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Physiological adaptation during short distance triathlon swimming and cycling sectors simulation

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Abstract

The aim of this study was to typify cardiorespiratory and metabolic adaptation capacity at race pace of high-level triathletes during simulations of short distance triathlon swimming sector, first transition and cycling sector. Six national and international-level triathletes performed a 1500 m swimming trial followed by a transition and one hour on ergocycle at race pace, with sequenced measures of blood lactate concentration, gas exchange and heart rate recording.

The mean speed obtained in the swimming sector was 1.29 ± 0.07 m s^{-1}, matching $98 \pm 2\%$ of MAS (Maximal Aerobic Speed), lactate concentration 6.8 ± 2.1 mM and heart rate 162 ± 15 beats min^{-1}. In the cycling sector, the mean power was 266 ± 34 W, matching $77 \pm 10\%$ of MAP (Maximal Aerobic Power), oxygen uptake 3788 ± 327 mL min^{-1} (82.8% of VO_{2max}), heart rate 162 ± 13 beats min^{-1} (92% of maximal HR) and ventilation 112.8 ± 20.8 L min^{-1}. MAS was correlated with performance in swimming sector ($r = 0.944$; $P < 0.05$). Despite intake 1.08 ± 0.44 L of a solution with 8% of sugars, a significant loss of body weight (2.80%; $P < 0.01$) was observed. Changes in cycling power, speed and frequency, especially towards the end of the effort, were also found. By contrast, differences in lactate concentration and in cardiorespiratory or metabolic variables between the end of the swimming sector and the end of the first transition did not appear.

In conclusion, this study remarks different relative intensities in cycling and swimming sectors. The observed loss of body weight does not modify pedalling economy in national and international-level athletes during the cycling sector, where effort intensity adapts itself to the one found in individual lactate threshold. However, changes in competition tactics and other effects, such as drafting in swimming and cycling, could alter the intensities established in this study for each sector.

Keywords: Short distance triathlon; Race pace; Movement economy; Energetic metabolism

1. Introduction

The short distance triathlon is a recently created sports category that made its official debut in the 2000 Sydney Olympic Games. This category must not be understood as three activities (swimming, cycling and running) that are performed separately but as three activities linked by two transitions (T_1, T_2) and resulting in a continuous and long endurance effort.

Several studies [8,18,16] have stated a decrease in performance towards the end of the trial and one of these [18] have suggested a possible loss in movement economy all along the short distance triathlon. It seems that the running sector suffers a residual effect caused by swimming and cycling sectors that, associated with a central temperature increase and a loss in the homeostasis of hydroelectrolytic balance, provokes an increase of energetic demands [18,23,24]. Due to the specific effects of cycling, these physiological modifications become more noticeable at the

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start of the running race. Specifically, Hue et al. [24] observed that the concatenation of ergocycle and running race efforts caused a remarkable increase in ventilatory response, as well as in CO_2 pulmonary diffusing capacity, setting off respiratory musculature fatigue and/or a pulmonary interstitial edema. This group [23] has also observed, during transition into the running race (T_2), a series of changes in metabolic and cardiorespiratory parameters (with respect to a control test) that provokes a higher energetic cost with lower ventilatory efficiency. This decrease in ventilatory efficiency was firstly suggested to be caused by respiratory changes recorded during long endurance exercise [23], especially hypoxia induced by exercise [5]. However, it was secondly demonstrated to be specific to both the transition in itself (i.e., the cycle to run transition) [24] and the performance level, since the best triathletes have a lower energetic and mechanical cost in the running race sector [35] and may have developed specific adaptation to the transition [25].

Moreover, these alterations concur with muscular discomfort probably related to differences in movement frequency observed in the cycling sector (1.5–2 Hz) respect to the running race sector (1.0–1.5 Hz). In addition, muscular activation, mainly concentric while pedalling, becomes eccentric in the running race sector [24].

Most triathlon studies analyze the second transition (T_2). Only one recent report [12], although not focused on sports reality, have carried out research on the physiological consequences of the first transition (T_1), despite their recognized tactical relevance [8,16].

The aim of the present study was to typify, among a group of national and international level athletes, cardiorespiratory and metabolic adaptation (at race pace) during short distance triathlon swimming sector, first transition and cycling sector simulations.

2. Material and methods

2.1. Subjects

Six male triathletes, involved in their competitive period, volunteered for the study, which was approved by the Sant Cugat del Vallés (Barcelona) High Performance Center (CAR) ethical committee. Triathletes were international ($n=4$) and national ($n=2$) level. Training and competition experience was 6.3±3.8 yearlong and the age was 25.3±4.2 year-old. At the time of the study, weekly training distances were 23 Km for swimming, 250 Km for cycling and 60 Km for running race. The results in the 2001 national championship were 1:57:24 h±0:01:54 h with a difference in their performance of 7.5±2.6% in relation to the national champion (5th place in the Sydney Olympic Games).

2.2. Physical conditioning evaluation

The following tests were performed at the Sant Cugat del Vallés CAR:

2.2.1. Kinanthropometric assessment

Fat percentage and muscular mass determinations were carried out following the four-compartment method described by Drinkwater and Ross [14]. Anthropometrical measurements were performed following the Ross and Marfell–Jones methodology [48], using a skinfold caliper (John Bull, England), a flexible and non-extendable metallic anthropometrical belt, an anthropometer (Holtain L TD, England) and a sliding caliper (Holtain LTD, England).

2.2.2. Determination of swimming Maximal Aerobic Speed (MAS)

Swimming MAS was assessed in a 25 m covered swimming pool, following a Lavoie and Leone modified protocol [31]. After a 500 m warm-up, at a cadence about 80–90% of the MAS and a 5–10 min passive pause, a continuous test, at 3.8 km h^{-1}, is started. It will increase its speed 0.1 km h^{-1} every two minutes until exhaustion. An acoustic system composed by two loudspeakers connected to a PC (with an Excel 95 calculation sheet where the test was programmed) was used to impose speed and guide triathletes. The trainer walked along the border of the swimming pool, marked at 5 m intervals, coinciding with the acoustic signals. All along the carrying out of the test, heart rate (XtrainerPlus®, Polar, Finland), stroke frequency (s min^{-1}) and timings every 50 m were recorded. Distance per stroke was calculated in meters per stroke (m s^{-1}). Lactate concentration 5 min after the end of the effort was determined in a portable lactate analyzer (Lactate Pro®, Arkray, Japan) [44]. For this analysis blood samples were taken from the ear lobe.

2.2.3. Determination of ergocycle Maximal Aerobic Power (MAP)

It was carried out on an electromagnetic brake ergocycle (Cardgirus®, Spain), following a Padilla et al. [42,43] modified protocol. After a 10 min warm-up at 100 W, 4 min long rectangular stages with no pause and 30 W risings are carried out until exhaustion. Ventilatory frequency (BF), volume stream (VT), O_2 exhaled fraction (FEO_2), CO_2 exhaled fraction ($FECO_2$), ventilation exhaled fraction (VE), respiratory quotient (RQ) and oxygen uptake (VO_2) were measured all along the test in real time by means of a Quark PFT® (Cosmed, Italy) pulmonary gas exchange system, breath by breath. Blood lactate concentration ([La^-]) was measured during the last 15 s of each rectangular stage and 3 and 5 min after finishing the test. MAP was calculated as the mean value developed in the last 4 min of effort. In this protocol VO_{2max} was defined as the highest VO_2 obtained in a 60 s-interval previous to reaching a plateau. A plateau of VO_2 was identified if the VO_2 of the latest stage was not greater than the previous one by 1.75 mL kg^{-1} min^{-1} [34]. When subjects did not reach a VO_2 plateau, VO_{2max} was defined as the highest 60-s oxygen uptake value reached during this incremental test with a respiratory exchange ratio greater than 1.0 ($RER=VCO_2/VO_2$) [37], and a peak HR at least equal to 95% of the age-predicted maximum [51]. Ventilatory threshold was determined using the "V-Slope" method [1]. Finally, evolution of lactate concentration in relation to the developed power complied with a second order polynomial equation, permitting the determination of individual lactate threshold (ILT) as suggested by Roecker et al. [46].

2.3. Experimental test

The experimental protocol consisted in swimming 1500 m in a 25 m covered swimming pool, followed by a fast transition running 100 m and finishing with a 1 h effort on the electromagnetic brake ergocycle (Cardgirus®, Spain). All subjects carried out the test between 7–10 days after determination of MAS and MAP. During the two days previous to the experimental test subjects were instructed to perform low intensity exercise, so that they came rested. Subjects were instructed in order to develop competition intensity all along the simulation (Fig. 1). Furthermore subjects were continuously encouraged to follow the individual swimming race pace.

In the swimming sector timing and stroke frequency was recorded every 50 m. Measures of blood lactate concentration at the end of the effort (and after transition) were also recorded, in this case with the individual already on the ergocycle. During cycling sector simulation, mechanical power (W), pedalling frequency (rpm) and heart rate (HR) were measured. In addition, VO_2, VE and $[La^-]$ were monitored, all along the simulation and breath by breath. Cardiorespiratory variables were calculated averaging the last 2 min at 10, 15, 30, 45 and 60 min; blood concentration lactate was also sampled at the end of each one of those time intervals. Moreover, during testing on ergocycle, triathletes averaged an ingesta of 1080±442 ml of sugared water at 8% (Just-aid2®, Spain), environment conditions during the test were a room temperature of 23.2±0.8 °C and a relative humidity of 48.5±9.4%. Respiratory variables, HR and blood lactate were measured using previously described methodology.

2.4. Statistical analysis

All results were expressed as mean±standard deviation (SD). Differences among cardiorespiratory, metabolic and mechanical variables were studied by means of ANOVA with repeated measures when there were more than two measurements, or by means of a paired Student's t test when there were only two measurements. Significance level was determined at $P<0.05$ for all carried out statistical tests. SPSS software pack and EXCEL.00 calculation sheet were used as tools for statistical analysis.

3. Results

3.1. Physical evaluation

Results concerning with triathletes' physical condition parameters appear in Tables 1–3.

3.2. Competition simulation: swimming sector

Swimming sector average values are represented in Table 4.

A collateral finding of the present study has been the relation between the MAS swimming test and the performance on the 1500 m experimental swimming test. Even though the sample of the study was small but quite homogeneous (1.33±0.08 m s^{-1}) a significant correlation between the swimming sector speed mean and the previous MAS (r=0.944; $P<0.05$) was observed (Fig. 2).

3.3. Competition simulation: cycling sector

Results concerning with the cycling sector are represented in Tables 5 and 6 (lactate values).

Power average in this sector was 266±34 W, equal to 77±10% of MAP. Pedalling rate averaged 99±3 rpm and the ergocycle calculated an average speed of 38.0±1.6 Km h^{-1}.

Mechanical power output values remained nearly constant all along the 44 first minutes of the exercise, not showing significant differences. In contrast, there was a significant increase at the end of effort. On the other hand, significant differences for VO_2, VE and HR were not found although there was observed a progressive rise in all three parameters all along the test.

3.4. First transition (T1)

The value of lactate at the end of the swimming sector was 6.8±2.1 mM, similar to the one at the end of T_1 (6.6±1.8 mM). In addition, during the cycling sector $[La^-]$ results did not show significant differences in relation to the ones of the ends of the swimming sector and T_1. Anyway, in this last sector lactate kinetics tend to decrease until min 45 and to rise towards the end of the test (Table 6). It is a remarkable fact that power output followed the same tendency. On the other hand, significant differences were not observed between HR values in the swimming sector (162±15 beats min^{-1}) and in the beginning of the cycling one (161±14 beats min^{-1}), equivalent to the end of the T_1.

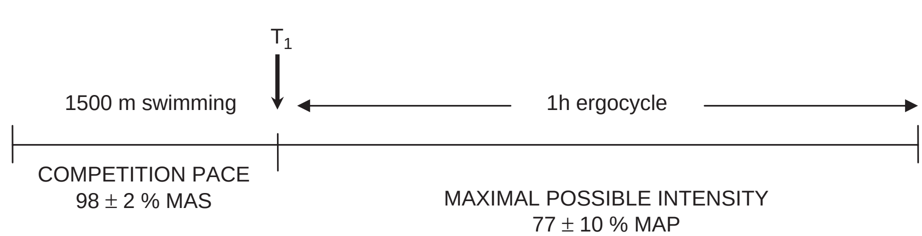

Fig. 1. Experimental test.

Table 1
Morphological characteristics (mean ± SD)

Physical characteristics	Mean ± SD
Weight (kg)	69.9 ± 4.6
Height (cm)	175.2 ± 4.5
Six skinfolds sum (mm)	38.9 ± 5.7
Fat (%)	7.6 ± 0.6
Muscular (%)	49.8 ± 1.4

Skinfolds: triceps, subscapular, abdominal, supraspinale, front thigh and medial calf; SD: standard deviation.

Furthermore, these values did not vary along the cycling sector.

Finally, a significant 2.8% loss in body weight all along the experimental protocol (71.7 ± 3.7 vs. 69.7 ± 3.4 Kg; $P < 0.001$) was also remarked.

4. Discussion

Results from this study showed that the link in triathlon's cycling and swimming sectors, far from resulting in a nearly 80 minute homogeneous effort, means differentiated relative effort intensities for each sector. In that sense, maximal aerobic power percentage, as well as blood lactate concentration at the end of the swimming sector show a tendency to increase, although not significant differences respect to one recorded in the cycling sector were found. On the other hand, HR values on the swimming sector show no significant differences with those ones on the cycling sector, probably due to a low decrease on the economy and its consequent HR drift [35].

The results found in the swimming simulation trial show a higher performance in relation to other studies [12,19,49], where triathletes showed lower swimming speed (1.18; 1.17 and 1.16 m s^{-1}, respectively). The main reason for this underlies in the swimming pool length, distance and swimming relative intensity. Swimming pool length has an important effect on metabolical and biomechanical variables that has to be taken into account when comparing results from different studies. In this way, studies made in a 25 m swimming pool [49], can directly be compared with those from this study, while those made in a 50 m swimming pool need to be reinterpreted [7,9,11]. In fact, swimming in a 25 m swimming pool results more efficient than doing it in a 50 m one. More concretely, due to the extra turns made in a 25 m swimming pool, blood lactate and HR are significantly lower than those measured in a 50 m one, swimming in both cases at the same relative intensity. It has also been noted that these differences get more significant as the intensity increases, except for the HR, than remains similar for maximal speeds. With regard to biomechanical variables, it has been noted that for increasing relative speeds, stroke lengths gets significantly higher in a 25 m swimming pool that in a 50 m one. No differences on the stroke rate had been observed [57,27]. On the other hand, comparing this study results with those corresponding to elite-swimmers, they turn out to be significantly lower than the ones found in three 2000 Sydney Olympic Games 1500 m final swimmers (41.8 ± 3.3 c min^{-1} and 2.4 ± 0.2 m c^{-1}). As well as the swimming pool length's effect previously mentioned, these differences are probably caused by a better aquatic-versatility (higher stroke frequency and distance per stroke) [11] in elite-swimmers. Furthermore, for the same metabolic power, elite-swimmers are able to apply more mechanical power than triathletes in order to propel themselves [28,54]. This higher propelling efficiency is determinant in swimming performance [52]. This disadvantage, which causes a significant energetic cost all along the triathlon, could be minimized in competition. It has been remarked that the use of drafting tactics in triathlon shows a 3.2% performance improvement, for a 400 m distance, with a 3.4% stroke frequency reduction and an increase in distance per stroke frequency of 6.2% [6,9]. Another tactic strategy is the use of a wet suit that reduces aquatic resistance by 16% for a 1.25 m sec^{-1} speed [7,53]. It also amplifies the coordination mode of the triathletes without modifying stroke rate, recovery phase or leg movements [22].

On the other hand, the relation between the MAS swimming test and the performance on the 1500 m found in the current study suggests that the use of MAS could be a tool for planning training intensities, as it has been proposed for middle and long-endurance athletes [32,46]. Some authors [40,36] have also found that MAS is much more related to performance in these categories than VO_{2max}. This relation can be explained by the fact that MAS is a variable

Table 2
Swimming MAS and ergocycle MAP test results (mean ± SD)

Swimming MAS		
MAS (m s^{-1})		1.33 ± 0.08
HR (beats min^{-1})		168 ± 12
F_{Stroke} (s min^{-1})		35.9 ± 6.2
D_{Stroke} (m s^{-1})		3.16 ± 2.76
$[La^-]_{max}$ (mM)		6.4 ± 1.4
Ergocycle MAP		
VO_{2max}	(ml kg^{-1} min^{-1})	64.7 ± 5.7
	(l min^{-1})	4.6 ± 0.3
MAP	(W)	345 ± 14
	(W kg^{-1})	4.9 ± 0.3
$[La^-]_{max}$ (mM)		8.8 ± 1.5
HR_{max} (beats min^{-1})		176 ± 14

MAS: maximal aerobic speed; HR: heart rate; SF: stroke frequency; DS: distance per stroke; $[La^-]_{max}$: maximal blood lactate concentration; VO_{2max}: maximal oxygen uptake; MAP: maximal aerobic power; $[La^-]_{max}$: maximal blood lactate concentration; SD: standard deviation.

Table 3
Submaximal ergocycle adaptation results (mean ± SD)

	ILT	2 mM	4 mM	V-Slope
MAP (%)	76 ± 4	74 ± 4	83 ± 5	81 ± 4
Power (W)	273 ± 38	266 ± 39	298 ± 40	290 ± 27
HR (beats min^{-1})	150 ± 14	148 ± 13	157 ± 11	155 ± 10
$[La^-]$ (mM)	2.4 ± 0.1	2.0 ± 0.0	4.0 ± 0.0	3.3 ± 1.1

MAP (%): maximal aerobic power percentage; ILT: individual lactate threshold; 2 mM: 2 mM blood lactate concentration; 4 mM: 4 mM blood lactate concentration; V-Slope: ventilatory threshold; SD: standard deviation.

Table 4
Swimming simulation trial (1500 m) results (mean ± SD)

	S (m s^{-1})	MAS (%)	F_{Stroke} (s min^{-1})	D_{Stroke} (m s^{-1})	[La$^-$]$_n$ (mM)	[La$^-$]$_{T1}$ (mM)	HR (beats min^{-1})
X	1.29	98	37.2	2.09	6.8	6.6	162
SD	0.07	2	3.2	0.18	2.1	1.8	15
Range	1.23–1.40	95–101	33.3–41.8	1.82–2.30	3.9–8.9	4.1–8.4	142–182

S: speed; MAS: maximal aerobic speed; F_{Stroke}: stroke frequency; D_{Stroke}: distance per stroke; [La$^-$]$_n$: blood lactate concentration at the end of swimming sector; [La$^-$]$_{t1}$: blood lactate concentration at the end of T1; HR: heart rate; SD: standard deviation.

in witch two factors interact: movement economy and VO_{2max}. Both factors are determinant in performance in middle and long-endurance activities [3]. In the light of these facts, determining MAS in swimmers and triathletes through a continuous, multistage and maximal test could be a more adequate functional assessment tool than other proposals, such as a 400 m free style swimming trial [47]. Furthermore, a triangular test offers a greater reliability than a 400 m trial in order to establish VO_{2max} [32]. With the latter, the highest correlation between 400 m performance and VO_{2max} in elite swimmers is $r = 0.80$ [45,10], while other authors [56] have not found significant correlations. Furthermore, performance in a 400 m all-out trial reaches a lower relation than the MAS trial with regard to 1500 m performance found by this study ($r = 0.84$, $P < 0.04$) [26]. In this line, future studies are necessary in order to confirm the relation between MAS in swimming, competition performance and its applicability to triathlete and swimmer training.

It must be remarked the fact that during transition towards the ergocycle effort, blood lactate concentration after the swimming effort and the one prior to the cycling effort show no significant differences. The reason for this could be that blood samples were gathered just as triathletes got on the ergocycle, giving no time to observe values for the 3rd and 5th minute and their logical evolution [15]. Another explanation would be that intensities at the end of the swimming sector and during T_1 are very similar, so that T_1 causes no increase in energy production with regard to swimming. In consequence, no significant decrease in VO_2 intake during T_1 is produced. That is the reason why any changes in lactate concentration could be observed. This involves a differential fact with regard to T_2, where Hue et al. [24] have suggested that anaerobic glycolysis takes part in energy production in order to provide the increase in energetic demands after finishing the cycling effort and starting the running effort. These authors [24] have indicated that the cause of this increase is probably the change in motor movement pattern.

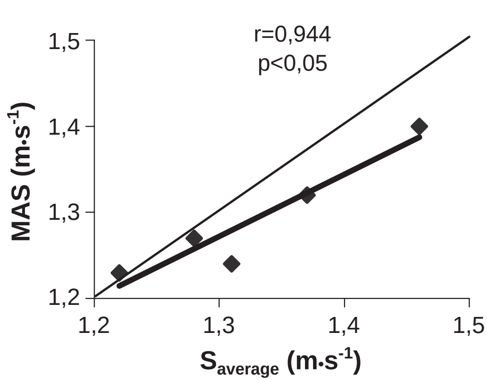

Fig. 2. Relation between MAS swimming test and the performance the 1500 m triathlon test.

During the cycling sector, HR, [La$^-$], pedalling rate and VO_{2max} values of the present study are very close to the ones found in other studies [12,19] working on all three triathlon sectors, despite being shorter its cycling sector: 15 and 30 min long, respectively. On the other hand, maximum oxygen uptake values in this study were higher than those of some other studies with sub-elite triathletes [29,58], similar to the ones found in recent studies [49,25,28], but lower than the ones found in elite triathletes usually taking part in World Cup championships [20,26]. Values are also far from the ones found in professional cyclists, that show values between 70 and 80 ml kg^{-1}·min^{-1} (even higher among climbers) and a lactate threshold near to 90% of VO_{2max} [33,35]. Lactate threshold in triathletes seemed to remain on lower percentages (72–88% VO_{2max}) [41]. This would suggest cyclists are more economical than triathletes, as stated by Laursen et al. [30].

Blood lactate values found in this study at the end of swimming sector are in agreement with those reported by Delextrat et al. [12] and are higher than those from Guézennec et al. [18], despite the fact that the distance that they swam in those studies was 750 and 1.500 m, respectively. On the other hand, it has also to be considered that swimming in a 50 m swimming pool, swimmers on these two other studies were less efficient than triathletes [27].

At the end of the swimming sector, the blood lactate concentration in triathletes tended to be higher than at the end of the cycling effort. Guézennec et al. [18] obtained similar results, using a very similar protocol. In fact, this could be due to the fact that relative intensity developed in the first sector is higher than the one of the second one, probably because of the length of the effort. It could be said that power developed during the cycling sector (although being relatively high) allows lactate build-up from the prior swimming effort to be eliminated. In this sense, power average developed by triathletes during the cycling sector (77% of MAP) was very close to the % MAP of the ILT measured during the ergocycle exercise in laboratory (about 76% of MAP), Stamford et al. [50] observed that ILT corresponds to the effort intensity where the highest blood lactate removal took place. This fact explains lactate kinetics observed in this study, where a considerable but not significant diminution (4.3 vs. 6.8 mM) can be observed

Table 5
Ergocycle trial results (mean ± SD)

	8–10 min	12–14 min	27–28 min	42–44 min	57–59 min	Mean ± SD
Power (W)	264 ± 35***	259 ± 32***	263 ± 29***	262 ± 30***	282 ± 39	266 ± 34
Power (%)	77 ± 10***	75 ± 9***	76 ± 8***	76 ± 9***	82 ± 11	77 ± 10
VO_2 (ml min^{-1})	3683 ± 240	3671 ± 180	3841 ± 354	3847 ± 562	3994 ± 422	3788 ± 327
VE (l min^{-1})	102.5 ± 13.2	106.1 ± 14.4	111.0 ± 20.0	114.9 ± 27.5	131.6 ± 24.0	112.8 ± 20.8
PR (rpm)	100 ± 4	99 ± 3	97 ± 4	98 ± 4	99 ± 3	99 ± 3
HR (beats min^{-1})	161 ± 14	161 ± 14	163 ± 13	164 ± 13	167 ± 13	162 ± 13

$P<0.05$*; $P<0.001$*** (differences with respect to 57–59 min).
VO_2: oxygen uptake; VE: ventilation; PR: pedalling rate; HR: heart rate; SD: standard deviation.

after 30 min of effort on ergocycle. This effort intensity freely chosen by subjects matches the one observed by other authors, who suggest the predominant use of glycolytic metabolism [19]. In the present tests, respiratory quotient averaged a contribution of 36.3 ± 14.8% to lypolitic metabolism and of 63.7 ± 14.6% to aerobic glycolysis, showing no significant differences during the cycling sector.

Even though, it can be argued that one of the limitations of the study was that in the ergocycle wind factor was not present, and therefore it is not possible to compare it with cycling studies made in real conditions. On the other hand, it can't be missed that in true competition triathletes tend to perform cycling in a sheltered position, reducing energetic cost up to 21–35% [39]. All this would be in accordance with Vercruyssen et al. [55] and Hausswirth et al. [19], that report that energetical economy during the cycling sector is crucial in order to maintain optimal conditions for the running sector, since it is the determinant one in an short distance triathlon [8,16].

On the other hand, it has been suggested that movement pattern is related to energetic cost [17] and that one of the main factors that determines performance is the capability of minimizing energy use [13]. In fact, during running trials, athletes naturally adopt stride rates and distances corresponding with minimal energetic cost [21], but in cycling this does not happen. Some authors determined that best energetic efficiency corresponds with pedalling rates of around 40 and 80 rpm [2,17]. Triathletes taking part in this study freely chose much higher pedalling rates than this optimal. In the same way, Hausswirth et al. [19] and Delextrat et al. [12] determinate pedalling rates over 90 rpm and confirm remarks from other authors for slightly lower rates [4], where no statistically significant differences were found (in long endurance exercises) between freely chosen rates and the most energetic one. Other studies with cyclists suggest pedalling rate might freely adapt itself to a motor unit recruiting pattern matching the one producing a minimal neuromuscular fatigue (90–100 rpm), and not the energetically optimal one [38].

Table 6
Ergocycle trial results (mean ± SD)

15 min		30 min	45 min	60 min	Basal
[La$^-$] (mM)	5.2 ± 1.5	4.3 ± 1.3	4.1 ± 1.6	4.8 ± 2.7	6.6 ± 1.8

[La$^-$]: blood lactate concentration; SD: standard deviation.

During experimental protocol triathletes lost 2.8% of their body weight. In relation to this data, several authors [18,23] have attributed this loss with a relative dehydration that would restrict performance in inexperienced or middle-level triathletes. The present study shows no significant differences in the evolution of metabolic and respiratory variables. All this in spite of a power and pedalling rate decrease towards the end of the cycling sector, with regard to the first ten minutes. Ingestion of a sweetened isotonic solution, the amount of training and triathlete's physiological profile could explain constant performance [35]. Increase in power development and energetic requirements at the end of the cycling effort could be because this simulation has not linked running with cycling. Triathletes, knowing the trial was finishing, made that extra-effort in the last minutes.

Finally, although triathlon is understood as a continuous effort, performance in each sector must be considered separately. The present study remarks that swimming and cycling are performed at different relative intensities. Competition intensities in short distance triathlon swimming and cycling simulations were, respectively, 98 ± 2% of MAS and 77 ± 10% of MAP. The 2.8% body weight diminution does not alter the pedalling economy of national and international-level triathletes while performing the cycling sector. In this sector triathletes adapt intensity to the one matching individual lactate threshold. Nevertheless, changes in competition tactics and other effects, such as drafting in swimming and cycling, could alter relative intensities determined in this study for each sector. It is still necessary to elucidate the effects of the remarked race pace on the running race.

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