Cadence, Stride Rate and Stride Length during Triathlon Competition

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ABSTRACT

Int J Exerc Sci 4(1): 40-48, 2011. Triathlon research shows cycling alters the physiological response of subsequent running but, at present, biomechanical changes are unresolved. This study examined cycling cadence and running stride rate (SR) and length (SL) used by senior elite triathletes during competition. These variables were then compared to running and triathlon performance. Data from 51 elite male World Championships triathletes were analyzed via video recordings and Video Expert II Coach. Triathletes revealed consistent cadences throughout the majority of the cycle (96.8 +2.7 rpm) and run (90.9 +2.4 rpm) disciplines. However, a cadence increase (99.6 +5.7 rpm) was recorded at the completion of the cycle prior to running. Running SR and SL was significantly lower at the end of the run indicating a level of fatigue ($p<0.01$). Running SL was significantly and positively correlated with running and triathlon performance ($p<0.01$) suggesting those that could maintain a longer SL had a faster run and better final finishing position.

KEY WORDS: Stride rate, stride length, cadence, triathlon, competition

INTRODUCTION

Olympic distance triathlon at the elite level is a sport sequentially linking 1500 m of swimming with 40 km of draft legal cycling and 10 km of running. Previous research has highlighted the importance of the swim and run in draft legal events impacting the final race outcome. [16, 17, 21, 23, 27].

Effective transitioning from cycling to running is difficult and is not yet fully understood. To improve this transition, coaches tend to increase ride-to-run practice to familiarize the body to the changes, or suggest "spinning" one's legs at the end of the cycle. Spinning increases cadence by gearing down to reduce the muscle loading and make transition easier. Currently, there is no evidence that spinning at the end of the cycle will enhance subsequent running performance.

Prior cycling and/or swimming have been shown to decrease endurance capabilities, which, in turn, increases the energy cost of running at the end of a triathlon [5, 10, 12, 15, 20, 22]. Drafting in cycling can reduce energy cost by up to 30% [7] and should decrease fatigue. Hence, run performance is improved following a drafting cycle [13, 14, 18, 21].

Cavanagh and Williams [3] found runners chose the most efficient stride length (SL) by altering the stride rate (SR) and SL combinations when running at various velocities. Running and triathlon studies [12, 6, 28] revealed decreased SL, but no change to SR where fatigue during running was reported. Bernard [1] and Gotshall and Palmer [9] reported higher SR within the first 500 m of running after cycling. However, others [15, 24] found no change in running biomechanics with prior cycling.

This study initially sought to determine self selected cycling and running cadences and SL of elite male triathletes during competition. This information was then used to determine if triathlon performance may be related to the cadences or SL used throughout the race.

METHOD

Participants

Subjects were 51 male senior elite Triathlon World finishers. Ethics approval for this study was granted by the Human Ethics Committee of The University of Western Australia. Permission to record data was obtained from the International Triathlon Union; however, triathletes gave individual informed consent.

Protocol

Each competitor was video taped at 25 Hz (Panasonic AG-450, Japan) during competition to determine individually selected cycling cadence and running SR and SL by digitizing the video via Video Expert II Coach (Australia, 1999) computer software. The event consisted of a 1500 m, one lap, wetsuit swim (18.8^{o}C); a six lap, 40 km draft legal cycle, and a three and a half lap, 10 km run.

Cameras were placed on flat sections of the course to reduce the effect of terrain on cadence selection. One camera was placed 1500 m after the swim-cycle transition area and 30 m perpendicular to the cycle course. This allowed collection at the start of each cycle lap as well as 1.7km from the end of the cycle (Pre-T2). A second camera was located 1200 m after the cycle-run transition and 30 m perpendicular to the run course allowing collection of data as soon as the triathletes entered the looped part of the run course (Post-T2), during each lap and then 1.5 km from the finish (Pre-finish) (Table 1). The road surface was marked at 1 m intervals with reflective masking tape for calibration when digitizing.

Table 1. Data collection points for the cycle and run disciplines

Cycle Lap	Distance (km)	Run Lap	Distance (km)
1	1.5	Post-T2	1.20
2	8.1	1	3.00
3	14.7	2	5.45
4	21.3	3	7.90
5	27.9	Pre-finish	8.50
6	34.5		
Pre-T2	38.3		

Note:
Pre-T2 = cycle data collection point at the end of the cycle prior to the second transition
Post-T2 = first run data collection point after the second transition
Pre-finish = final run data collection point prior to finishing the event

The video was replayed after the event and cycle cadence, running SRs and SLs for each triathlete were calculated at each of the points described above. Cycle cadence was determined by determining the time taken to complete one full revolution of the pedals. In most cases two revolutions were measured and the mean was used for further calculations.

A stride was defined as completing a complete running cycle from toe-off of one foot to the subsequent toe-off on that same foot. The SL was determined as the horizontal distance covered with each stride (m) and the SR defined as the number of strides completed each minute (strides.min^{-1}). Again, two complete strides were measured at each point and the means recorded.

Statistical Analysis

Mean data for all variables at each collection point were graphed against time. A simple repeated measures ANOVA was conducted to determine any main effects for cadence, SR or SL during the event. A post-hoc paired sample t-test was conducted where a main effect was detected. To determine if differences occurred between the mean cadence used during the cycle and the mean SR during the run a paired sample t-test was undertaken. Run split times, run rankings and final ranking, were used as performance variables, and correlated with cycle cadence, run SR and SL via Pearson and Spearman Rho correlations. Finally, the mean cadence and the final cadence recorded during the cycle were correlated with the initial and mean run SR to determine any possible relationship between the leg frequencies of the two disciplines. All statistical analysis was conducted using SPSS Statistics 18 (2009), alpha was set at $p<0.01$ for all statistical analysis.

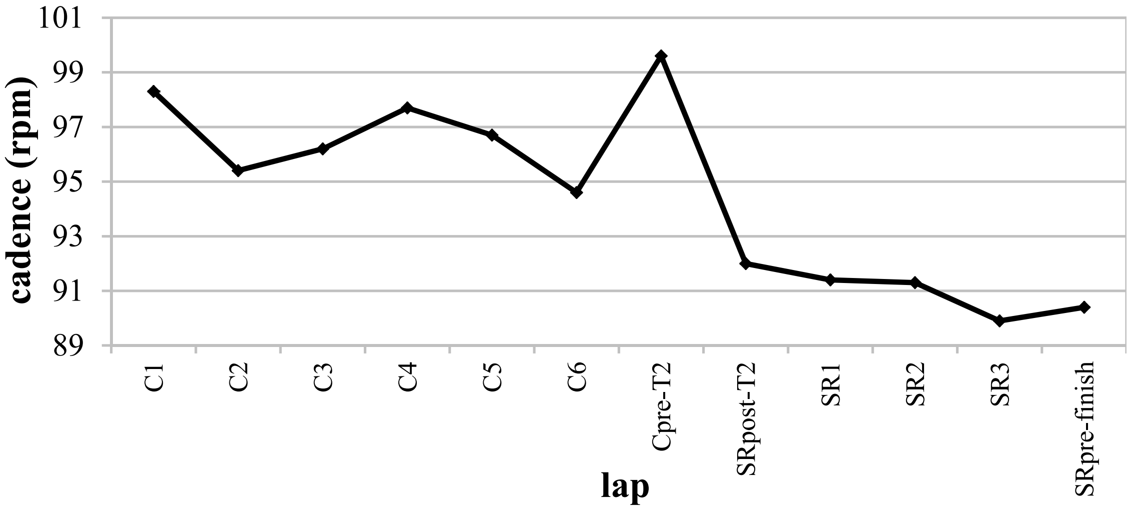
RESULTS

The mean cycle cadence (96.8 $\pm$ 2.7 rpm) used by the senior elite male triathletes was significantly greater than the mean SR (90.9 $\pm$ 2.4 rpm) in the run ($p=0.0001$). During the cycle, triathletes used a significantly faster cadence ($p=0.005$) at the end of the final lap (Pre-T2 = 99.6 $\pm$ 5.7 rpm) than that used at the start of the final lap (C6 = 94.6 $\pm$ 6.0 rpm) and the SR recorded at the end of the race was significantly slower than the start of the run ($p<0.01$: Figure 1).

No significant correlations were found between the final cycle cadence (Cpre-T2) and the initial run SR (SRpost-T2) ($r=-0.001$, $p=0.993$) nor was there any relationship indicated between the mean cycle cadence and mean SR ($r=0.093$, $p=0.518$).

Tables 2 and 3 present the inter-correlations of SR and SL. Significant positive correlations ($p<0.01$) existed between some SR variables (Table 2); namely, the initial SR (SRpost-T2) with the final two recorded SRs (SR3 and SR4). The correlation between the final cycle cadence (Cpre-T2) and initial SR (SRpost-T2) was not significant ($r= -0.001$, $p=0.993$). Significant positive correlation existed between SL measures throughout the run (Table 3) with the exception of the final two SL (SL3 and SLpre-finish) with the initial SL (SLpost-T2).

Figure 1. Male cycle cadences and running stride rates over time
Note: C = relates to cycle cadence data; SR = relates to running stride rate data; a = significantly different than C6; b = significantly different than SRpost-T2; $p < 0.01$



The male triathletes' SL during the post-T2, and SLpre-finish were significantly less than at other points during the run (figure 2).

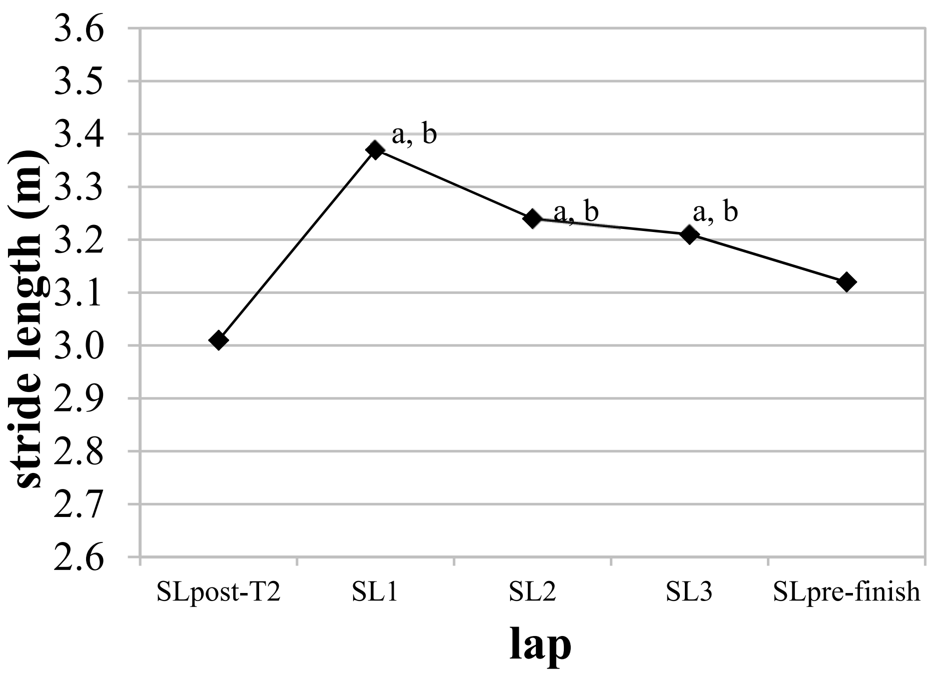


Figure 2 Male stride lengths over time
Note:
SL = relates to running stride length
a = significantly different than SL post-T2
b = significantly different than SLpre-finish
$p < 0.01$

No significant correlations were found between the final cycle cadence (Cpre-T2) and the initial run SR (SRpost-T2) (r=-0.001, p=0.993) nor was there any relationship indicated between the mean cycle cadence and mean SR (r=0.093, p=0.518).

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Table 2. Pearson correlation of stride rate for male triathletes

	SR1	SR2	SR3	SRpre-finish
SRpost-T2	0.216	0.242	0.497**	0.395**
SR1		0.164	0.302	0.204
SR2			0.212	0.371
SR3				0.602**

Note: ** = p<0.01

Table 3. Pearson correlation of stride length for male triathletes

	SL1	SL2	SL3	SLpre-finish
SLpost-T2	0.465**	0.493**	0.359	0.309
SL1		0.790**	0.791**	0.839**
SL2			0.713**	0.624**
SL3				0.794**

Note: ** = p<0.01

Tables 4 and 5 present data for the correlations between the selected SR or SL with measures of performance. Table 4 highlights little shared variance between SR and running or triathlon performance. However, a significant negative correlation between SL and running time, running rank and triathlon performance was shown in table 5.

Table 4. Correlation between stride rate and triathlon performance variables (run time via Pearson correlation; run rank & final rank via Spearman Rho) for male triathletes

	SRpost-T2	SR1	SR2	SR3	SRpre-finish
Run time (r)	0.045	0.137	-0.144	-0.093	-0.236
Run rank (ρ)	-0.066	0.264	-0.249	-0.121	-0.312
Final rank (ρ)	-0.069	0.301	-0.282	-0.137	-0.284

Note: ** = p<0.01

Table 5 Correlation between stride length and triathlon performance variables (run time via Pearson correlation; run rank & final rank via Spearman Rho) for male triathletes

	SLpost-T2	SL1	SL2	SL3	SLpre-finish
Run time (r)	-0.296	-0.804**	-0.604**	-0.765**	-0.841**
Run rank (ρ)	-0.195	-0.735**	-0.467**	-0.691**	-0.814**
Final rank (ρ)	-0.114	-0.724**	-0.467**	-0.608**	-0.704**

Note: ** = p<0.01

DISCUSSION

This study sought to determine the self selected cycle cadences, run SR and SL during elite triathlon competition, and then to compare these variables with performance criterion. The main findings of this study indicate that SL during the run is significantly related to running and overall triathlon performance, whereas SR during the run did not reveal a significant relationship with running performance nor the final finishing position. It is also evident that cycling cadence and running SR did not show much variation throughout the majority of the cycle and run portions of the race for elite competitors. The exceptions to this were during the last 1700m of the cycle where cadence increased prior to transition and the last 2.5 km of the run where SR reduced. Also, SL was significantly shorter at the start and finish of the run compared to the middle stages.

The consistent cadences and SR selected by triathletes during competition in this study suggest triathletes attempt to remain efficient during each discipline. Results of previous research indicated people normally self-select the most economical cadence frequency in aerobic activities such as cycling [11, 25], running [3], and upper body activities [19] to preserve energy.

The variations in cadence recorded at the end of the cycle phase and then during the run are consistent with the belief of some coaches and triathletes that an increased cadence at the end of the cycle may improve running ability 'off the bike'. Research has attempted to explore this theory [4, 8, 25] which proposes that an increased cycle cadence may improve venous return through reduced vascular resistance and improved muscle-blood pumping action, in turn, it is proposed that athletes can improve lactate removal [8]. When finishing the cycle leg with a fast cadence others suggests this reduces muscle tension as less force is required per pedal stroke [4, 25] thereby relaxing the legs in preparation for the subsequent run.

However, the increased cadence at the end of the cycle and the higher SR at the start of the run probably relate more to the demands of competition, where there may be a trade-off between the most efficient cadence or SR compared to gaining the best position into transition or at the end of the event. That is, increased cycling cadence prior to the run transition is probably due to increased velocity as triathletes look for better positioning prior to transition [21]. The increased SR during the commencement of the run may be due to similar reasons as past research has indicated that elite male triathletes who increased SR were able to maintain running velocity [12, 26]. Once again this may not be the most efficient SR, but the strategy may be adopted to allow triathletes to maintain a higher speed to stay at the front of the race.

A number of studies have investigated the biomechanical effects of prior cycling on subsequent running [1, 2, 9, 12, 15, 24, 26, 29]. It has been shown that after cycling at faster cadences, running SR may be elevated [26]. It has been hypothesised that this increase may be via changes in muscle firing patterns where, during cycling, is typically done at a slightly higher frequency (1.5-2 Hz) than running (1-1.5 Hz) [24]. The male triathletes cycle cadence (96.8 rpm = 1.6 Hz) was significantly greater than mean run SR (90.9 rpm = 1.5 Hz) thus supporting the notion that cycling is conducted at a higher frequency than running.

Although the results do not indicate a significant correlation between the cycle cadence and running SR, it is not possible to ascertain if the initial SR is directly related to the significantly higher cycle cadence at the end of the cycle as the first run data collection point was possibly too far from the bike-to-run transition (1200 m) as others have seen increased SR only during the first 500 m [1, 9].

A significantly shorter SL was observed at the first data collection point of the run which may indicate possible local muscle fatigue of the lower limbs. This has been suggested by Hausswirth et al. [12] who also recorded a reduced SL following cycling and attributed it to muscle fatigue of the hip flexors which reduces the range of motion and the SL attainable at this joint. It is unlikely it is related to aerobic fatigue as the triathletes at this point in time are running with an increased cadence in an attempt to maintain a high velocity. However, as SR and SL are related [3] it may be a combination of muscle fatigue [12] and that prior cycling may have influenced an increased SR above the frequency used when running without prior cycling [26].

A significant decrease in SL during the final stages of the run may be due to a number of reasons. The two most likely causes relate to fatigue or acceptance by the triathlete of the final outcome. It is quite possible that a number of triathletes sacrificed efficiency for speed in an attempt to maintain their positions in the field, running at an unsustainable higher velocity in the initial stages of the run creating fatigue; subsequently the athlete succumbs with a marked decrease in SL [6, 12, 28]. However, another likely cause of significantly reduced SL could be due to the triathlete simply accepting the inevitability of their final finishing positions. Therefore reducing their effort and selectively reducing their velocity through a reduction in SL.

Most triathletes in this study who chose a longer SL maintained this throughout the run (Table 3). The importance of this relationship is highlighted by the significant and negative correlation recorded between SL and performance measures (Table 5) indicating those using a larger SL ran faster and finished the event in a better position. The results also show that there is little association between the selected SL post-T2 and the SL used during the remainder of the run or with final run time. This again highlights the effect prior cycling has on subsequent run performance. The greatest strength of association appeared to be during the last two measurement points (SL3 and SLpre-finish). Those with the longest strides during the final 5 km recorded the fastest run times and finished the triathlon in a better position. As SL influences running velocity [3], it would be expected that, if SR is relatively similar, those with longer strides will run faster and finish higher in the rankings. Also, as there is no significant relationship between SR and performance, it would be interesting to investigate the possible relationship between body size and SL as previous research has indicated an association between race outcome and anthropometric variables [17].

The results of this study indicate cycle cadence was significantly greater than run SR and that a significant increase in cycle cadence was observed at the end of the cycle; however, it is unclear if this change is due to an effort to improve position at end of cycle or to improve running ability of the bike. Unlike the SR results, SL could have a greater influence in determining the velocity of a triathlete's run time, run rank and, in most instances, final finishing position. The mechanisms by which this is attained is not clear; however, data from this experiment during competition does support laboratory based findings that prior cycling has an impact on subsequent running. The triathletes who ran faster, utilized a longer SL which highlights the importance of training to improve fatigue resistance.

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