Effect of two drafting modalities in cycling on running performance

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[1]Laboratoire de Biomécanique et de Physiologie, Institut National du Sport et de L'Education Physique (INSEP), 75012 Paris, FRANCE; [2]Unité Ergonomie sportive et performance, Université de Toulon, 83957 La Garde, FRANCE; [3]Queensland Triathlon, AUSTRALIA; [4]Faculté des Sciences du Sport, Université de Montpellier, and [5]French Triathlon Federation, Boulouris, FRANCE

ABSTRACT

HAUSSWIRTH, C., J-M. VALLIER, D. LEHENAFF, J. BRISSWALTER, D. SMITH, G. MILLET, and P. DREANO. Effect of two drafting modalities in cycling on running performance. *Med. Sci. Sports Exerc.*, Vol. 33, No. 3, 2001, pp. 485–492. **Purpose:** The purposes of this study were first to compare the physiological responses during a triathlon where cycling was performed alternatively with another cyclist (alternate draft triathlon, ADT) or continuously behind him (continuous draft triathlon, CDT), and second to study the incidence of these two drafting modalities in cycling on the subsequent running performance done during a simulated triathlon. **Methods:** Ten male triathletes of national level performed a sprint distance triathlon (0.75-km swim, 20-km bike, 5-km run) on two different sessions, one where the triathlete alternatively rode in front or at the back of another cyclist and rotating every 500 m, the other where the triathlete drafted continuously a professional cyclist whose task was to reproduce all split times recorded during the alternate situation. Oxygen uptake ($\dot{V}O_2$), expiratory flow ($\dot{V}E$), heart rate (HR) were recorded during the entire bike and run sections and blood lactate concentrations ($[La^-]_b$) were analyzed at the end of each event composing the triathlon. **Results:** The results showed that expiratory flow, oxygen uptake, heart rate and blood lactate concentrations were significantly lower in CDT on the bike compared with drafting in alternation (148.1 vs. 167.2 $L \cdot min^{-1}$, 49.9 vs. 59.8 $mL \cdot min^{-1} \cdot kg^{-1}$, 154.7 vs. 173.1 $beats \cdot min^{-1}$, 3.5 vs. 6.3 $mmol \cdot L^{-1}$, respectively). The results also revealed that running after biking in CDT (for similar cycling speeds) significantly improved the subsequent running speed compared to ADT (17.87 vs. 17.15 $km \cdot h^{-1}$). Furthermore, $\dot{V}E$, $\dot{V}O_2$, HR, and $[La^-]_b$ were significantly higher during CDT run compared with ADT run (175.6 vs. 170.4 $L \cdot min^{-1}$, 69.7 vs. 66.8 $mL \cdot min^{-1} \cdot kg^{-1}$, 182.6 vs. 177.3 $beats \cdot min^{-1}$, 9.6 vs. 7.5 $mmol \cdot L^{-1}$, respectively). **Conclusions:** These results showed that drafting continuously behind a lead cyclist allows triathletes to save a significant amount of energy during the bike leg of a sprint triathlon and creates the conditions for an improved running performance compared with a situation where cycling is performed alternating the lead with another cyclist. **Key Words:** TRIATHLETES, SHELTERED POSITION, OXYGEN UPTAKE, PEDALLING RATE, STRIDE RATE

Because of the important energy requirement to overcome wind resistance in several activities, the benefits of drafting behind a leader have been investigated by several researchers. Indeed, the effects of wind resistance on the energy demand have been well documented in swimming (1,5), cycling (8,16,18), running (18,22,23), cross-country skiing (3), speed skating (27), and more recently in triathlon (14).

Moreover, the emergence of new sports, such as triathlon (swimming-cycling-running), has led scientists and coaches to raise various questions about the physiological and/or biomechanical characteristics regulating these new disciplines. Widely perceived as an endurance sport, triathlon apparently shares much with long-distance running (14,17) but also claims its own specificity (20). As an example, one may assume that the present evolution of triathlon tending to systematize draft-legal races (group riding) during the bike leg of a triathlon (whereas until recently triathlon was considered as a pure individual sport) modifies the energy expenditure of cycling and therefore incidentally alters the overall performance of the subsequent run (14). These authors indicated recently that running after riding in a drafting position (for a similar bike speed) significantly improved the running speed as compared with the no-draft modality. Because of the generalization of drafting in cycling during international triathlon events (e.g., Olympic games) and the various race strategies now induced, it is important that triathletes know the effects of pacing up with another cyclist in order to save energy for the consecutive run. Thus, the present study investigates the physiological responses of

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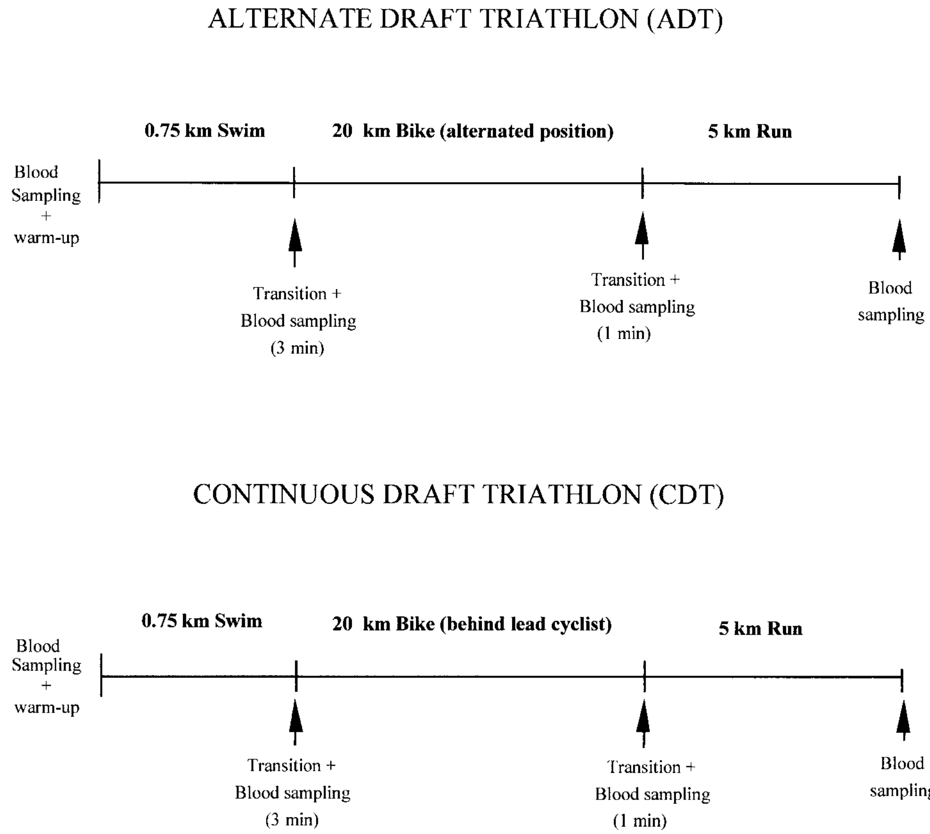

FIGURE 1—Protocol of experiment.

riding alternatively or continuously behind another cyclist during a sprint triathlon.

Specifically, the aims of the present study were: i) to compare the energy cost of riding in alternation or in continuous behind another cyclist during the bike leg of a sprint triathlon, and ii) to compare the physiological differences (heart rate, oxygen uptake, expiratory flow, lactatemia), the evolution of pedaling and stride rates, and the differences in subsequent running performance between the proposed race sessions (alternate draft triathlon vs continuous draft triathlon).

MATERIAL AND METHODS

Subjects

Ten well-motivated French male triathletes participated in this study. They were fully informed of the content of the experiment and provided written consent. They were selected on the basis of their performance time over the Olympic distance triathlon (116 ± 4 min). The triathletes were familiarized with all cycling and running circuits of the experiment: a light training program was conducted before and during the experiment, and the subjects had not performed any exhausting exercise in the 48 h preceding each test. The triathletes appeared to be extremely motivated, and, in that case, the precise order of the experiments did not affect the results of the study due to motor skills learning or a lack of motivation. Mean age was 25.6 ± 4.1 yr (20–31). Mean body weight and height were 67.2 ± 4.4 kg and 175.6 ± 8.1 cm, respectively. Average training distance per week were 15.7 km in swimming, 335 km in cycling, and 66.3 km in running. These data are in accordance with others recorded in previous studies (15,20).

Maximal Oxygen Uptake ($\dot{V}O_{2max}$) Evaluation

After a 48-h restriction from strenuous physical activity, each of the 10 triathletes performed a continuous, incremental running test on a 340-m indoor running track. The test began with a warm-up at 12 $km \cdot h^{-1}$ (3.3 $m \cdot s^{-1}$) for 10 min, and the running speed was increased by 1 $km \cdot h^{-1}$ (0.27 $m \cdot s^{-1}$) every 2 min until volitional exhaustion. A ring signal was given to the triathletes every 20 m to keep the required pace at each stage. During this incremental exercise, oxygen uptake ($\dot{V}O_2$), minute ventilation ($\dot{V}E$), respiratory rate (RR), and respiratory exchange ratio (RER) were continuously measured every 15 s using a previously validated telemetric system (13) collecting gas exchanges (Cosmed $K4_{RQ}$, Rome, Italy). The criteria used for the determination of $\dot{V}O_{2max}$ were: a plateau in $\dot{V}O_2$ despite an increase in running speed, a RER above 1.1, and a heart rate (HR) over 90% of the predicted maximal HR (1). $\dot{V}O_{2max}$ retained was the average of the last three highest $\dot{V}O_2$ values recorded. It amounted on average to 73.3 ± 5 $mL \cdot min^{-1} \cdot kg^{-1}$. The maximal aerobic running speed (MAS) was the highest speed completed for 2 min (20 ± 1.2 $km \cdot h^{-1}$; 5.5 $m \cdot s^{-1}$). The data collected indicated that the subjects studied were representative of triathletes (20).

Protocol and Experimental Procedures

All experiments (Fig. 1) were carried out in Paris, precisely at the French National Institute of Sport and Physical Education (I.N.S.E.P.). The study was conducted on indoor cycling and running tracks. Inside air temperatures ranged from 14 to 16°C. The two experimental triathlons were performed over the sprint distance (0.75-km swim, 20-km bike, 5-km run) with a 3-d recovery between them. The swim was staged on an indoor 50-m pool (24–25°C). The 20-km bike course was conducted on an indoor cycling track (166 m) next to the pool. The 5-km run was staged inside the cycling track, on a synthetic running track (150 m). All triathletes had to perform both tests one by one; they always started with the alternate draft triathlon (ADT), which they were instructed to complete as fast as possible. During the first 3-km of the bike in the ADT situation, the triathlete had to reach the speed to be maintained during the last 17 km. During the entire bike course (ADT situation), the triathlete alternatively rode in front or at the back of another cyclist, rotating every 500 m and keeping the reached speed always constant. A ring signal at each half-lap (83 m) indicated precisely the speed he had to keep. The speed of the last 17-km was the one conducted from the second to the third kilometer, considering therefore that the two first kilometers was the distance necessary to reach a constant speed. The subsequent 5-km run was performed all-out. During the swim of the continuous draft triathlon (CDT), triathletes had to respect their ADT swim times, being informed at each 50 m of their pace by visual and ring signals. During the bike leg of the CDT, each triathlete drafted a professional road cyclist of comparable frontal projection, whose task was to respect all split times recorded during the ADT by the triathlete they were sheltering. Finally, the run section of the CDT was left free, the only instruction given to the performing triathlete being to run as fast as possible during the entire 5 km. In addition, no feedback was given to the triathlete about his running velocity. He had to perform his run section alone without any outside information like he did in the ADT situation. During both triathlon tests athletes could drink 250 mL at each of the two transitions (swim-to-bike and bike-to-run).

Measurement of Respiratory Gas Exchanges

The oxygen uptake ($\dot{V}O_2$) and expiratory flow ($\dot{V}E$) were recorded continuously for all bike and run sections by means of a gas exchange telemetric system (Cosmed $K4_{RQ}$). This system had previously been experimentally validated (13) in a protocol comparing it with a standard laboratory system (CPX, Medical Graphics, Saint-Paul, MN). The calculation of the energy cost of running (Cr) is usually performed using the formula given by Di Prampero (9): The 0.083 (in $mL \cdot kg^{-1} \cdot s^{-1}$) is $\dot{V}O_2$ value corresponding to the y-intercept of the $\dot{V}O_2$–speed relationship established in young male adults (19).

During the experiment, the respiratory data were stored every 15 s. Furthermore, heart and pedalling rates were recorded by Polar Electro Cyclovantage computers (Anglet, France) positioned on each athlete and bike. All frequency meters were calibrated before the start of the experiment to integrate the body mass of the subjects in the calibration system determining instantaneous racing speeds. The heel strike was recorded by an Alcyon contact device (Alcyon Electronique, Beynes, France) placed in the runner's right shoe and the stride rate per lap was calculated afterward.

TABLE 1. Time performances obtained during each session; values are means (± SD).

	Alternate Draft Triathlon (ADT)	Continuous Draft Triathlon (CDT)	ANOVA Situation
Swim (0.75 km)	618 ± 25 s	614 ± 20 s	NS
Bike (20 km)	1758 ± 31 s	1765 ± 26 s	NS
Run (5 km)	1049 ± 21 s	1008 ± 33*	$P < 0.01$

Significantly different from the corresponding ADT value, * $P < 0.01$.

Blood Sampling

Capillary blood samples were collected from subjects' earlobes in 25-μL heparinized capillary tubes at the following moments: before and after each incremental running test, and at the end of the swim and bike legs of the experimental triathlons. Blood lactate concentration was then assayed by an enzymatic method (2).

Statistical Analysis

The global statistical analysis to appreciate the evolution of all studied parameters in relation to the various moments and types of exercise identified (alternate draft triathlon (ADT), continuous draft triathlon (CDT)) was performed by means of a two-way analysis of variance plan, ANOVA (2 × 3). The comparison of variables between the experimental conditions was conducted with Student's *t*-test for paired samples. All values are expressed as mean ± standard deviation (SD). In all statistical tests the level of significance was set at $P < 0.05$.

RESULTS

Performances

Swim times (t_s) were 618 ± 25 s and 614 ± 20 s for ADT and CDT, respectively. HR values reached 172 ± 7 $beats \cdot min^{-1}$ for ADT and 170 ± 11 $beats \cdot min^{-1}$ for CDT. Postswim blood lactate values $[La^-]_b$ were 8.7 ± 0.6 $mmol \cdot L^{-1}$ for ADT and 8.5 ± 0.7 $mmol \cdot L^{-1}$ for CDT. No significant difference between the two swim legs was recorded for any of the studied parameters (t_s, HR, La). Performances in cycling and running are represented in Table 1. The significant increase in running speed was +4.2% for CDT vs ADT.

Ventilatory Parameters and Heart Rate

Cycling. The analysis of variance showed a global effect of exercise type ($P < 0.01$) on $\dot{V}O_2$ (Fig. 2-A) and HR (Fig.

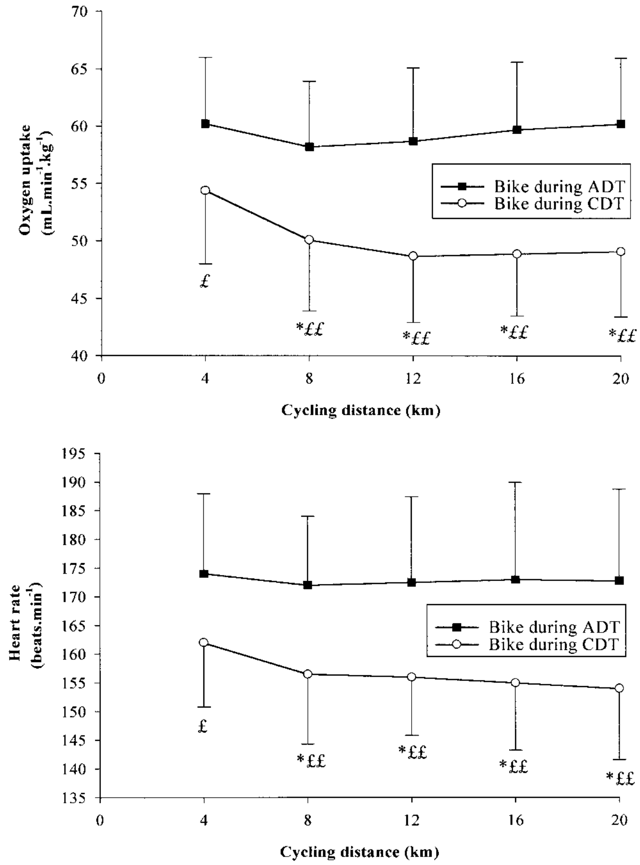

FIGURE 2—A, Changes in oxygen uptake values obtained during the bike section of the alternate draft triathlon (ADT) vs the continuous draft triathlon (CDT). B, Changes in heart rate values obtained during the bike section of ADT vs CDT. Significantly different from the initial value, * P < 0.05. Significantly different compared with the corresponding ADT value, £ P < 0.05, ££ P < 0.01.

2-B). Mean values every 4 km were significantly higher at all times for ADT compared with CDT, for both $\dot{V}O_2$ and HR. Furthermore, mean values ($\dot{V}O_2$, HR) at km 8, 12, 16, and 20 of the CDT bike section were significantly lower than the mean initial values at km 4 ($P < 0.05$). Overall mean values of $\dot{V}O_2$ and HR for the entire 20-km bike course of both triathlon trials are shown in Table 2. We noted a significant decrease for both $\dot{V}O_2$ and HR between ADT and CDT (−16.5% and −10.6%, respectively). With regard to ventilation, mean bike $\dot{V}E$ values were significantly higher for ADT compared with CDT (Table 2).

Running. Mean $\dot{V}O_2$ and HR values for km 1, 2, 3, 4, and 5 were significantly lower for ADT compared with CDT ($P < 0.01$) (Figs. 3-A and 3-B, respectively). Mean $\dot{V}O_2$ and HR values for the two runs (ADT, CDT) are shown in Table 2. The ADT run elicited values significantly lower ($P < 0.01$) than those collected during CDT. In terms of percentages, $\dot{V}O_2$ was higher during CDT compared with ADT (+6.2%). In the same way, mean HR was higher during CDT compared with ADT (+2.4%). Finally, mean $\dot{V}E$ proved significantly higher during CDT compared with ADT ($P < 0.01$).

Blood Lactate Concentrations

A summary of cycling and running values is presented in Table 2. No significant difference was observed between the CDT and ADT swims. The comparison of bike blood lactate values clearly showed that CDT $[La^-]_b$ was significantly lower than ADT $[La^-]_b$ (3.5 mmol·L^{-1} and 6.3 mmol·L^{-1} respectively, $P < 0.01$). And CDT $[La^-]_b$ proved significantly higher than ADT $[La^-]_b$ ($P < 0.05$) during the runs.

Pedalling Rate

The results are reported on Table 2. The pedalling rate was at all times lower during CDT compared with ADT situation ($P < 0.01$).

Stride Rate and Stride Length

The results are showed on Fig. 4. The stride rate was significantly higher during the first km of ADT run compared with the first km of CDT run ($P < 0.05$). No significant difference was found for the last stages of the two runs (i.e., from the second km to the fifth km, $P > 0.05$). An inverse relationship was recorded for the stride length: the stride length was significantly shorter immediately at the

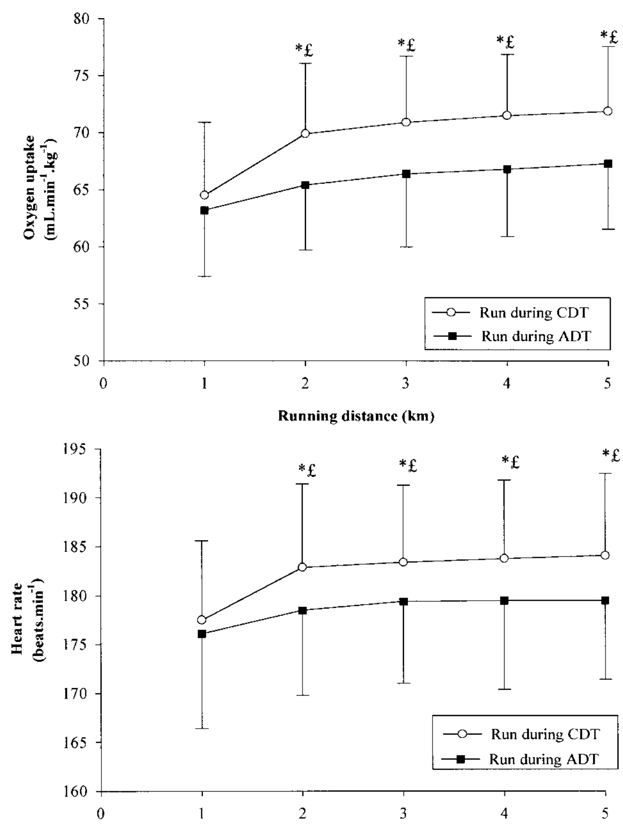

FIGURE 3—A, Changes in oxygen uptake values obtained during the run section of the alternate draft triathlon (ADT) vs the continuous draft triathlon (CDT). B, Changes in heart rate values obtained during the run section of ADT vs CDT. Significantly different from the initial value, * P < 0.05. Significantly different from the corresponding ADT value, £ P < 0.05, ££ P < 0.01.

TABLE 2. Mean speed, oxygen uptake, expiratory flow, heart rate, and blood lactate concentration during the alternate draft triathlon (ADT) and the continuous draft triathlon (CDT); values are means (± SD).

Parameters	Alternate Draft Triathlon (ADT)		Continuous Draft Triathlon (CDT)		ANOVA
	Bike	Run	Bike	Run	Situation
Speed ($km \cdot h^{-1}$)	40.95 ± 0.7	17.15 ± 0.5	40.79 ± 0.7	17.87* ± 0.6	$P < 0.01$
Oxygen uptake ($mL \cdot min^{-1} \cdot kg^{-1}$)	59.8 ± 6.1	66.8 ± 4.1	49.9* ± 5.3	69.7** ± 3.9	$P < 0.01$
Expiratory flow ($L \cdot min^{-1}$)	167.2 ± 11.2	170.4 ± 6.4	148.1* ± 9.8	175.6* ± 6.1	$P < 0.01$
Heart rate ($beats \cdot min^{-1}$)	173.1 ± 10.2	177.3 ± 6.1	154.7* ± 10.4	182.6* ± 5.8	$P < 0.01$
Lactatemia ($mmol \cdot L^{-1}$)	6.3 ± 0.4	7.5 ± 0.5	3.5* ± 0.2	9.6* ± 0.6	$P < 0.01$
Pedalling rate ($rev \cdot min^{-1}$)	102 ± 6.2		85* ± 5.8		$P < 0.01$

Significantly different from the corresponding ADT value, * $P < 0.01$, ** $P < 0.05$.

beginning of the ADT run compared with CDT run ($P < 0.05$).

DISCUSSION

The main findings of the present study emphasize that in drafting situation in cycling (i) a high benefit is obtained during a continuous drafting position behind a lead cyclist compared with an alternate drafting situation, and (ii) triathletes have a higher gain in subsequent running performance when the previous cycling event is performed in a continuous drafting situation versus an alternate drafting situation.

Benefits and Drafting Modalities

The first interesting finding of this study was that drafting continuously behind a lead cyclist lowered oxygen uptake ($\dot{V}O_2$, −16.5%, $P < 0.01$), HR (−11.4%, $P < 0.01$), expiratory flow ($\dot{V}E$, −10.6%, $P < 0.01$) and blood lactate concentrations ($[La^-]_b$, −44%, $P < 0.01$) in comparison with drafting in alternation with another cyclist. To our knowledge, drafting during a cycling section composing a sprint triathlon is not well scientifically documented. Only a recent study (14) proposed the first scientific contribution to characterize the impact of drafting during the bike leg of a sprint triathlon (0.75-km swim, 20-km bike, 5-km run) accomplished in field environment. The results of this previous study comparing the evolution of physiological parameters during a cycling session done alone or behind a cyclist at the same pace showed a decrease of $\dot{V}O_2$ (−14%, $P < 0.01$), HR (−7.5%, $P < 0.01$), and $\dot{V}_E$ (−30.8%, $P < 0.01$) for the drafted cycling session compared with cycling alone for a mean cycling speed of 39.5 $km \cdot h^{-1}$. Although the cycling speed in our present study was slightly higher (40.9 $km \cdot h^{-1}$) in both alternate draft triathlon (ADT) and continuous draft triathlon (CDT), the triathletes were able to reduce their energy cost of cycling in a continuous drafting situation versus alternate situation (−16.5%): this reduction was less important when we compared a continuous drafting situation to an isolated cycling session (−14% (14),). This obvious discrepancy, confirmed by heart rate values (−11.4% vs −7.5% for Hausswirth et al. (14) study), cannot be explained by the level of performance of the triathletes tested. Indeed, in both studies the maximal oxygen uptake values recorded firstly were similar (range from 70 to 80 $mL \cdot min^{-1} \cdot kg^{-1}$) and the mean performance time over an Olympic distance triathlon was also quite similar (less than 2 h in both studies). Therefore, we explain the high benefit obtained in terms of oxygen uptake and heart rate as follows: the bike leg of the proposed triathlons in our study (CDT and ADT situations) was performed on a cycling track where all environmental parameters were controlled (no wind, constant cycling speed, no gradient on the track). The high difference recorded in terms of $\dot{V}O_2$ (−16.5% in CDT vs ADT) could be then explained by the easier way to reach 40 $km \cdot h^{-1}$ on a wood cycling track compared with a road including slight uphill (see (14)). This hypothesis is confirmed by the HR and $\dot{V}O_2$ values obtained in the first 4km of the bike section, i.e., immediately after the swim. Contrary to the previous study (14), we observed a steady-state at the beginning and along the bike section may be because of the no-gradient cycling circuit and the constant cycling speed performed. The authors highlighted that in field conditions triathletes were probably less efficient at drafting during the initial phase of the cycling section.

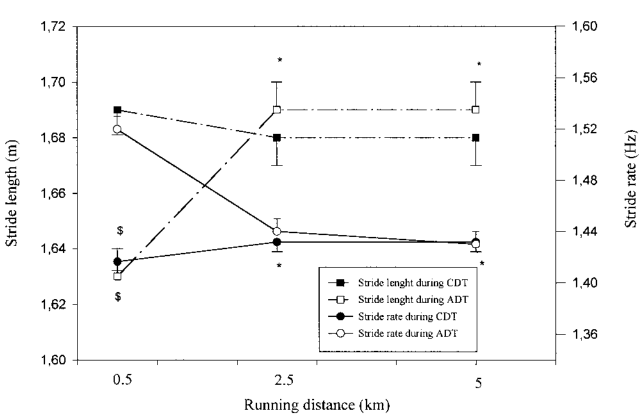

FIGURE 4—Changes in stride length and stride rate values obtained during the run section of the alternate draft triathlon (ADT) vs the continuous draft triathlon (CDT). Significantly different from the initial value, * $P < 0.05$. Significantly different from the corresponding ADT value, £ $P < 0.05$.

The lower oxygen uptake and heart rate values obtained during the bike leg of CDT vs ADT may be explained not only by the drafting position adopted by the athletes but also by the pedalling frequencies used during cycling (see Table 2). The results showed that on the cycling track and at the same speed, the triathletes of the present study adopted higher freely chosen cadence during ADT (102 rpm) compared with CDT situation (85 rpm, $P < 0.01$). Moreover, this cadence stayed constant along the 30 min of cycling. The lower pedalling cadence obtained during CDT was associated with lower oxygen uptake vs ADT situation. However, previous studies have demonstrated an obvious conflict between the most energetically optimal cycling cadence (EOC) (i.e., minimum oxygen uptake for a given power output (21)) and the higher freely chosen cadence (FCC) used by competitive cyclists (7,11,26). This result has been recently confirmed in triathletes pedalling at different cadences ranging from 50 to 110 rpm (including FCC) at 80% of maximal power (P_{max}) (4). According to this study, the relationship between optimal cadence and energy cost of cycling in triathlon could be influenced by several constraints such as the exercise intensity, exercise duration, and drafting conditions. If the FCC was associated with higher energy cost of cycling at the beginning of the 30-min exercise, the authors showed however not only an increase in energy cost for all cadences when exercise ended but also a shift in the EOC toward FCC with exercise duration. Although the bike exercise duration was 30 min in our study, we did not find a shift of the FCC at the end. A number of reasons could explain this result: first, the bike segment was part of a sprint triathlon (i.e., previous 0.75-km swim) and not an isolated event (4,7); second, the triathletes performed the cycling session on a cycling track, whereas the previous studies (4,7) were using ergocycles in laboratory conditions; and third, in our study, the triathletes rode alternatively or continuously with another cyclist while other studies were manipulating cyclists (7) or triathletes (4) one by one. Moreover, the lower lactate values recorded after the CDT bike section (3.5 mM vs 6.3 mM in ADT) highlighted that drafting continuously behind a lead cyclist involved mainly the aerobic component, whereas alternate drafting certainly involves an aero-anaerobic glycolysis component due to the physiological variations proposed by the exercise modality itself. However, if blood lactate concentrations obtained after a continuous drafting situation (14) did not differ from those recorded in our study in the CDT modality (3.5 mM vs 4.0 mM (14)), the ADT situation seemed to induce lower lactate values than an isolated cycling section performed at a quite similar cycling speed during a sprint triathlon (6.3 mM vs 8.4 mM (14)): this result could enable the triathlete to save energy to prolonged the exercise either for cycling (same exercise modality) or for a different discipline (e.g., running).

Effects on Running Performances

The second main finding of the present study was that running performance proved better (+4.2%, $P < 0.01$) in the CDT modality, compared with the ADT modality.

Obviously, there is a lack of scientific results on cycling in field conditions (in contrast with laboratory situations) and most studies originate from running. However, only few studies have investigated the relationship between the energy cost of running (Cr), defined as the energy required to transport the subject's body over one unit of distance (9), and the incidence of previous cycling event done before. Results from earlier studies (10,12) showed a higher energy cost of running at the end of an Olympic triathlon than that for a control run performed at the same pace. However, for these studies, the Cr values remained constant throughout the triathlon run. In our experiment, $\dot{V}O_2$ and HR values (Fig. 2-A, 2-B) during CDT run were constant from the second to fifth km: these values were higher than ADT run values ($P < 0.01$). However, $\dot{V}O_2$ and HR values recorded during the first km of the CDT and ADT runs were not significantly different. This could be explained by the higher running speed the triathletes choose immediately after the CDT cycling event compared with the following 4 km of the run. The lower anaerobic solicitation at the end of CDT cycling compared with ADT cycling (3.5 mM vs 6.3 mM, respectively) associated with a lower energy cost of cycling during CDT cycling (−16.5%) obviously induced a high energy saving: this allowed the triathlete to adopt a higher running speed at the beginning of the CDT run compared with ADT run. The improvement of the run split times for all triathletes in CDT compared with the run performed in ADT has been similarly recorded with short-track skaters (25) who improved their best performance in an isolated sprint distance test in short-track skating, performed after a 4-min drafting situation behind a pack of skaters. The data observed in this recent study demonstrated that a skater who had the opportunity to draft off other skaters before a sprint event is able to achieve a better performance than when alternate draft or no-draft was proposed. The results of our study showed an improvement of +4.2% in terms of running speed in CDT versus ADT run. However, we did not observe any significant difference in the energy cost of running between the two situations (CDT: 234.0 mL of $O_2 \cdot min^{-1} \cdot km^{-1}$ and ADT: 233.7 mL of $O_2 \cdot min^{-1} \cdot km^{-1}$). These values are in accordance with Cr values previously observed during a sprint triathlon (14), an experiment where the run section was performed immediately after a continuously sheltered or isolated cycling trial. However, in contrast with this recent study that demonstrated nonsignificantly different lactate values after the various run sections, the high blood lactate concentration recorded after the different runs in our experiment was associated with a high level of performance during the run (CDT: 9.6 mM and ADT: 7.5, $P < 0.01$, see Table 2). However, because triathletes did not have to exert as hard in CDT cycling phase versus in ADT cycling phase, they probably pushed themselves harder in the subsequent running section. This could partly explained the more elevated lactate values recorded after the CDT run versus ADT run. All triathletes of our study took benefits of the continuous drafting position in cycling. This induced better performance times in the consecutive run. Moreover, the higher expiratory flow values obtained in CDT run versus ADT run ($+5\ L \cdot min^{-1}$) could be partly explained by the respective +4.3% increase in oxygen uptake stemming from an enhanced oxygen flow to the active muscle (6,24). It is suggested that as resistance increases, more energy is needed to generate sufficient tension in the muscles to obtain the pressures required for airflow to occur while some energy is also used to prevent deformation of the chest wall during increased work.

Another important result of the present study is the obvious necessity to implement drafting techniques and positions into triathlon racing strategy to save energy for the final run associated with the stride length triathletes adopted immediately after the bike leg (see Fig. 4). At the beginning of the ADT run, the stride was significantly shorter compared with the CDT run value (1.63 m vs 1.68 m, respectively). We suggest that the shorter stride observed could be linked to the high pedalling rate triathletes chose during the entire ADT bike, and that, a relationship might exist between the increase of stride rate and the previous high pedalling rate values. However, the pedalling rate could influence the stride rate only during the first part of the run, as evidenced by the lack of change in stride length and stride rate recorded from the 2nd km to the 5th km run. A previous study (12) have shown stride length to be 5 cm shorter during an overground triathlon in comparison with an isolated run done at the same speed. As the results recorded in our experiment, the authors underlined that if the stride length was shorter during the initial phase of the triathlon run, there was a specific adaptation of the triathlete to adopt high stride length values from 15 min of the run section. This induced no significant difference in terms of stride length between the triathlon run and the isolated run until the end of the run (45-min run). We confirmed that for high trained triathletes, the stride length alteration recorded during the first stage of the run should be influenced by the exercise done before (i.e., cycling). However, similar stride length values were obtained from the middle to the end of the final run section of both triathlons (CDT and ADT), suggesting with exercise duration the triathlete adopted spontaneously the same pattern of locomotion, i.e., the one eliciting the same lowest energy cost of running.

CONCLUSION

The results of the present investigation indicate that the benefit of drafting modalities in cycling is important for the subsequent running performance in triathlon. Drafting continuously behind a cyclist corresponds to a large reduction of energy demand whereas drafting in alternation with him leads to high oxygen uptake values related to the ability of changing their position alternatively in front or at the back of this cyclist. These two drafting modalities proposed are often used by the triathletes when drafting is allowed (e.g., world cups, Olympic games). The results demonstrated that drafting continuously behind a cyclist improves the subsequent running performance compared with an alternative lead position with the rider off of whom they are drafting. Finally, for high-trained triathletes who are familiarized with drafting technique in training and triathlon races, the run performance depends on the previous cycling event (drafting modality, pedalling rate) but appealed the same energy cost of running in a sprint triathlon.

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