 20 km ITT time following the steady state draft ride was significantly faster than the variable power output protocol. In a study on the effect of drafting during a triathlon bike leg, Hausswirth *et al*. (1999) reported a rise in cadence by approximately 6.3%, a 47% decrease in blood lactate response (BLC) and a reduction in VO_2 of 14%. This effect is not surprising given the reduction in energy expenditure of 26% when behind a single rider and up to 39 % sitting in a group of riders (McCole *et al*., 1990). According to Hausswirth *et al*. (1999) the effect of the draft bike leg improved 5 km running speed compared with the no draft mode (17.8 vs 17.1 $km \cdot hr^{-1}$) and furthermore, increased the physiological values of VO_2, HR and BLC during the draft run leg.

The decision towards a 'draft-legal' and criterium styled cycle leg has placed a greater importance upon the assessment of the triathlete's physiological and psychological responses towards running. It appears that a draft cycle leg may provide for a psychological readiness and reduced physiological fatigue which may allow the triathlete to run at a higher intensity in comparison to that which can be attained after a variable power output cycle leg. This is an important consideration given that it has already been well established that the running portion of the ODT is the most difficult of the three segments to complete.

Given the support that a non draft cycle triathlon is more demanding than a draft triathlon, the principal purpose of this study was to investigate the effects of differing cycle leg protocols (variable power output, steady state ITT and simulated draft cycle protocols) on self-paced treadmill run time trial performance.

Methods

Subjects

Four (n=4) male triathletes (ODT = 2hrs) participated in this research study (See Table 1). Each triathlete completed a pre-test medical questionnaire and signed an informed consent statement. Testing was conducted just prior to the commencement of the triathlon season. All subjects had been engaged in at least eight weeks of training in all three disciplines of the triathlon when assessed as a part of this study.

Experiment Design

All subjects took part in five testing sessions at the Human Performance Laboratory of the Tasmanian Institute of Sport. The test sessions were completed over a 14 day period. Subjects were asked to refrain from training for 48 hours leading into the testing sessions.

All subjects completed an isolated self-paced 7.5 km run time trial test (RTT) on day one. Seventy two hours later the subjects completed progressive maximal bike and run tests with 4 hours separating the tests. The subjects then completed three bike/run tests (BRICK TEST) in a random counter balanced manner. Each BRICK test consisted of a cycle leg protocol lasting 45 minutes immediately followed by a 7.5 km self-paced run time trial. A minimum of 72 hours recovery was given between testing protocols. The three cycle protocols were:

- a simulated draft time trial (TT^{DRT});
- a self paced individual time trial (TT^{ITT});
- a variable power output bike time trial (TT^{ITU}).

Progressive maximal cycling test (CT)

The CT was conducted on a Lode Excalibur Sport (v 1.5; Groningen, Netherlands) cycle ergometer which interfaced with a Lode BV Work Load Programmer (WLP). Subjects warmed up on the ergometer for 10 min at a power output of 75 Watts (W). The progressive VO_2max and lactate test consisted of 5 min stages commencing at 100W and increased 50W until volitional exhaustion (cadence < 80 revolutions.min^{-1}). All subjects performed the test at a cadence between 85-95 revolutions.min^{-1}. Maximum power output was determined by using the formula:

$$P@VO_{2Max} = P_p + (t_f \text{ x } (V_f - V_p / 5 \text{ min})$$

where P_p is the power output of previous stage, V_f is the power output of the final stage and t_f is the time (in min) at final power.

Expired gas was collected continuously during the CT and analysed with a Quinton Metabolic Cart (QMC: Quinton ® Instruments Co, Seattle, U.S.A).

At the completion of each 5 min interval, a blood sample was taken from the finger to determine blood lactate, pH and bicarbonate ion concentration. Lactate analysis was conducted using a Yellow Springs Instruments (YSI, Ohio, U.S.A.) 1500L Lactate Analyser and pH and bicarbonate ion concentration was assessed using a AVL Omni (Graz, Austria) blood gas analyser.

Heart rate (beats.min^{-1}) was recorded by telemetry (Polar Advantage NV, Polar, Finland) during the last 15 seconds of each 5 min interval, and the maximum heart rate reached by each subject was recorded.

Following completion of the test, all subjects completed a 10 min warm down at 50-75W. Data attained during this test is represented in Table 1.

Progressive maximal run test (RT)
The RT was conducted on a calibrated Quinton treadmill (Model Q-65: Quinton ® Instruments Co, Seattle, U.S.A). Subjects warmed up on the treadmill for 10 min at a speed between 8-10 km.hr $^{-1}$. The RT consisted of 4 min stages commencing at 10km.hr^{-1} and increasing 2km.hr^{-1} until 18km.hr^{-1}, thereafter the velocity increased 1km$\cdot$hr^{-1} each minute until volitional exhaustion. Velocity at VO_{2max} (V@VO_{2max}) and oxygen consumption variables: VO_2 (mL.kg^{-1}.min^{-1}), ventilation (L.min^{-1}) and respiratory exchange ratio (RER) were recorded. VO_{2max}, maximal ventilation and RER were determined as the average of the highest two consecutive values obtained during the last increment.

At the end of each 4 min interval, the treadmill was stopped for 1 min and a blood sample was collected from the finger in a heparinsied capillary tube to determine blood lactate, pH and bicarbonate ion concentration. Heart rate was recorded during the last 15 s of each 4 min interval during the incremental test and maximum heart rate was also recorded.

Velocity, VO_2, heart rate, blood lactate, pH, and bicarbonate concentrations at AT was determined using the log-log transformation method (Beaver *et al*., 1985) from the progressive maximum test.

Run Time Trial Testing (RTT)
The RTT was conducted on a single day, with the same treadmill, gas and blood analysis equipment described above. The subjects completed a ten min warm up at 10km$\cdot$hr^{-1}. They then selected a starting velocity (10-14km$\cdot$hr^{-1}) and proceeded to cover 7.5km as quickly as possible, being permitted to self-select velocity at the completion of every minute. VO_2 was recorded between 1-3 (start), 14-17 (mid) and 24-27 (end) min of RTT. At the 10 and 20 min blood samples were taken from the finger, whilst the subject continued to run and analysed for blood lactate, pH and bicarbonate ion concentration. The same procedure was repeated immediately at the completion of RTT. Heart rate was recorded continuously throughout RTT. RPE was recorded at each 5 minute period during the RTT and at the end of the trial. The changes in run velocity were recorded throughout RTT. The same procedure and distance of RTT was employed for the run portions of all BRICK protocols.

BRICK Testing
The BRICK protocols were conducted using the same cycle ergometer and treadmill equipment described above. Every 8 min during the 45 min cycle test a blood sample was taken from the finger and analysed for blood lactate, pH and bicarbonate ion concentration. RPE was also recorded at this time. Heart rate was monitored continuously for the 45 min protocol.

At the completion of the cycle protocol the subjects changed into running shoes and commenced the self-paced run time trial as outlined in RTT.

BRICK Protocols

BRICK$^{\text{DRT}}$ (TT$^{\text{DRT}}$ + run) consisted of a series of intermittent sprints combined with a draft simulated effort. The sprints involved 2 sets of 24 efforts with each sprint lasting 10 s and ranging in intensity from 80 –183 % peak power. The sets were separated by a 20 min draft simulated effort of variable power (mean 67 ± 10% peak power). BRICK$^{\text{ITU}}$ (TT$^{\text{ITU}}$ + run) required the subjects to repeat intermittent 10 s sprints (80 – 183 % peak power) and recover (150 watts) in a stochastic manner with open cadence. The subjects then completed 3 sets of 30 sprints continuously for 45 min. Sprints were randomised and the sprint power had to be reached and held to be valid. BRICK$^{\text{ITT}}$ (TT$^{\text{ITT}}$ + run) required the subject to maintain the highest power output for 45 min. The linear factor for the Lode Excalibur cycle ergometer was calculated based on a cadence of 90 rpm and factored by the subject's power at individual anaerobic threshold as determined by Beaver *et al*., 1985.

LF X = IAT watts/90 rpm/90rpm

Where: IAT = Individual anaerobic threshold (W)
X = linear factor for each individual

All values are reported as mean ± standard deviation and significance was set at p = 0.05.

Results

Table 1 outlines the descriptive statistics for the subjects. The mean ± SD for lactate, heart rate and VO_2 can be found in Table 2 for each of the BRICK cycle protocols. Table 3 outlines the mean time taken to complete the 7.5 km time trial following each cycle protocol and RTT.

Maximal physiological measures and significance of ANOVA between the RTT and BRICK$^{\text{DRT}}$, BRICK$^{\text{ITU}}$ and BRICK$^{\text{ITT}}$ are presented in Table 4. No significant differences were found between RTT and BRICK$^{\text{DRT, ITU}}$ or $^{\text{ITT}}$ for run time, mean run velocity, blood lactate, bicarbonate ion concentration, perceived exertion and average heart rate. Significant differences were observed for mid (p = .0102) and end (p = .0024) oxygen consumption (VO_2) values between BRICK$^{\text{DRT, ITU, ITT}}$ and RTT. Similarly, significant differences were recorded for % VO_{2max} for mid (p = .0083) and end (p = .0015) between BRICK$^{\text{DRT, ITU, ITT}}$ and RTT.

Table 1. Subject characteristics

Test Parameters	Mean	SD ±
Mass (kg)	69.6	8.8
Height (cm)	178.9	5.7
Maximum Power (watts)	365	32.4
V @VO_{2max} ($km \cdot hr^{-1}$)	19.5	0.40
Bike VO_{2max} ($L \cdot min^{-1}$)	4.42	0.26
Run VO_{2max} ($L \cdot min^{-1}$)	4.60	0.46

Table 2. Bike Brick Summary

Brick	Parameter	Mean	SD ±
ITT	Lactate ($mmol \cdot l^{-1}$)	3.9	.09
DRT		3.3	.86
ITU		4.4	.58
ITT	Heart rate($b \cdot min^{-1}$)	160	6
DRT		147	4
ITU		150	9
ITT	VO_2 ($L \cdot min^{-1}$)	3.603	.213
DRT		3.145	.064
ITU		3.349	0.38

Table 3: Mean times for 7.5 km run time trial

Run Protocol	Mean Time (min)	SD
RTT	28.34	1.52
$BRICK^{ITT}$	28.41	1.34
$BRICK^{DRT}$	28.43	1.41
$BRICK^{ITU}$	28.42	1.16

Table 4: Comparisons between physiological variables for each run time trial

	VO2 ($L.min^{-1}$)			**Lactate ($mmol.L^{-1}$)**			**pH**			**Bicarbonate ion ($mmol.L^{-1}$)**			**Heart Rate ($beats.min^{-1}$)**			**RPE**	
	Start	**Mid**	**End**	**Start**	**Mid**	**End**	**Start**	**Mid**	**End**	**Start**	**Mid**	**End**	**Start**	**Mid**	**End**	**Start**	**Mid**
RTT	3.37 (0.32)	**3.91** **(3.39)**	**3.99** **(0.28)**	4.3 (0.9)	4.4 (1.7)	5.3 (3.1)	7.396 (0.022)	7.387 (0.056)	7.373 (0.063)	20.8 (2.7)	20.3 (2.8)	18.7 (3.6)	167 (5)	176 (5)	180 (6)	14 (1)	16 (1)
BRICK^{ITT}	3.33 (0.17)	**3.62** **(0.16)**	**3.74** **(0.24)**	4.5 (0.7)	4.6 (1.2)	5.1 (1.3)	7.397 (0.030)	7.404 (0.033)	7.392 (0.032)	20.3 (1.4)	20.4 (1.4)	19.4 (1.9)	167 (3)	174 (6)	179 (3)	15 (1)	16 (1)
BRICK^{DRT}	3.24 (0.08)	**3.68** **(0.25)**	**3.70** **(0.23)**	4.4 (2)	4.9 (2.4)	5.7 (2.7)	7.398 (0.016)	7.393 (0.039)	7.382 (0.055)	20.3 (2.4)	19.4 (2.9)	18.3 (3.0)	168 (7)	175 (5)	178 (5)	15 (2)	17 (2)
BRICK^{ITU}	3.19 (0.26)	**3.55** **(0.30)**	**3.67** **(0.16)**	4.1 (1.6)	4.2 (1.9)	5.7 (2.4)	7.394 (0.026)	7.393 (0.034)	7.363 (0.047)	21.0 (2.2)	20.2 (2.0)	18.6 (2.6)	167 (8)	173 (6)	179 (7)	16 (1)	17 (1)

Bold values represent significant differences ($p = 0.05$)

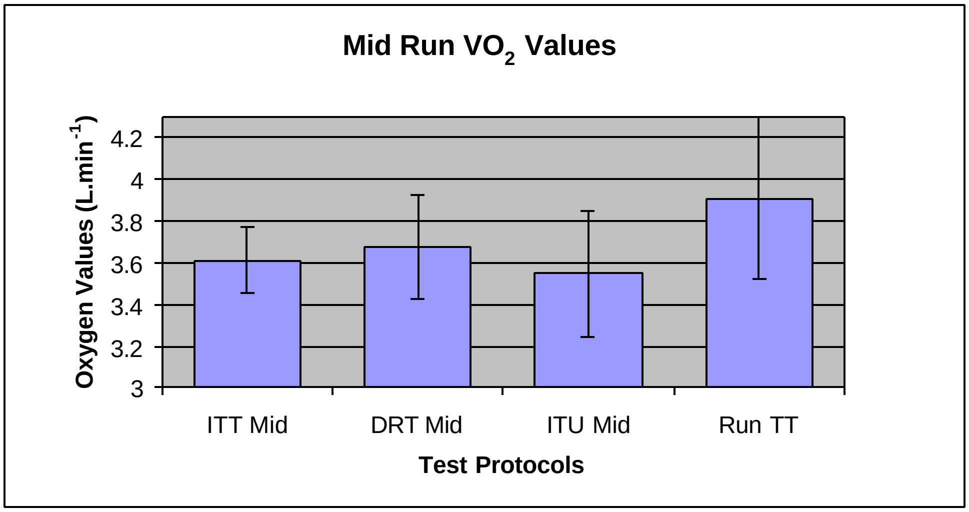

Figure 1: Mid run mean and SD for VO_2 values for all BRICK protocols and RTT.

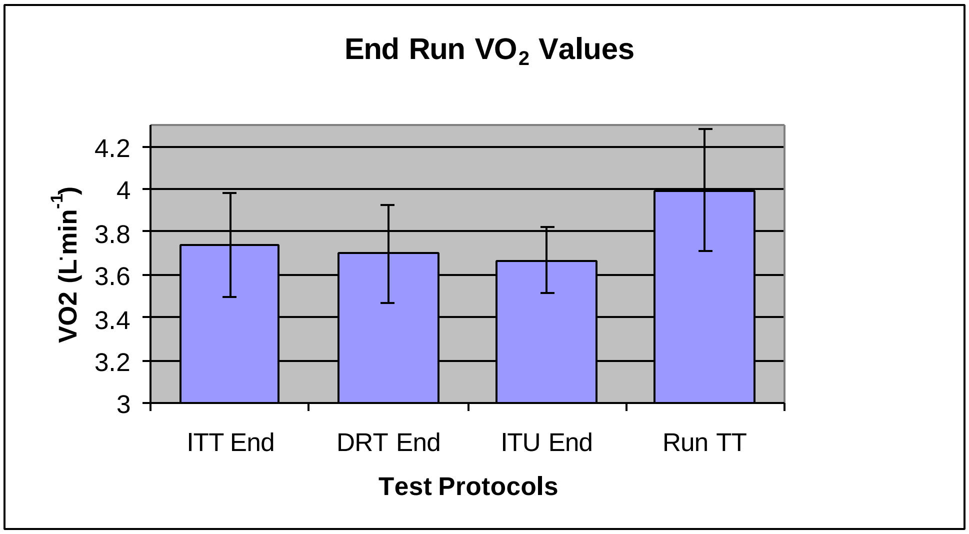

Figure 2: End run mean and SD for VO_2 values for all BRICK protocols and RTT.

Discussion

The principle finding of this research was the reduction in VO_2 during the run portion of all three BRICK protocols. De Vito *et al*. (1994) conducted an isolated incremental run test and one week later another incremental run test following a 1.5 km swim and 40 km cycle leg and found a 12% and 7.2% decrease in VO_2 at AT and VO_{2max}, respectively. This would equate to the same VO_{2max} being achieved at a lower velocity due to the physiological responses characterising decreased running economy. De Vito *et al*. (1994) made the assumption that a reduction in economy would result in a reduced run performance; however, this was not tested directly. In the present study a reduction of 6.2 % in mid and end VO_2 values was found, without any differences between all BRICK run and RTT 7.5km time. Thus, despite reductions in VO_2 during the BRICK run, performance time and average velocity did not decrease. This suggests a transitory improvement in economy.

Studies conducted by Kreider *et al*. (1988), Hue *et al*. (1998) and Guezennec *et al*. (1996) analysed triathlon pace over a 10 km run distance and in addition investigated changes in oxygen consumption where they found a mean increase of 0.44 L.min^{-1} (6.0 mL.kg^{-1}.min^{-1}), 0.24 L.min^{-1} (3.4 mL.kg^{-1}.min^{-1}) and 0.25 L.min^{-1} (3.5 mL.kg^{-1}.min^{-1}), respectively. The increase in VO_2 may be explained by changes in running mechanics whereby there is a decrease in stride length and increase in stride rate possibly resulting in greater energy expenditure (Hue *et al*. 1998).

It is thought that fatigue processes may cause decreases in VO_2 during the run portion. Hausswirth *et al*. (1999) conducted a study on the effect of a draft legal cycle leg on physiological and performance parameters using elite male triathletes. It was found that VO_2 was higher and run velocity greater (17.1 v's 17.8 km.hr-1) during the run leg, following the draft legal triathlon (Hausswirth *et al*., 1999). This indicates that the athletes were more fatigued during the run after riding the non-draft format and thus were not able to fully utilise their metabolic systems. It is claimed that glycogen depletion may explain the feelings of heaviness and be related to reduced muscle fibre recruitment (Wilmore and Costill, 1994). With glycogen depletion, slow twitch (ST) fibres fail to develop maximum tension and recruitment of fast twitch (FTa and FTb) fibres becomes reduced, decreasing muscle tension and ultimately run velocity. It is also claimed that hyperthermia may explain the reductions in VO_2 and run performance (Cade *et al*., 1992). The additive effects of glycogen depletion, hyperthermia and psychological trauma can affect fibre recruitment and hence VO_2. To achieve peak performance, athletes must learn to improve pacing, which may explain similar run performance, despite physiological fatigue in the subjects of this study.

Significant differences were expected between RTT and BRICK^{ITT} and BRICK^{ITU}, with similar run times expected between BRICK^{DRT} and RTT. This; however, was not the case as there were no significant differences reported for run time between RTT and BRICK$^{ITT, ITU}$ and ^{DRT}. According to Palmer *et al*. (1997), 20 km bike time trial performance was faster following a 150 minute pre-ride at steady state power output (58% peak power) versus a variable power output pre- ride (58± 12 % peak power) (26:32 ± 1:30 min v's 28:08 ± 1:47). These results indicate for cycling, that improved time trial performance is expected following a steady state pre-ride at 58% of peak power. This effect may be explained in part by the recruitment of FTa and FTb fibres during the variable power output protocol, in turn causing more physiological fatigue.

In this research, the similar run times between all protocols, despite significant variations in power output, may be explained by the subject group. The subjects may have had limitations in their ability to increase running pace, despite varied pre-run physiological cost. Thus the subjects may have employed the same run pace strategy for all run conditions. Biomechanical limitations in stride rate and frequency, as well as a lack of run speed, may explain the similar run times. Further analysis of the study by Hausswirth *et al*. (1999) reveals that performers with established running backgrounds gained the greatest time improvements in run time after a draft cycle protocol. Thus, better runners appear to be able to profit from reduced bike efforts and increase run pace as a result. The similar run times in this research may be related to limitations in running and pacing ability but also the small sample size. The implications for the competitive triathlete may be that drafting may not improve run times and individual bike efforts could produce faster overall times. It also appears that the competitive triathlete could benefit from speed specific run training and pacing.

This research on the effect of cycle leg intensity on self-paced run performance showed no differences in run times, despite findings to the opposite in the literature. The results indicate the subject group may have running velocity and pacing limitations. Research comparing the effect of BRICK protocols on run pacing between competitive and elite triathletes is recommended. Furthermore, investigations are needed with a larger sample size to measure the effect of cycle leg intensity on run time.

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