Journal of Science and Medicine in Sport (2008) **11**, 424—432

Journal of Science and Medicine in Sport

www.elsevier.com/locate/jsams

ORIGINAL PAPER

# Pacing during an elite Olympic distance triathlon: Comparison between male and female competitors

**Veronica E. Vleck**[a,*], **David J. Bentley**[b], **Gregoire P. Millet**[c], **Adrian Bürgi**[d]

[a] *University of Westminster, Department of Human and Health Sciences, UK*
[b] *The University of New South Wales, Health and Sports Science, Australia*
[c] *Aspire Academy for Sports Excellence, Quatar*
[d] *Trainerbildung Swiss Olympic, Switzerland*

Received 16 May 2006; received in revised form 16 January 2007; accepted 16 January 2007

**KEYWORDS**
Elite;
Triathlete;
Drafting;
Ranking;
Performance;
Gender

**Summary** This study investigated whether pacing differed between 68 male and 35 female triathletes competing over the same ITU World Cup course. Swimming, cycling and running velocities ($m\,s^{-1}$ and $km\,h^{-1}$) were measured using a global positioning system (Garmin, UK), video analysis (Panasonic NV-MX300EG), and timing system (Datasport, Switzerland). The relationship between performance in each discipline and finishing position was determined. Speed over the first 222 m of the swim was associated with position ($r = -0.88$ in males, $r = -0.97$ in females, both $p < 0.01$) and offset from the leader, at the swim finish ($r = -0.42$ in males, $r = -0.49$ in females, both $p < 0.01$). The latter affected which pack number was attained in bike lap 1 ($r = 0.81$ in males, $r = 0.93$ in females, both $p < 0.01$), bike finishing position (both $r = 0.41$, $p < 0.01$) and overall finishing position ($r = 0.39$ in males, $r = 0.47$ in females, both $p < 0.01$). Average biking speed, and both speed and pack attained in bike laps 1 and 2, influenced finishing position less in the males ($r = -0.42$, $-0.2$ and $-0.42$, respectively, versus $r = -0.74$, $-0.75$, and $-0.72$, respectively, in the females, all $p < 0.01$). Average run speed correlated better with finishing position in males ($r = -0.94$, $p < 0.01$) than females ($r = -0.71$, $p < 0.001$). Both sexes ran faster over the first 993 m than most other run sections but no clear benefit of this strategy was apparent. The extent to which the results reflect sex differences in field size and relative ability in each discipline remains unclear.


## Introduction

The Olympic Games triathlon involves a 1.5 km swim, 40 km cycle and 10 km run completed under 'draft-legal' conditions.[1] To become eligible for selection, Elites must attain a designated Interna-

* Corresponding author.
*E-mail address:* V.E.Vleck@wmin.ac.uk (V.E. Vleck).

1440-2440/$ — see front matter © 2007 Sports Medicine Australia. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.jsams.2007.01.006

tional Triathlon Union (ITU) Olympic qualification ranking, via a cumulative 'points for places' system of tiered competition in which the most commonly raced events are ITU World Cups. The points awarded for a given race position are adjusted according to a 'quality of field factor' (QFF) published by ITU (www.triathlon.org), and are limited to athletes finishing within a set percentage of the winner's time. The ability of a given athlete to attain ranking points will be influenced by his or her absolute performance level in each discipline (relative both to him- or her-self and to other competitors), and by the extent to which he or she experiences residual fatigue from the preceding discipline(s).[1] The latter is likely to be affected by how effort is distributed within each stage.[2,3] Where there is little physiological difference between competitors,[4] athletes may 'win or lose depending on their pacing'.[5]

Although the Elite triathlete may draft within the swim[6–8] and run sections of competition, thereby being exposed to less metabolic demand and being able to race at a higher speed, it is within the cycle[9,10] that the formation of drafting packs is likely to be most competitively significant. In males, the poor cyclist who swims fast enough not to miss, or drop off, the first or second cycle pack may still be able to maintain a good race position. He whose inferior swimming performance leads him to lose the pack, or work relatively harder to catch it, may suffer greater residual fatigue during the run, with negative consequences for overall performance.[3]

No published data exists regarding the extent to which discipline specific pacing, and ability to form or 'catch' bike packs, is associated with performance in elite females, although sex differences in ability to run after cycling have been shown.[4] This study aimed, therefore, to determine whether sex differences exist in how Elites complete a triathlon and in which stages are especially important for performance.

## Methods

### Subjects

Timing and race position data was obtained from the official race timers for all 68 males and 35 females in the 2002 ITU Lausanne World Cups. Field size was within the normal range for 2002. The subjects were informed of the benefits and purposes of the study beforehand, according to the Declaration of Helsinki.

### Procedures

Each subject was examined over the swim, bike and run. The swim comprised a 2× 693 m non-wetsuit course with a 20 m section (here termed transition zero or 'T0') after lap 1 where the athletes left and then re-entered the water. The pontoon was 46 m long. The bike involved six laps of a 6.7 km circuit (including a short hill at each lap start). The run comprised four laps of a flat 2.5 km circuit.

### Instrumentation

A video analysis system (Panasonic NV-MX300EG) was synchronised with the official timing system (Datasport, Zollikofen, Switzerland). Timing mats and or cameras were situated at the swim start, at each swim turn-around buoy (222, 496 m), the swim exits (693 m), the end of the swim-cycle transition (T1), the start and end of the cycle-run (T2) transition, 993 m after the end of T2, and the end of each bike and run lap. Distances between the timing points were measured using calibrated ropes, a global positioning system (GPS) (Garmin E-trex Vista, Garmin Europe, UK), measuring wheel (Debrunner, Givisiez, art.851.236), and theodolite (Leica TC600).[3]

### Data collection

Elapsed time (s), position and time-gap(s) to the next athlete(s) were determined at each stage. Researchers with downloadable multi-lap stopwatches (Digitimer, Leisure Systems International, UK) also indicated athlete(s') race numbers, stopwatch lap number and or times to the camera(s) as the athletes passed. They were pre-warned by researchers at previous stages, via walkie-talkie (Model TP329, Oregon Scientific, UK), of pack sizes, composition, and estimated arrival times. Athletes less than or 4 s behind the next competitor were considered to be within the same pack. Athlete speed ($m\,s^{-1}$) for each section was calculated at 222, 496, 693 m (the swim exit), 693 plus 20 m (the swim re-entry) and at 1385 m of the swim. Speed ($km\,h^{-1}$) was calculated for each bike lap and between 993, 3505, 4932, 6017, 7444, 8529 and 9890 m of the run.

### Statistical analysis

One-way ANOVAs (in conjunction with the Tukey or Tamhane's T2 posthoc test for equal or unequal variance, respectively) were used to compare various proportions of the field for speed during, and position at, each stage, and pack formation (i.e. whether differences existed in the time gaps between successive athletes) between different stages. Pearson's product moment correlation was used to determine the relationship between speed for each stage and position. The 'Statistics Package for the Social Sciences' (SPSS, High Wycombe, UK), Version 13.0, was used throughout. The 95% confidence limit was set as the level of significance.

**Table 1** Number of packs formed (followed by number of athletes involved) at various points of the Lausanne 2002 ITU World Cup triathlons

| | Lap | Distance | Males | | Females | |
|---|---|---|---|---|---|---|
| S | 1 | 222 m | 1 | $54$ | 1 | $35$ |
| | | 496 m | 1 | $53$ | 4 | $22^{6}, 8^{6}, 4^{12}, 1$ |
| | | 693 m | 2 | $49^{7}, 5$ | 4 | $25^{6}, 5^{9}, 4^{29}, 1$ |
| | 2 | 693 + 20 m | 2 | $49^{7}, 5$ | 4 | $25^{6}, 5^{9}, 4^{29}, 1$ |
| | | 1385 m | 8 | $9^{4}, 1^{5}, 1^{4}, 15^{4}, 24^{19}, 1^{4}, 1^{36}, 3$ | 5 | $20^{28}, 1^{7}, 4^{20}, 9^{99}, 1$ |
| T1 | | | 7 | $60^{6}, 1^{11}, 1^{4}, 1^{4}, 1^{28}, 4^{6}$ | 9 | $10^{4}, 4^{4}, 3^{6}, 3^{27}, 1^{8}, 4^{18}, 3^{5}, 6^{27}, 1$ |
| B | 1 | 6.7 km | 6 | $40^{10}, 4^{9}, 15^{17}, 2^{16}, 5^{43}, 1^{62}$ | 7 | $10^{24}, 8^{57}, 4^{7}, 2^{11}, 8^{24}, 2^{110}, 1$ |
| | 2 | 13.4 km | 4 | $31^{5}, 16^{47}, 2^{75}, 4$ | 6 | $1^{29}, 9^{28}, 8^{78}, 12^{42}, 2^{22}, 2^{92}, 1$ |
| | 3 | 20.1 km | 6 | $44^{31}, 1^{31}, 1^{24}, 2^{21}, 1^{7}, 4^{65}, 1$ | 6 | $9^{43}, 10^{62}, 11^{60}, 1^{50}, 3^{64}, 1$ |
| | 4 | 26.8 km | 5 | $43^{8}, 1^{92}, 4^{47}, 2^{16}, 4$ | 5 | $8^{57}, 12^{58}, 9^{118}, 1^{43}, 4^{33}, 1$ |
| | 5 | 33.5 km | 4 | $2^{20}, 42^{105}, 3^{55}, 6$ | 4 | $8^{58}, 12^{50}, 9^{169}, 1^{27}, 5$ |
| | 6 | 40.2 km | 4 | $2^{31}, 42^{135}, 3^{45}, 6$ | 4 | $8^{57}, 3^{24}, 9^{29}, 9^{227}, 6$ |
| T2 | | | 4 | $2^{29}, 43^{136}, 3^{42}, 8$ | 6 | $8^{55}, 1^{6}, 2^{24}, 9^{21}, 9^{222}, 6$ |
| R | L1 | 993 m | 11 | $2^{16}, 34^{4}, 6^{4}, 1^{6}, 1^{125}, 1^{5}, 2^{38}, 1^{4}, 1^{9}, 3^{11}, 2$ | 16 | $2^{6}, 3^{7}, 2^{8}, 1^{5}, 1^{69}, 2^{10}, 1^{9}, 2^{5}, 4^{10}, 5^{8}, 1^{6}, 3^{6}, 2^{208}, 2^{5}, 1^{20}, 2^{8}, 1$ |
| | L1 | 2420 m | 16 | $35^{5}, 2^{6}, 1^{6}, 2^{4}, 1^{16}, 1^{5}, 1^{18}, 1^{82}, 1^{12}, 1^{18}, 1^{20}, 1^{6}, 1^{14}, 2^{10}, 2^{19}, 1$ | 20 | $1^{6}, 1^{7}, 2^{10}, 2^{16}, 1^{11}, 1^{13}, 2^{40}, 1^{20}, 10^{16}, 1^{7}, 1^{6}, 1^{6}, 2^{6}, 1^{9}, 1^{12}, 2^{170}, 1^{33}, 2^{30}, 1^{26}, 1$ |
| | L2 | 3505 m | 20 | $4^{13}, 13^{6}, 14^{5}, 3^{4}, 1^{4}, 1^{10}, 1^{9}, 2^{4}, 3^{27}, 1^{22}, 1^{58}, 1^{16}, 1^{26}, 1^{12}, 1^{5}, 1^{18}, 2^{6}, 1^{10}, 1^{35}, 1$ | 21 | $1^{8}, 1^{8}, 2^{21}, 2^{23}, 1^{7}, 2^{16}, 1^{18}, 2^{26}, 1^{15}, 3^{11}, 6^{8}, 2^{7}, 1^{11}, 1^{12}, 3^{19}, 1^{143}, 1^{7}, 1^{53}, 1^{35}, 2^{45}, 1$ |
| | L2 | 4932 m | 21 | $4^{9}, 1^{6}, 2^{4}, 1^{5}, 17^{5}, 4^{5}, 1^{6}, 3^{8}, 2^{7}, 1^{5}, 1^{14}, 1^{10}, 2^{11}, 1^{11}, 2^{17}, 1^{46}, 1^{22}, 1^{40}, 3^{19}, 3^{29}, 1$ | 25 | $1^{13}, 1^{6}, 1^{36}, 2^{35}, 2^{10}, 2^{7}, 1^{9}, 1^{29}, 1^{11}, 2^{8}, 1^{9}, 1^{9}, 7^{8}, 1^{8}, 1^{8}, 1^{9}, 1^{11}, 1^{16}, 2^{111}, 1^{8}, 1^{81}, 1^{36}, 1^{10}, 1^{57}, 1$ |
| | L 3 | 6017 m | 27 | $3^{10}, 1^{12}, 1^{9}, 3^{5}, 2^{5}, 15^{5}, 2^{9}, 3^{6}, 2^{7}, 1^{6}, 2^{21}, 2^{4}, 1^{13}, 1^{7}, 1^{13}, 1^{6}, 1^{32}, 2^{24}, 1^{25}, 1^{36}, 2^{10}, 1^{20}, 2^{4}, 2^{4}, 1^{41}, 1^{46}$ | 22 | $1^{19}, 46^{2}, 2^{9}, 1^{10}, 3^{31}, 1^{10}, 2^{16}, 2^{19}, 2^{11}, 4^{11}, 1^{15}, 3^{21}, 1^{14}, 1^{7}, 1^{80}, 1^{10}, 1^{102}, 1^{37}, 1^{20}, 1^{67}, 1$ |
| | L3 | 7444 m | 28 | $1^{6}, 2^{17}, 1^{16}, 1^{5}, 2^{4}, 2^{7}, 1^{8}, 10^{4}, 3^{10}, 2^{5}, 2^{12}, 1^{4}, 3^{8}, 3^{6}, 1^{25}, 2^{9}, 1^{9}, 2^{16}, 1^{38}, 1^{6}, 1^{5}, 1^{36}, 1^{13}, 1^{22}, 2^{25}, 1^{7}, 3^{61}, 1^{46}, 1$ | 27 | $1^{25}, 2^{48}, 1^{11}, 1^{26}, 1^{17}, 1^{10}, 1^{11}, 3^{18}, 1^{12}, 2^{18}, 1^{6}, 1^{25}, 3^{9}, 3^{11}, 1^{15}, 1^{6}, 1^{11}, 1^{21}, 1^{11}, 1^{25}, 1^{30}, 1^{11}, 1^{129}, 1^{48}, 1^{32}, 1^{70}, 1$ |
| | L4 | 8529 m | 32 | $2^{12}, 1^{15}, 1^{18}, 3^{7}, 1^{6}, 1^{6}, 1^{5}, 5^{4}, 4^{4}, 2^{12}, 1^{9}, 2^{10}, 1^{5}, 1^{6}, 3^{9}, 3^{5}, 1^{27}, 2^{9}, 1^{7}, 2^{4}, 2^{27}, 1^{21}, 1^{26}, 1^{6}, 1^{15}, 1^{32}, 2^{24}, 1^{13}, 2^{6}, 2^{71}, 1^{51}, 1$ | 24 | $1^{23}, 2^{53}, 1^{23}, 1^{10}, 1^{27}, 2^{20}, 2^{8}, 1^{6}, 3^{22}, 1^{8}, 1^{25}, 2^{7}, 1^{15}, 4^{21}, 2^{21}, 1^{17}, 1^{11}, 1^{30}, 2^{6}, 1^{149}, 1^{51}, 1^{59}, 1^{67}, 1$ |
| | L4 | 9890 m | 35 | $1^{6}, 1^{28}, 1^{7}, 1^{14}, 2^{7}, 1^{4}, 1^{4}, 2^{4}, 8^{4}, 1^{4}, 1^{19}, 1^{7}, 2^{9}, 1^{4}, 1^{7}, 5^{11}, 1^{16}, 1^{12}, 1^{4}, 1^{10}, 2^{4}, 1^{6}, 2^{38}, 1^{14}, 1^{43}, 1^{10}, 1^{7}, 1^{11}, 3^{8}, 1^{40}, 1^{18}, 1^{10}, 1^{45}, 1^{25}, 1$ | 29 | $1^{18}, 2^{59}, 1^{25}, 1^{8}, 1^{33}, 2^{17}, 1^{7}, 3^{8}, 1^{14}, 1^{12}, 1^{10}, 1^{19}, 1^{7}, 1^{7}, 1^{11}, 2^{12}, 1^{9}, 1^{19}, 2^{29}, 1^{14}, 1^{8}, 1^{10}, 1^{10}, 1^{26}, 1^{136}, 1^{57}, 1^{77}, 1$ |

Key: B: bike, L: lap, R: run, S: swim, T1: first transition, T2: second transition. Superscripts denote time gap to next athlete in seconds, where it exceeds or equals 4 s.

## Results

### Overview

Sixty three percent of the male and 91% of the female field finished within the cut-off time (at 5% and 8% of the winner, respectively) for awarding of world ranking points.

### Pack formation

The number of packs that formed in the two fields at various points of the race is illustrated in Table 1. The time gaps between successive males differed between when they exited the water at the end of the first and second swim laps ($p < 0.02$), between the end of T1 and bike lap 1 ($p < 0.01$), between the end of run laps 1 and 2 ($p < 0.02$), and between run laps 2 and 3 ($p < 0.05$). In females, the time differences between successive athletes did not differ between consecutive event stages (ns).

Pack formation differed between the leading 32 males and females at both swim exits ($p < 0.02$ and $p < 0.05$, respectively), at the end of T1 ($p < 0.05$), at the end of bike laps 1—3 (all $p < 0.05$), and at the end of the first, second and third run laps ($p < 0.05$, $p < 0.02$, $p < 0.02$, respectively). These 'time-gap' differences no longer existed in the swim and bike when only the leading 25 athletes were compared. They were maintained within the run section up until nine competitors (the number in the lead female group at the run start) were examined.

### Swimming performance

Speed over the first 222 m of the swim was faster than between any other swim timing points (all $p < 0.02$ or less) in males (Table 2). It was faster than between 222 and 496 m in females ($p < 0.01$). The males who attained the first bike pack at the swim end swam faster over the first 222 m than those who did not ($1.41 \pm 0.04$ versus $1.35 \pm 0.03$ m s$^{-1}$, $p < 0.01$). Their average positions at 222 m were $21 \pm 13$ versus $40 \pm 11$, respectively ($p < 0.01$). Although they also swam faster over other swim sections, the average position of the males who made it into the first bike pack and those who did not only changed again (to $23 \pm 16$ versus $52 \pm 13$, $p < 0.05$) when they went over the equivalent section (i.e. from the pontoon back to the first buoy) of the second swim lap. Those who got into the first bike pack finished the swim within

**Table 2** Average speeds (m s$^{-1}$ for swimming and running, km h$^{-1}$ for cycling) and correlations of speed with overall finishing position for the entire race field over specific stages of the Lausanne 2002 ITU World Cup triathlons

| | Section | Speed | | *r* | |
|---|---|---|---|---|---|
| | | Males | Females | Males | Females |
| Swim | 0—222 m | 1.39 ± 0.01 abcdef | 1.21 ± 0.06 a | −0.42** | −0.49*** |
| | 222—496 m | 1.27 ± 0.00 aghij | 1.19 ± 0.01 bcd | −0.44** | −0.27 |
| | 496—693 m | 1.26 ± 0.00 bgklm | 1.24 ± 0.01 bde | −0.38** | −0.45*** |
| | (693 + 20) to 1385 m | 1.27 ± 0.00 chk | 1.14 ± 0.01 ace | −0.33** | −0.42** |
| | (693 + 20) to 915 m | 1.29 ± 0.07 dno | — | −0.42** | — |
| | 915—1189 m | 1.24 ± 0.04 eilnp | — | −0.302* | — |
| | 1189—1385 m | 1.27 ± 0.03 fjmop | — | −0.23 | — |
| Bike | Lap 1 (0—6.7 km) | 37.60 ± 0.51 | 35.51 ± 0.17 fg | −0.20 | −0.71** |
| | Lap 2 (6.7—13.4 km) | 37.88 ± 0.41 | 35.71 ± 0.15 hi | −0.47** | −0.74** |
| | Lap 3 (13.4—20.1 km) | 39.16 ± 0.16 ab | 35.51 ± 0.17 jk | −0.49** | -0.63** |
| | Lap 4 (20.1—26.8 km) | 38.58 ± 0.16 cd | 35.27 ± 0.17 l | −0.51** | −0.72** |
| | Lap 5 (26.8—33.5 km) | 37.64 ± 0.31 ace | 34.87 ± 0.12 fhj | −0.31* | −0.69** |
| | Lap 6 (33.5—40.2 km) | 37.97 ± 0.10 bdf | 34.47 ± 0.13 gikl | −0.58** | −0.63** |
| Run | 0—993 m | 5.33 ± 0.03 abcdef | 4.55 ± 0.22 mnopq | −0.71** | −0.63** |
| L1 | 993—2420 m | 5.16 ± 0.03 bghij | 4.43 ± 0.20 rs | −0.74** | −0.61** |
| L2 | 2420—3505 m | 5.07 ± 0.03 c | 4.41 ± 0.03 mt | 0.84** | −0.65** |
| L2 | 3505—4932 m | 5.01 ± 0.03 dg | 4.34 ± 0.18 nu | −0.82** | −0.56** |
| L3 | 4932—6017 m | 5.00 ± 0.03 eh | 4.35 ± 0.03 osv | −0.87** | −0.66** |
| L3 | 6017—7444 m | 4.96 ± 0.03 fi | 4.28 ± 0.18 prw | −0.81** | −0.44** |
| L4 | 7444—8529 m | 4.95 ± 0.03 j | 4.31 ± 0.03 qx | −0.83** | −0.61** |
| L4 | 8529—9890 m | 5.07 ± 0.03 | 4.46 ± 0.03 stuvwx | −0.59** | −0.22 |

** $p < 0.01$, * $p < 0.05$, letters (a—x) significantly different, within the specified triathlon discipline in the same sex, at the $p < 0.05$ level.

102.49 ± 1.40% (i.e. within 13.6 ± 8.5 s) of the best swimmer's time and were up to 29 s behind him at the swim end. The females who made it into the first and second packs at the end of bike lap 1 finished the swim within 101.14% and 102.90% of (i.e. 13—33 s behind), the first swim finisher.

## Cycling performance

Average speed in the males, both overall and in each pack, increased over the bike until 20.1 km (lap 3) (Fig. 1) It then decreased until 33.5 km (lap 5), and increased in the final bike lap (Fig. 1). The difference in average speed in males who were in packs 1 or 2 in lap 1 and those in pack 3 approached significance ($p < 0.06$). Those male swim finishers who had not made it into packs 1 or 2 in lap 1 cycled faster than those who had over laps 2 and 3 ($p < 0.05$). Between 13.4 and 20.1 km the field came together—83% of the males were in one group by the end of lap 3 (Table 1). The first and second males at the bike end had 'made' gaps of 20 and 31 s, by the end of laps 5 and 6, respectively, to the next athletes. This lead over the main pack was maintained through T2 but decreased to 2 s by the end of run lap 1, when the maximum time gap between consecutive athletes in the top 32 was 4 s. No males who had been in the 4th or 5th pack in bike lap 1 continued racing after T2.

The time-gaps between the first and second female packs at T1 end widened to 24 and 57 s after bike lap 1. These time-gaps did not subsequently decrease at any time within subsequent laps—instead they moved up the field (Table 1). Pack formation in females did not then change between successive bike laps (ns). The females who were in pack 3 in bike lap 1 increased speed until 20.1 km but had neither attained the speeds of, nor reached, packs 1 or 2 by the end of bike lap 3 (Fig. 2). They cycled slower than those who did, over every lap (all $p < 0.05$) except lap 2. Although average speed tended to decline over the bike after lap 1, the average rate of decay in cycling speed after lap 3 did not differ between females who had been in different packs in bike lap 1 (ns) (Fig. 2).

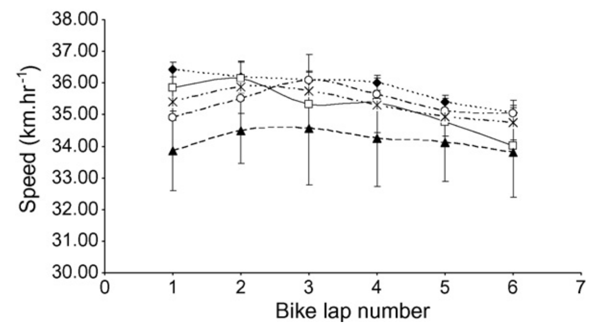


**Fig. 2** Speed (average ± S.E. (km $h^{-1}$)) over each bike lap by pack number to which the athletes belonged in bike lap 1: females. (♦) First pack ($n = 10$); (□) second pack ($n = 8$); (▲) third pack ($n = 4$); (○) fourth pack ($n = 2$); (⋇) fifth pack ($n = 8$).

## Running performance

Position at the bike end did not differ between males who had been in packs 1 or 2 in lap 1, and males who had been in pack 3 (22.7 ± 14.0 versus 36.1 ± 16.5, ns) (Fig. 1). All except one started the run within 35 s of each other. No differences were seen between athletes who had been in the first or second pack in bike lap 1, and those who had attained either pack by lap 3, either in rank at the bike end or running speed (Fig. 3, ns) but the top 50% of finishers ran faster than the bottom 50% over every run section (all $p < 0.01$). Speeds over the first 993 m were faster than over the other sections (Table 2, all $p < 0.01$).

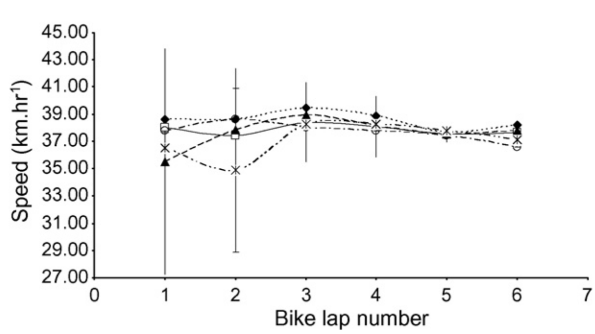


**Fig. 1** Speed (average ± S.E. (km $h^{-1}$)) over each bike lap by pack number to which the athletes belonged in bike lap 1: males. (♦) First pack ($n = 40$); (□) second bike pack ($n = 4$); (▲) third bike pack ($n = 15$); (○) fourth pack ($n = 2$); (⋇) fifth pack ($n = 5$).

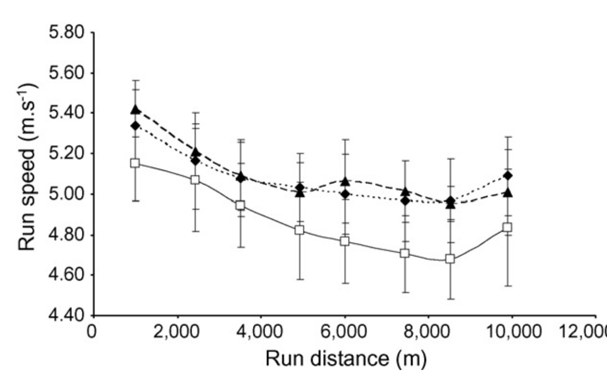


**Fig. 3** Run speed (average ± S.E. (m $s^{-1}$)) by pack number in bike lap 1: males. (♦) First pack; (□) second pack); (▲) third bike.

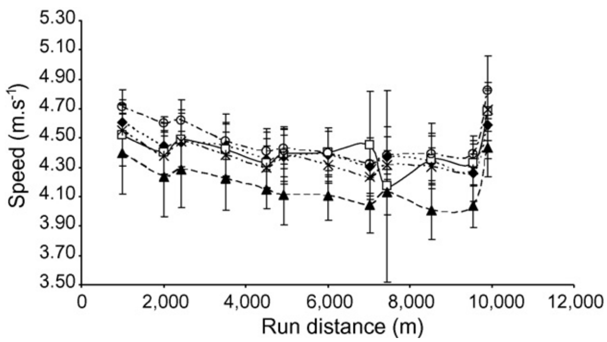


**Fig. 4** Run speed (average ± S.E. (m $s^{-1}$)) by pack number in bike lap 1: females. (♦) First pack ($n$ = 10); (□) second pack ($n$ = 8); (▲) third bike pack ($n$ = 4); (◯) fourth pack ($n$ = 2) ; (✳) fifth pack ($n$ = 8).

The females had separated out into four main groups at the end of T2 (Fig. 4, Table 1). The top 50% of finishers ran faster than the bottom 50% in each individual run stage (all $p < 0.05$) except between 6017—7024, 7024—7444, and 9536—9890 m (all ns). The females' running speeds were faster over the first 993 m of the run (all $p < 0.01$) than over all the other measured run sections except the last 354 m (ns) (Table 2).

## Relationships between discipline specific and overall performance

Speed over the first 222 m of the swim correlated with final swim and race finishing position in males ($r = -0.88$ and $-0.42$, both $p < 0.01$) and females ($r = -0.97$ and $-0.49$, both $p < 0.01$). Speed between the first swim exit and back to the first buoy at metre 915 of lap 2 also correlated with eventual swim ($r = -0.68$, $p < 0.01$), and race placing, in males ($r = -0.42$, $p < 0.05$). No comparative female data were available. However, the grouping of female athletes differed between the first swim exit and the swim end (Table 1, $p < 0.01$).

Athletes' offset from the fastest swimmer at the swim finish influenced which pack they attained in bike lap 1 ($r = 0.81$ in males and $r = 0.93$ in females, both $p < 0.01$), bike finishing position (both $r = 0.41$, $p < 0.01$) and race finishing position ($r = 0.39$ in males and $r = 0.47$ in females, both $p < 0.01$). Being in the second pack at the end of bike lap 1, instead of the first, did not affect finishing position (45.8 ± 16.7 versus 26.9 ± 18.0 in males and 15.5 ± 7.6 versus 9.1 ± 8.8 in females, both ns). Those females who made it into either packs 1 or 2 at the end of bike lap 1 attained a higher race finishing position than those in packs 3 and 4 (12.6 ± 8.5 versus 24.5 ± 9.1, $p < 0.01$). The same applied for bike lap 2, where finishing positions of 8.0 ± 6.1 versus 16.9 ± 9.3, respectively ($p < 0.05$) were seen. Finishing position did not differ between males who were in packs 1 or 2 in bike laps 1 or 2 and males who had only made it there by lap 3 (23.0 ± 14.3 versus 28.6 ± 14.9, ns).

Speed over bike lap 1 (Figs. 1 and 2) was important for overall performance in females ($r = -0.71$, $p < 0.01$) but not males ($r = -0.20$, ns) (Table 2). Bike speeds over the second and last bike lap were more important for overall finishing position in females (Table 2). Average bike speed correlated more strongly with finishing position in females than males ($r = -0.74$ versus $-0.42$, both $p < 0.01$).

T2 time correlated better with finishing position in females than males ($r = -0.81$ and $-0.57$, respectively, both $p < 0.01$). Finishing position correlated better with running speed in males ($r = -0.94$, $p < 0.01$) than females ($r = -0.61$, $p < 0.01$). Although the males ran fastest over the first 993 m of the run ($p < 0.01$) the strength of the correlation between running speed and finishing position for this section ($r = -0.71$, $p < 0.01$) was not markedly different from that seen for various other sections (Table 2). In females, the correlation between speed over the first 993 m of the run and finishing position was, at $-0.62$ ($p < 0.01$), similar to those for several other run sections where they ran slower (Table 2). Running speed between the last 8529 and 9890 m correlated better with finishing position in males ($r = -0.59$, $p < 0.01$) than females ($r = -0.22$, $p < 0.05$).

## Discussion

This study investigated whether sex differences existed in pacing during, and the importance for overall finishing position of performance in, specific sections of an ITU World Cup competition. We extended our finding that speed over the first stage of a non-wetsuit swim is important for performance in males[3] to females, and obtained data to suggest that speed back to the first buoy in the second lap of a two lap swim may also affect race performance in males. The extent to which level of adjustment to T0 can affect performance over swim lap 2,[10,11] remains to be seen.

Our results indicated that bike performance may be more important for overall race performance in elite females than elite males. Although data was not obtained for this section in isolation, examination of the race videos suggested that the critical point at which fragmentation of the bike field occurred was within one kilometre of T1 (agreeing with Ackland, 2001),[12] over a hill of 10—15% gradient. This point is supported by SRM data obtained from two Olympic Squads over the Lausanne 2005 course (Bürgi and Vleck, unpublished data). Differences between the sexes in average speed and number of riders in each bike group (Figs. 1 and 2, Table 1), may also have meant that females experienced less of the potential benefits of drafting[9] (i.e. less decrease in drag, and less 'energy saving') over the bike,[13–15] than males.

Our data (Table 1) suggested that females do not tend to 'bridge gaps' in the cycle section. The decline in bike speed that they exhibited over successive sections of the course (Fig. 2), regardless of pack number, is interesting. Anecdotal evidence (Fernandes and Santos, Portuguese Triathlon Federation, personal communications, 2006) suggests that this pacing is characteristic of elite females but we do not know whether it is deliberate or reflects fatigue.[1,2,16] Although females in packs 3 and 4 in lap 3 cycled faster until lap 3, presumably attempting to bridge the gap to packs 1 and 2, all four packs experienced similar rates of decay in speed over the rest of the bike (Fig. 2). Without obtaining details of the 'performance power'[3,17] of the athletes in each group (via heart rate and SRM data and or visual analogue scales of perceived exertion administered immediately post-race), it is not clear what effect the pack a female athlete was in had on her fatigue levels at the run start.[9,16,18] Nor do we know the extent to which their swimming performance affected the ability of the stronger female cyclists to be in the leading bike pack, and thus the relative advantage that was perceived by a following pack in attempting to reach it.

However, in line with Millet and Bentley (2004)'s suggestion,[4] that 'female athletes who have the capacity to limit the negative effects of intensive cycling may have a better advantage than other athletes,' the females narrowed the sum of time gaps between successive athletes after T2 from that which existed between the last two bike laps (Table 1). The premise that the stronger female cyclist may be relatively more at a competitive advantage than the male has clear training implications. This is particularly so as speed over the remaining run did not then appear to influence overall performance in females as much as in males (Table 2). Whether this applies to ITU World Cups in general (where the males are not necessarily all entering T2 at similar times) should be investigated.

Little has been published regarding optimal pacing strategy over the run section of ITU World Cups. Given the importance of this part of the race for the overall result, particularly in males, it is worthwhile noting that most athletes ran faster over the first 993 m than most other run sections (Table 2, Figs. 3 and 4). This echoed results obtained for both sexes in the Lausanne 2001 World Cup triathlons (Bürgi and Vleck, unpublished data), but no clear benefit of this strategy for finishing position was evidenced (Table 2). Whether maintaining a more even pace, or use of a negative split strategy, over the duration of the run,[19] might be preferable, is worth investigating.

It remains to be seen to what extent differences between elite males and females competing over the same course in both pacing, and in the relative importance of performance in each discipline for overall placing, reflect different relative swimming, T0, T1, cycling, T2 and running abilities. The extent to which such findings hold as field composition (as expressed by QFF or the world rankings of the athletes) changes between races also warrants attention. Anecdotal evidence (Bürgi, Swiss Olympic, 2005, personal communication) suggests that only the top 15 male and female athletes in the rankings may be equivalent in terms of relative ability in each discipline. We question the extent to which the changes in field composition that occur between races affect spacing at the swim end and pack formation in bike lap 1,[12] and thus the relative importance of performance in each discipline for race finishing position, in the two sexes.

The extent to which the athletes are 'spaced' at the swim end will influence the number who may then form a bike 'draft pack'[20,21] and the work required by each to reach the leading pack(s). This will affect the number who can attain the group—since the power required of each will be successively higher up to an individual metabolic limit.[22] How many athletes are in the group will then influence both average speed of, and the energy savings experienced by athletes within, said group.[9,13] This may then affect the level of fatigue[1,23] experienced at the run start and the number of competitors who will finish within the cut-off time for ranking points. Whether elite males are more similar to each other in biking ability than elite females, and whether this makes the influence of spacing at the swim end on pack formation greater in males, is of great interest. The (generally) smaller field sizes in female ITU World Cups may compound any negative effects that differences that they exhibit from males in relative swimming, cycling and running ability are having on their ability to benefit from drafting. If females are also relatively weaker in terms of power/weight ratio (and ability to 'climb')[14] they may be further disadvantaged relative to the males by the locating of hills within kilometer one of the bike course.[24–26]

Of additional interest is the fact that in this specific race, whether a male athlete was in the first, second or third bike pack at the end of bike lap

1, did not appear to significantly affect his later running performance (Fig. 3). This result may be related to whether or not the best cyclists in the field were all in the top group at the swim end (Bürgi, Swiss Olympic, 2005, personal communication) or, rather, had to 'come from behind.'

## Conclusion

Our results, although they need to be confirmed by further competition analysis, suggest that the elite females with better swimming and cycling ability than the rest of the field may incur a relatively greater competitive advantage at the run start than occurs in elite male competition. The (normally) smaller field size, lower field density, and lower racing speeds, of females in ITU World Cup competitions may additionally disadvantage them relative to males in both their possibilities to draft and the drafting distance that they are likely to achieve to the next competitor. Although the ITU adjusts the number of ranking points that are awarded for a particular finishing position in ITU World Cups according to which competitors are racing, it is not clear whether the combination of the current 'QFF' and 'cut-off point' system fully accounts for differences either in field size or in relative swimming, cycling and running ability that might exist within or between the sexes. Nor is sufficient data yet available for an athlete to use knowledge of the 'start-list', and both inter- and intra-athlete variability in performance[27] to anticipate where/when packs might form on the course[22] and thus 'how best to pace.'

### Practical implications

Performance in Elite triathlon might be maximised through

- training to swim fast up to, and maintaining a steady pace after, the first buoy of each swim lap.
- relatively more focus on development of cycling ability in females than is generally required in males.
- use of a more even run pacing strategy.

## Acknowledgements

This study was funded by grants awarded to Mssrs. Brügger, Schlapbach and Martin. We gratefully acknowledge the ITU, Mr. Thomas—the race director, Dr. Pfützner and Mr. Möller of the Institute of Applied Training Science, Leipzig; Mr. Schoberer (Schoberer Rad Messtechnik, Jülich, Germany), and the Olympic Squad triathletes, coaches and doctors [most especially Mr. Schuwey (SUI) Dr. Noack (SUI), and Mr. Santos (POR)], who participate in our research, for their support.

## References

1. Bentley DJ, Millet GP, Vleck VE, et al. Specific aspects of contemporary triathlon: implications for physiological analysis and performance. *Sports Med* 2002;**32**:345—59.
2. Swain DP. A model for optimizing cycling performance by varying power on hills and in the wind. *Med Sci Sports Exerc* 1997;**29**(8):1104—8.
3. Vleck V, Bűrgi A, Bentley DJ. The consequences of swim, cycle and run performance for overall result in elite Olympic distance triathlon. *Int J Sports Med* 2006;**27**: 43—4.
4. Millet GP, Bentley DJ. The physiological responses to running after cycling in elite junior and senior triathletes. *Int J Sports Med* 2004;**25**:191—7.
5. Garland SW. An analysis of the pacing strategy adopted by elite competitors in 2000 m rowing. *Br J Sports Med* 2005;**39**:39—42.
6. Chatard JC, Chollet D, Millet G. Performance and drag during drafting swimming in highly trained triathletes. *Med Sci Sports Exerc* 1998;**30**:1276—80.
7. Chatard JC, Wilson B. Drafting distance in swimming. *Med Sci Sports Exerc* 2003;**35**:1176—81.
8. Delextrat A, Tricot V, Bernard T, et al. Drafting during swimming improves efficiency during subsequent cycling. *Med Sci Sports Exerc* 2003;**35**:1612—9.
9. Hausswirth C, Lehénaff D, Dreano P, et al. Effects of cycling alone or in a sheltered position on subsequent running performance during a triathlon. *Med Sci Sports Exerc* 1999;**31**(4):599—604.
10. Hausswirth C, Vallier C, Vallier JM, et al. Effect of two drafting modalities in cycling on running performance. *Med Sci Sports Exerc* 2001;**33**(3):485—92.
11. Faria EW, Parker DL, Faria IE. The science of cycling: factors affecting performance—Part 2. *Sports Med* 2005;**35**(4):313—37.
12. Chollet D, Hue O, Auclair F, et al. The effects of drafting on stroking variations during swimming in elite male triathletes. *Eur J Appl Physiol* 2000;**82**(5/6):413—7.
13. Zamparo P. Effects of age and gender on the propelling efficiency of the arm stroke. *Eur J Appl Physiol* 2006;**97**:52—8.
14. Ackland J. Pack formation in cycling and orienteering. *Nature* 2001;**413**:127.
15. McCole SD, Claney K, Conte JC, et al. Energy expenditure during bicycling. *J Appl Physiol* 1990;**68**(2):748—53.
16. Davison RC, Swain D, Coleman D, et al. Correlates of simulated hill climb cycling performance. *J Sports Sci* 2000;**18**(2):105—10.
17. Palmer GS, Borghouts LB, Noakes TD, et al. Metabolic and performance responses to constant-load vs. variable-intensity exercise in trained cyclists. *J Appl Physiol* 1999;**87**(3):1186—96.
18. Abbiss CR, Laursen PB. Models to explain fatigue during prolonged endurance cycling. *Sports Med* 2005;**35**(10):865—98.
19. Nevill AM, Jobson SA, Palmer GS, et al. Scaling maximal oxygen uptake to predict cycling time-trial performance

in the field: a non-linear approach. *Eur J Appl Physiol* 2005;**94**(5/6):705—10.

20. Atkinson G, Brunskill A. Pacing strategies during a cycling timetrial with simulated headwinds and tailwinds. *Ergonomics* 2000;**43**(1):1449—60.
21. Millet GP, Vleck VE. Physiological and biomechanical adaptations to the cycle-run transition in 'Olympic triathlon': review and implications for training. *Br J Sports Med* 2000;**34**:384—90.
22. Ackland J. The effect of pack formation at the 2005 world orienteering championships. *Sci J Orienteer* 2005;**17**(12).
23. Olds T. Modeling road cycling performance. *J Appl Physiol* 1995;**78**(4):1596—611.
24. Olds T. The mathematics of breaking away and chasing in cycling. *Eur J Appl Physiol* 1998;**77**(6):492—7.
25. Fukuba Y, Whipp BJ. A metabolic limit on the ability to make up for lost time in endurance events. *J Appl Physiol* 1999;**87**(2):853—61.
26. Noakes TD. Physiological models to understand exercise fatigue and the adaptations that predict or enhance athletic performance. *Med Sci Sports Exerc* 2000;**10**:123—45.
27. Paton CD, Hopkins WJ. Competitive performance of Elite Olympic distance triathletes: reliability and smallest worthwhile enhancement. *Sportscience* 2005;**9**(1/5), available at www.sportsci.org/jour/05/wghtri.htm, accessed September 26, 2006.