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Relationships Between Triathlon Performance and Pacing Strategy During the Run in an International Competition

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Purpose: The purpose of the present study was to examine relationships between athlete's pacing strategies and running performance during an international triathlon competition. ***Methods:*** Running split times for each of the 107 finishers of the 2009 European Triathlon Championships (42 females and 65 males) were determined with the use of a digital synchronized video analysis system. Five cameras were placed at various positions of the running circuit (4 laps of 2.42 km). Running speed and an index of running speed variability ($IRSV_{race}$) were subsequently calculated over each section or running split. ***Results:*** Mean running speed over the first 1272 m of lap 1 was 0.76 km·h^{-1} (+4.4%) and 1.00 km·h^{-1} (+5.6%) faster than the mean running speed over the same section during the three last laps, for females and males, respectively ($P < .001$). A significant inverse correlation was observed between RS_{race} and $IRSV_{race}$ for all triathletes (females $r = -0.41$, $P = .009$; males $r = -0.65$, $P = .002$; and whole population -0.76, $P = .001$). Females demonstrated higher $IRSV_{race}$ compared with men (6.1 ± 0.5 km·h^{-1} and 4.0 ± 1.4 km·h^{-1}, for females and males, respectively, $P = .001$) due to greater decrease in running speed over uphill sections. ***Conclusions:*** Pacing during the run appears to play a key role in high-level triathlon performance. Elite triathletes should reduce their initial running speed during international competitions, even if high levels of motivation and direct opponents lead them to adopt an aggressive strategy.

Keywords: race analysis, speed variability, performance level, gender comparison

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It has been well established that the distribution of work within an exercise event can have a considerable impact on overall performance (for a review, see Abbiss and Laursen[1]). Tucker[2] proposed that energy expenditure is regulated throughout an exercise task in order to delay the deleterious effects of fatigue and achieve the best possible performance outcomes. In triathlon, understanding and improving the influence of pacing on performance seems particularly relevant for the run portion of the event. Indeed, recent studies conducted during ITU World Cup (ie, short distance) triathlon competitions have reported high correlation between finish position and running performance in both genders (r values of 0.71 to 0.99, $P < .01$).[3–5] Such high correlations with overall ranking were not evident in either swimming ($r = .36$ to 0.52) or cycling ($r < .74$).[3–5] In this context, recent field-based research has found that triathletes tended to progressively reduce speed (ie, positive pacing strategy) throughout the run phase of ITU World Cup races.[3–5] For instance, during the 2001 and 2002 Lausanne World Cups, most athletes ran faster over the first kilometer than the majority of other run sections, while residual effects of prior cycling were the highest.[3,4] Similarly, Le Meur et al[5] showed that all of the 136 triathletes competing in the 2007 Beijing ITU World Cup event adopted a positive pacing strategy through the running phase of the event. During this race, the first of the four laps was run 10.0% faster than the three remaining laps.[5] This pattern of energy expenditure contradicts current recommendations to adopt an even pacing strategy (ie, constant pace) for endurance events (see Abbiss and Laursen[1]). From this point of view, some authors have identified pacing strategy during running as a possible factor of progress for elite triathletes.[4,5]

Hausswirth et al[6] showed that, for highly trained triathletes, performance during a 10 km running portion of a triathlon was improved if athletes performed the first kilometer 5% slower than their average 10 km pace. In this study, a 20 s variation in running time over the first kilometer (210 s vs 190 s; ie, 17 $km \cdot h^{-1}$ vs 19 $km \cdot h^{-1}$) led to an improvement of 150 ± 21 s over the entire 10 km run. It is likely that the lowered intensity at the start of the run reduced the early development of fatigue and thus improved overall performance when compared with the overly aggressive fast start pacing strategies self-selected by the triathletes. The reason highly trained triathletes self-selected such aggressive pacing strategies is unclear. However, it has been shown that one's perceived exertion may be a major factor influencing running speed regulation.[2,7] Further, exertion or effort may be significantly influenced by both external (ie, race dynamics or environmental conditions)[2,7,8] and internal (ie, motivational) factors.[2,7] These findings suggested that pacing strategy is partially determined by the specific emotion arousal associated with competition. In this perspective, Baron et al[7] hypothesized that athletes occasionally follow pacing patterns that seem unreasonably aggressive compared with those of prerace performances, potentially because of the motivation provided by competition. Considering the discrepancy between the results from Hausswirth et al[6] and the spontaneous fast running start systematically adopted by elite triathletes during world cup races,[3–5] further investigations are required to assess the benefit of a less aggressive strategy in the particular context of major international mass-start competitions. Since pacing strategies are based on robust cultural representations[9] and taking into consideration the small differences in performance determining a competition outcome (often < 1% between top 10 triathletes in World Cup competitions), information concerning the best way to extend the limited energetic sources available to the triathlete is of considerable value.

The aim of the present study was to determine relationships between running pacing strategy and running performance during an international level triathlon competition. As pacing strategy may affect running performance during a triathlon competition, we analyzed if the best male and female runners exhibited differences in running speed distribution over the 10 km triathlon run.

Materials and Methods

Participants

Sixty-five male and 42 female elite triathletes were involved in the present study. The experimental methodology was performed in accordance with the Declaration of Helsinki.

Procedures

Performance of each participant was examined during the running section of an international triathlon competition (European Triathlon Championships, Netherlands, Holten, July 5, 2009). The running portion consisted of four 2.42 km hilly laps (total of 9.68 km). Each lap contained a change in altitude of 18 m, which was condensed in a 335 m hill at a 3% gradient. Since the remainder of the course contained no sections with a grade greater than ± 0.5%, no downhill sections were identified. Little wind was observed over the circuit during the competition day (mean < 2 $m{\cdot}s^{-1}$; data obtained from Royal Netherlands Meteorological Institute).

In order to ascertain performance times over the course, a video analysis system recording at a frequency of 25 Hz (Sony HDR-CX12 AVHD) was synchronized with the official timing system (Omega, Swatch Group, Swiss). The video analysis system included five digital cameras located at the beginning of the run (ie, exit of bike transition, 0) and at 283, 937, 1272, and 1829 m. Distances between these points were measured using both a measuring wheel (Debrunner, Givisiez, art. 851.236) and a global positioning system, with an accuracy of 2–3 m (GPS, Garmin GPSRAP 60CSx, Garmin Europe, United Kingdom).

Data Processing

The elapsed times for the entire run circuit, each lap, and each section (ie, uphill and flat sections) were determined for each athlete using the race timing system and video data. Running speed of each athlete (RS, $km{\cdot}h^{-1}$) was determined via a subsequent video analysis (Pro suite version 5.0, Dartfish, Fribourg, Switzerland) over the following sections: 0–283 m flat, 283–937 m flat, 937–1272 m uphill, 1272–1829 m flat, and 1829–2420 m flat. In order to perform comparisons of running speed over laps and sections of the course, data were subsequently pooled over each of the four laps, and for flat (RS_{flat}, 2085 m per lap) and uphill sections (RS_{uphill}, 335 m per lap), independently.

The difference in running speed between flat and uphill sections ($\Delta_{F/U}$, %) was calculated for each athlete using the following equation:

$$\Delta F/U, \% = \frac{\text{Mean running speed over flat sections} - \text{Mean running over uphill sections}}{\text{Mean running speed over flat sections}}$$

In order to further examine the pacing strategy selected by athletes, an index of running speed variability over the entire run ($IRSV_{race}$, $km \cdot h^{-1}$) was calculated using the following equation:

$$IRVS_{race} = \frac{\sum_{n=1}^{20}\left(RSsection(n) - Mean\,RS\right) * \left(Time\,over\,section(n)\right)}{Total\,running\,time}$$

Variability in running speed during each lap ($IRSV_{lap}$, $km \cdot h^{-1}$), and over flat ($IRSV_{flat}$, $km \cdot h^{-1}$), and uphill ($IRSV_{uphill}$, $km \cdot h^{-1}$) sections were also determined independently, as defined by the following equations.

$$IRVS_{lap} = \frac{\sum_{n=1}^{5}\left(RSsection(n) - Mean\,RS(lap)\right) * \left(Time\,over\,section(n)\right)}{Lap\,running\,time}$$

$$IRVS_{flat} = \frac{\sum_{n=1}^{16}\left(RSsection(n) - Mean\,RS(flat)\right) * \left(Time\,over\,flat\,section(n)\right)}{Total\,running\,time\,over\,flat\,sections}$$

$$IRVS_{uphill} = \frac{\sum_{n=1}^{4}\left(RSsection(n) - Mean\,RS(uphill)\right) * \left(Time\,over\,uphill\,section(n)\right)}{Total\,running\,time\,over\,uphill\,sections}$$

Statistical Analysis

Three females and nine males did not finish the race and were excluded from the analysis. All statistical analysis was conducted using (Origin 8.0, OriginLab, Northampton, MA, USA). Data are expressed as mean ± standard deviation (SD), unless otherwise stated. The influence of running sections (ie, uphill and flat) and laps on running velocity, $IRSV_{lap}$ and $\Delta_{F/U}$ were analyzed using a one-way repeated-measures ANOVA. A one-way ANOVA was used to determine the effects of gender on $\Delta_{F/U}$, $IRSV_{race}$, $IRSV_{flat}$, and $IRSV_{uphill}$. Where significant effect was observed, Tukey's post hoc test was conducted to further delineate differences between running sections (ie, uphill and flat) and laps. Pearson's product-moment correlation was used to determine the relationship between $IRSV_{race}$ and the average running speed over the entire run circuit. The equation of the linear function representing $f(x)$: $IRVS = a * RS + b$ was calculated for the whole population, females and males independently, when considering the whole run and each lap. For analysis, significance was accepted at $P < .05$.

Results

Overall Performance

The mean finish times for the entire event were 121 ± 4 min and 108 ± 3 min, for females and males, respectively.

Running Speed. Mean time and speed over the running section were 37 min 32 ± 3 min (15.6 ± 1.0 $km \cdot h^{-1}$) for females and 33 min 30 ± 2 min (17.4 ± 1.1 $km \cdot h^{-1}$) for males respectively. Running speed values are presented in Table 1. Mean running

Table 1 Evolution of running speed throughout the running segment over the whole circuit, flat sections, and uphill sections for female and male triathletes (n = 39 and n = 56 for females and males, respectively)

Gender	Circuit Sections	Overall Run	Lap 1	Lap 2	Lap 3	Lap 4
Female	Whole ($km \cdot h^{-1}$)	15.6 ± 1.0	16.1 ± 1.0	15.6 ± 1.0*#	15.4 ± 1.0*	15.5 ± 1.1*
	Flat ($km \cdot h^{-1}$)	16.1 ± 1.0	16.5 ± 1.0	16.1 ± 1.0*#	16.0 ± 1.0*#	16.1 ± 1.0*
	Uphill ($km \cdot h^{-1}$)	13.1 ± 0.9	14.0 ± 1.2	13.0 ± 0.9*#	12.7 ± 0.8*#	12.7 ± 0.8*
	Δflat/uphill (%)	18.9 ± 1.2	15.0 ± 0.5	19.2 ± 0.3*#	20.2 ± 0.3*	20.7 ± 0.3*
Male	Whole ($km \cdot h^{-1}$)	17.4 ± 1.1	18.0 ± 1.4	17.3 ± 1.2*#	17.1 ± 1.1*#	17.3 ± 1.0*
	Flat ($km \cdot h^{-1}$)	17.6 ± 1.1	18.1 ± 1.2	17.4 ± 1.2*#	17.3 ± 1.1*#	17.5 ± 1.1*
	Uphill ($km \cdot h^{-1}$)	16.6 ± 1.1	17.4 ± 1.7	16.6 ± 1.6*#	16.3 ± 1.2*#	16.2 ± 1.2*
	Δflat/uphill (%)	5.9 ± 2.5	4.4 ± 0.5	4.5 ± 0.8	6.2 ± 0.4	8.0 ± 0.4*#

*Significantly different from lap 1, $p < 0.0001$. #Significantly different from previous lap, $p < 0.0001$. Females demonstrated significant differences from males over each lap in running speed and relative decrease in running speed between flat and uphill sections.

speed over the first 1272 m of lap 1 was 0.76 km·h^{-1} (+4.4%) and 1.00 km·h^{-1} (+5.6%) faster than the mean running speed over the same section during the last three laps, for both females and males, respectively ($P < .001$). A similar result was found when considering the whole circuit (+0.6 km·h^{-1} and +3.7% for females and +0.8 km·h^{-1} and +4.3% for males, respectively, $P < .0001$) or flat sections (+0.5 km·h^{-1} and +2.7% for females and +0.7 km·h^{-1} and +4.0% for males, respectively, $P < .0001$) and uphills independently (+1.2 km·h^{-1} and +8.6% for females and +1.0 km·h^{-1} and +5.9% for males, respectively, $P < .0001$) (Table 1). The speed at each point of the running portion is depicted in Figure 1. Thirty-seven of the 95 finishers (12 females and 25 males) demonstrated an increase of at least 5% over the run section before the finish line (ie lap 4), compared with the same section during lap 3. For 11 of them (3 females and 8 males), this increase reached more than 10%.

The mean running speed for each section (ie, uphill and flat) of the course and the average $\Delta_{F/U}$ per lap are presented in Table 1. Females demonstrated higher $\Delta_{F/U}$ than males over each lap ($P < .0001$, Table 1). The $\Delta_{F/U}$ increased significantly after lap 1 in females ($p < 0.0001$); however, it remained stable until lap 3 for males ($P = .99$, $P = .04$, $p = 0.001$ between lap 1, and lap 2, lap 3, lap 4, respectively, Table 1).

Running Speed Variability. A significant inverse correlation was observed between RS_{race} and $IRSV_{race}$ for all triathletes ($r = -0.41$, $P = .009$, $r = -0.65$, P

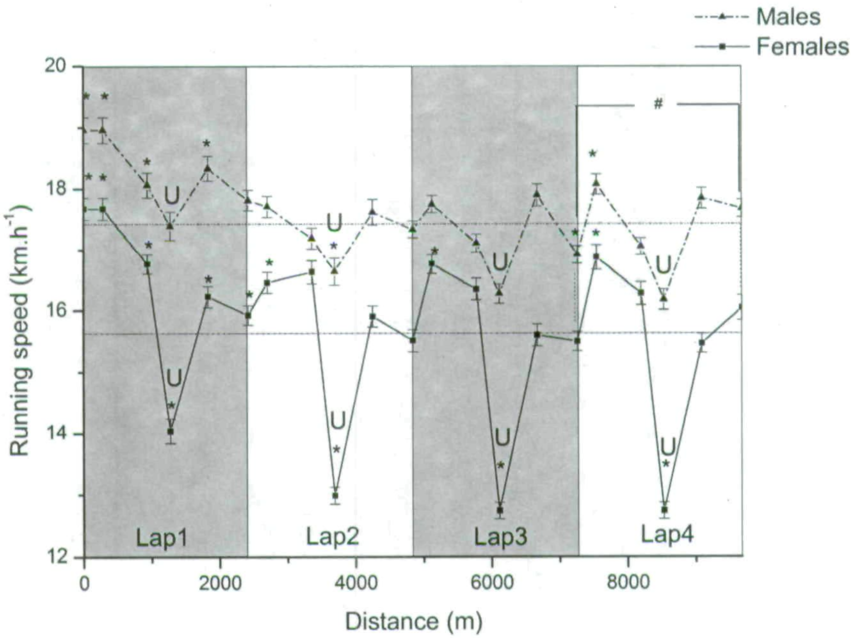

Figure 1 — Average running speed for each of the running sections for elite female (n = 39) and male triathletes (n = 55) during the European Triathlon Championships. U: uphill sections (sections without any indication were flat). *Significantly different from the mean running speed over the whole circuit. #Significantly different from the speed over the same section during previous lap.

= .002, and $r = -0.76$, $P = .001$, for females, males, and the whole population, respectively, Figure 2). Similarly, an inverse correlation was observed when considering each lap independently ($r = -0.61$, -0.75, -0.57, and -0.57, for lap 1, lap 2, lap 3, and lap 4, respectively, when considering the whole population, $P < .001$). Females demonstrated higher $IRSV_{race}$ than males (6.1 ± 0.5 km·h^{-1} and 4.0 ± 1.4 km·h^{-1}, for females and males, respectively, $P = .001$, Figure 2). $IRSV_{lap}$ increased immediately after lap 1 for females (+23.8%, +24.6%, and +31.6% for lap 2, lap 3 and lap 4, when compared with lap 1, respectively, $P < .001$, Figure 3), whereas no significant difference was reported until lap 4 for males (+6.8% with $P = .88$, +21.9% with $p = 0.07$, +46.6% with $P = .004$, for lap 2, lap 3 and lap 4, when compared with lap 1, respectively, Figure 3). The linear function representing $IRSV_{race} = a * RS_{race} + b$ demonstrated a greater heterogeneity of running speed variability for males than for females because a greater slope (absolute value) was reported for males than for females: $|a| = 0.22$ [0.05 to 0.38; mean (95% confidence interval)], and $|a| = 0.79$ (0.53 to 1.04) for women and men, respectively, Figure 2.

The results revealed a significant inverse correlation between $IRSV_{flat}$ and RS_{flat} for both genders and the whole population ($r = -0.41$, $P = .01$, $r = -0.60$, $P = .0001$, and $r = -0.37$, $P = .001$, for females, males, and the whole population, respectively, Figure 2). The correlation between $IRSV_{uphill}$ and RS_{uphill} was significant for males ($a = -0.78$, $r = -0.44$, $P < .0001$) but not for females ($P = .09$) or the whole population ($p = 0.88$). No significant effect of gender was observed concerning $IRSV_{flat}$ ($p = 0.23$) and $IRSV_{uphill}$ ($p = 0.15$).

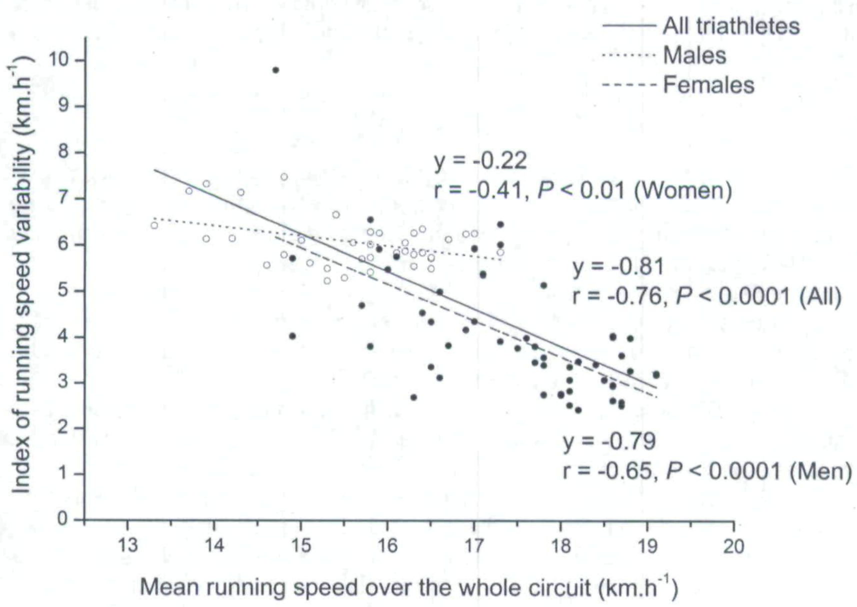

Figure 2 — Index of running speed variability over the whole running section for senior males (n = 55), females (n = 39), and all triathletes during the European Triathlon Championships.

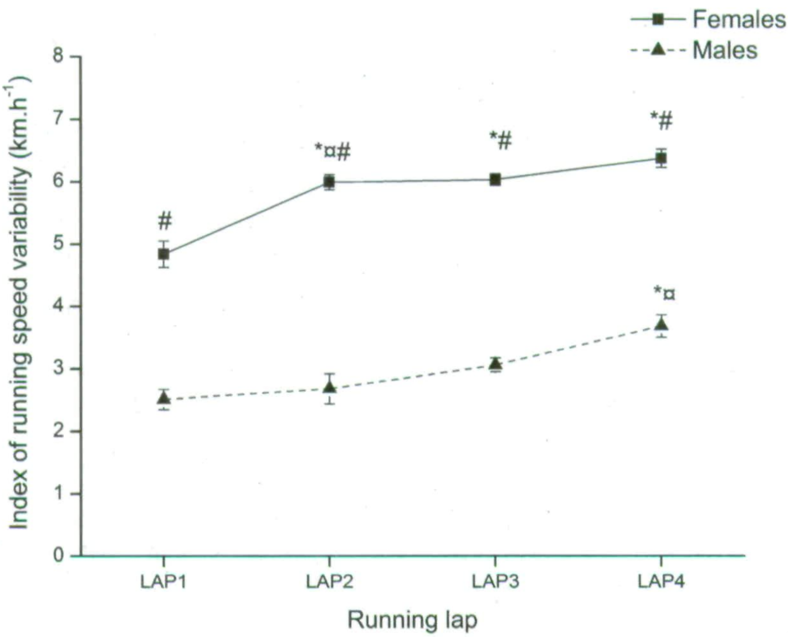

Figure 3 — Average index of running speed variability for each of the four laps for elite female (n = 39) and male triathletes (n = 55) during the European Triathlon Championships. *Significantly different from Lap1. ¤Significantly different from previous lap. #Significantly different from men.

Discussion

Although all triathletes adopted a positive pacing strategy during the run segment of the 2009 European Triathlon Championships (ie, positive split), the present results demonstrated that the best runners tended to adopt a more evenly paced strategy. This finding extended previous results[6] collected during individual time-trial triathlons by suggesting that triathletes should avoid an aggressive fast-start pacing strategy during mass-start competitions. Furthermore, results of the present study also indicate that the more successful competitors during this event also slowed to a lesser degree on uphill sections of the course.

In the present study, athletes performed the first lap of the run significantly faster than the remaining three laps (Table 1). After the first lap, both males and females decreased their average running speed by 0.5 $km \cdot h^{-1}$ (ie, 3.1%) and 0.7 $km \cdot h^{-1}$ (ie, 3.9%), respectively (Table 1). Thereafter, the difference in mean running speed did not vary more than 0.2 $km \cdot h^{-1}$ over the remaining laps. These results support previous research conducted during World Cup triathlon events which highlighted similar systematic fast start pacing strategies during short- to middle-distance competitions.[3–5] Nevertheless, the effectiveness of such positive pacing during the running section of a triathlon event remains unclear. Indeed, it has previously been shown that a fast start pacing strategy may improve, hinder, or have no effect on athletic performance.[1] Despite this, Hausswirth et al[6] recently showed that performing the first kilometer of a simulated time-trial triathlon 5% slower than the average pace of a 10 km control run resulted in significant improvements in performance, when compared a relatively fast start (ie, first kilometer 5% faster than the average pace of a 10 km control run). In that study, Hausswirth et al[6] hypothesized that the relatively slow start may have prevented development of high physiological stress early in the exercise bout, thereby preventing athletes from considerably slowing later in the event. Results of the present study indicate that this strategy is also viable for major mass-start international triathlons, as a significant inverse correlation was found between running speed variability and mean running speed over the 10 km triathlon run ($r = -0.76$, $p < 0.0001$). This correlation was also significant when considering both genders independently ($r = -0.41$, $P < .01$ and $r = -0.65$, $P < .001$ for females and males, respectively). Considering that all triathletes adopted a fast running speed at commencement of the run (Figure 1), it appears that the better performers demonstrated a greater ability to limit decrements in running speed throughout the later stages of the race.

Since all triathletes in the present study self-selected a relatively fast-starting strategy and better performers were able to maintain a more even pacing strategy over the entire run, it may be suggested that elite triathletes should reduce their spontaneous initial running speed in order to improve overall performance. However, it should also be noted that the high intensity at the beginning of the run phase may be a tactical technique adopted by triathletes in order to stay in the same group/ pack as their direct opponents. Conversely, Tucker et al[9] analyzed the evolution of pacing during 32 consecutive world records of the 5 km performed over the past century and suggested that pacing strategy might be associated with a cultural learning process. Their results revealed that since 1920, running speed variability in the 5 km world record has progressively decreased. Furthermore, the pacing select by world record holders has shifted from a "reverse J-shaped" strategy[1] toward a more even strategy, suggesting that the pacing strategy of elite athletes may be optimizing over decades. The systematic fast start adopted by triathletes during the cycle-to-run transition in competitions[3–5] and multitransition training sessions[10] may therefore be associated with a learned template of performance, rather than an optimal strategy. Further research is needed in order to gain a greater understanding as to the influence of unconscious/physiological and conscious/ emotional (ie, motivation and tactics) factors influencing pacing strategies during elite athletic competition.

In addition to maintaining a more even pacing strategy over the entire event, the results of the present study showed that top performers slowed to a lesser degree on the uphill section of the course, as evidenced by a significant relationship between running speed variability and performance within laps. It has previously been shown, with the use of mathematical models[11,12] and actual performance trials,[13] that increasing energy expenditure to counter periods of high external resistance (eg, uphill and into a headwind) and decreasing expenditure when resistance is low (eg, downhill and with a tailwind) results in meaningful improvements in performance. Since energy expenditure or power output varies, this theory has previously been termed a *variable pacing strategy*[1,13]; however, such variation is performed in an attempt to maintain an even pace/speed. As a result, the better runners in the present study tended to adopt a more even pacing strategy when compared with the less successful athletes. Since such strategy may be dependent of the circuit design (ie, uphill and downhill lengths and grades), further investigations are necessary to determine the acceptability of running speed variation over hilly course.

Interestingly, the relative difference in running speed observed between uphill and flat sections in the present study was 18.9% for females, whereas males slowed down by only 5.9% ($P < .001$). This difference is likely to explain the higher running speed variability over the whole run observed by females, compared with males ($r = -0.41$, $P = .009$ and $r = -0.65$, $P = .002$, respectively). The greater influence of uphill sections on running speed variability in female triathletes may be linked to a lower power-to-mass ratio and thus a greater influence of changes in gradient on running speed. Le Meur et al[5] recently reported that female triathletes (with similar level of performance of the ones in the present race) spent relatively more time than males above their maximal aerobic power in the hilly sections of the cycling circuit. These authors proposed that females were disadvantaged by their lower power-to-mass ratio, which was correlated with the time spent above their maximal power output in uphill sections ($r = -0.73$, $P < .05$). From this perspective, the present research furthers previous research collected during the cycling leg of world cup triathlon[5] by demonstrating that female triathletes should focus on their aptitude for running over incline sections by improving their running skills or their power-to-mass ratio.[14]

Interestingly, the variability in running velocity of both males and females over the entire run increased significantly over the four running laps (Figure 2). As such, it appears that athletes' pacing strategy became significantly less even as the trial progressed. The factors responsible for such increases in the variability of pace are currently unclear; however, it has been suggested that greater fluctuations in speed later in the event may be related to the development of fatigue and associated alterations in neural drive.[15] Supporting this, it has recently been found that the variability in power output during a 40 km cycling time trial may be significantly greater in hot (32°C) compared with cool (17°C) climates.[15] This study hypothesized that the increase in the variability of power output in conditions of high physiological stress (ie, exercise in the heat) was related to alterations in afferent feedback, arousal, and central drive.[15] Indeed, it has been suggested that the brain continuously performs subconscious calculations by comparing the physiological demands of an exercise task with the athlete's physiological capacity, and the level of motivation, in order to ensure that the exercise can be maintained for the expected duration without any catastrophic failure in physiological and emotional homeostasis.[15] As a result, triathletes in the present study may have experienced difficulties to sustain a constant pace later in the run due to high negative load associated with increases in perceive exertion/fatigue. Further research is warranted in order to better understand the factors influencing the variability speed and energy expenditure during exercise.

Even though previous field-based studies[3–5] have shown that triathletes adopted a systematic positive pacing strategy, the high number of split times measured in the present research (ie, 20) allowed a more accurate description of running speed evolution during the triathlon and revealed that 39% of the finishers of the present race demonstrated an "end spurt." The video analysis revealed that the majority of these competitors were packed at the penultimate split point (571 m from the finish line), which likely resulted in increasing intensity in the final section to complete the race ahead of their direct opponents. This observation confirmed that the presence of other competitors influence pacing strategy by suggesting that the global positive pacing systematically adopted by triathletes may shift toward a "reverse J-shaped" strategy depending on race dynamics. Given the high percentage of triathletes that displayed a final increase in running speed, it appears that elite triathlon performance is associated with a capacity to sprint at the end of the 10 km run.

Conclusion

This study demonstrated that the running performance (and overall performance) during an international triathlon is correlated with running speed variability. Top female and male international triathletes demonstrated a trend to adopt a more even pace, whereas less successful athletes chose an unreasonably aggressive pacing pattern over the initial phase of the run resulting in a significant subsequent decrease in running speed.

Practical Applications

The present research showed that elite triathletes should reduce their initial running speed during international competitions, even if high levels of motivation and direct opponents lead them to adopt an aggressive start. In this regard, more research is required to observe the way in which triathletes develop their preexercise strategy and which intervention could influence their initial starting effort to optimize their running performance level. This study also highlighted the idea that elite triathlon performance may be associated with the capacity to sprint at the end of the 10 km run and that female triathletes should focus on their aptitude for running over incline sections by improving their running skills or their power-to-mass ratio.

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