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Ventilatory threshold and maximal oxygen uptake during cycling and running in duathletes

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Background. Duathlon, an emerging sport discipline, is an endurance competition based on a sequence without interruption of running, cycling and again running fractions. The performance in duathlon, as well as triathlon, depends on the ability of the athlete to effect the three competition fractions without creating fatiguing levels which would inevitably cause a decrease of the performance in the following fractions. Currently there are no studies which have examined the relation between ventilatory threshold (T_{vent}) and maximal oxygen uptake ($\dot{V}O_{2max}$) in the cyclists and the runners comparing them with the ones of the athletes who train and compete in duathlon. Therefore the main aim of the present study has been the following ones:

1) the identification of the relationship between T_{vent} and $\dot{V}O_{2max}$ in eight élite duathletes for cycling and running and the comparison of said relationship with the one found in cyclists or runners in maximal trials with cycloergometer and on the treadmill.

2) Moreover it has been carried out an analysis of the modification of the physiological parameters through the laboratory simulation of the commitment faced in a duathlon competition by a top duathlete (Case Report).

Methods. The research methods have been the following:

a) maximal incremental test—till exhaustion—on treadmill and cycloergometer carried out on eight duathletes in different days and with an interval of no more than seven days between one trial and the other;

b) incremental exhaustion test carried out an a top duathlete on cycloergometer after 5 km of running; incremental exhaustion test on treadmill after 5 km of running and 30 km of cycling.

Results. The study has show, through its data, that $\dot{V}O_{2max}$ recorded in the duathletes during running and cycling was inferior to the values recorded for triathletes. For the duathletes, $\dot{V}O_{2max}$ obtained with running was higher than the value obtained with cycling. The ventilatory threshold (T_{vent}) recorded in duathletes was lower than the value reported for élite runners but comparable with the one reported for race cyclist, duly endurance trained.

Conclusions. These data can be explained with the different training methods for duathletes, both as far as quantity and quality are concerned, in comparison with race top athletes in the single disciplines confirming that the fit answers to the endurance exercise in the single sport are, in par, a function of motion schemes specific for that training,

Key words: Duathlete - Anaerobic threshold - Ventilatory threshold - Maximal oxygen uptake.

The duathlon, an emerging sports discipline, is an endurance competition, based on running, cycling and running in that respective order. Performance in the duathlon, as in the triathlon, depends on the athlete's capability to carry out the three successive events without accumulating fatigue, which could affect his performance in the following fraction. A successful duathlete should therefore have an extremely efficient aerobic metabolism

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TABLE I.—*General physical characteristics, duathlon experience and training regimen data for eight male duathletes.*

	Age (yrs)	Weight (kg)	Height (cm)	Duathlon experience (yrs)	Duathlon completed (yrs)	Mean training distances (km/wk)	
						run	bike
	34	72.5	181	2	12	80	300
	33	71.7	181.6	3	22	92	340
	32	62.5	172.7	3	18	88	240
	41	83.4	189	3	14	75	280
	38	72.1	177.8	3	12	72	320
	28	68.4	176	2	20	90	280
	29	66.2	175	2	16	86	300
	36	62.8	174	3	24	76	240
Means±SD	33.8±4.39	69.95±6.74	178.4±5.33	2.625±0.518	17.25±4.53	82.4±7.6	297.5±35.36

based on a well developed oxygen transportation and utilisation system, and consequently the ability to produce valuable energy for prolonged periods of time without accumulating metabolic acidosis.

More is the aerobic metabolism efficiency, less is the utilisation of the carbohydrates as energy source. Thus, the intensity of exercise has to be decided in function of the race distance to avoid early muscle glycogen depletion.

Maximal oxygen uptake ($\dot{V}O_{2max}$) is generally considered to be a useful index of good performance in endurance activities when subjects have different $\dot{V}O_{2max}$.[1 2]

The anaerobic threshold has been studied as one of the many factors, besides $\dot{V}O_{2max}$, which could contribute to success in endurance competitions.[2 3] Several studies confirm that anaerobic threshold could be a critical factor in determining running pace.[4]

Powers *et al.*[1] confirmed that oxygen uptake measured at the anaerobic threshold was a better indicator than $\dot{V}O_{2max}$ to predict performance in long distance runners. Few studies have examined the relationship between $\dot{V}O_{2max}$ and anaerobic threshold during running and cycling in a duathlon for athletes who train and compete in these two endurance sports, for each of which the biomechanics as well as the muscles used are different.[1 3-8]

In conclusion the main issues of this research were as follows:

1) The definition of the relationship between $\dot{V}O_{2max}$ and T_{vent} in cycling and running, in reference to a high-level duathlete compared to athletes of one or other of the disciplines.

2) The modification of the physiological parameters investigated ($\dot{V}O_{2max}$ and T_{vent}) in the duathlete by simulating race conditions in the laboratory, in order to evaluate the performance of the "human machine" during the various transition phases—from running to cycling to running—to document eventual worsening in performance related parameters.

Methods

After written informed consent was obtained, eight male duathletes were tested during cycle ergometry and treadmill running. All the athletes were actively training and competing in duathlons during the five-week testing period. The general physical characteristics, duathlon experience and training regimen data for each subject are presented in Table I. The athletes had been training for the duathlon for an average of 2.625 yrs and had completed a mean of 17.25 duathlons of varying distances. Average training distances per week were 82.4 km running and 287.5 km cycling. Two of the eight duathletes were professional competitors. Each of the

TABLE II.—*Maximum metabolic and cardiorespiratory values obtained during incremental cycle ergometry and treadmill running for eight male duathletes.*

Variables	Cycle ergometer	Treadmill running
$\dot{V}O_{2max}$ ($l \cdot min^{-1}$)	4.65±0.78	5.02±0.89
$\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	66.3±9.0	71.4±10.3
HR max ($beats \cdot min^{-1}$)	176±10.0	179±8.0
R	1.15±0.4	1.18±0.7
Ve max ($l \cdot min^{-1}$)	145.3±18.7	142.4±19.2
Vt (l)	2.94±0.56	2.85±0.48
fr ($breaths \cdot min^{-1}$)	60.1±10.6	57.9±9.0
(HLa) (mmol)	10.4±2.6	10.8±2.2
Power output (W)	360.0±60.0	400.0±40.0

Values are mean±& L. R is the maximum respiratory exchange ratio obtained during incremental exercise. Vt indicated the tidal volume measured during maximal exercise. The respiratory frequency determined during maximal exercise is represented as fr. (HLa) is the peak lactate concentration measured two minutes after reaching volitional exhaustion.

TABLE III.—*Metabolic and cardiorespiratory values measured at ventilatory threshold for the cycle ergometer and treadmill running.*

Variables	Cycle ergometer	Treadmill running
$\dot{V}O_2$ ($l \cdot min^{-1}$)	3.17±0.32	3.67±0.33
$\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	43.9±4.3	50.9±6.8
%$\dot{V}O_{2max}$	68.8±3.7	73.9±6.6
Ve ($l \cdot min^{-1}$)	82.6±9.1	99.7±9.3
Vt (l)	2.86±0.52	2.50±0.47
fr ($breaths \cdot min^{-1}$)	28.1±5.1	40.7±9.0
HR ($beat \cdot min^{-1}$)	152.0±8.0	158.0±9.0
% HR max	80.4±3.2	86.0±4.2

Values are means±SD.

eight duathletes performed a continuous incremental test to a volitional exhaustion on a cycle ergometer (Technogym-Bikerace) and on a treadmill (Technogym-Runrace).

The exercise protocols were performed on separate days, with no more than seven between tests. Exercise protocols were constituted by two minutes steps with 40 watt of increment on the cycloergometer, and two minutes steps with 1 km of increment on the treadmill.

The $\dot{V}O_{2max}$ was determined when the $\dot{V}O_2$ uptake didn't increase in two subsequent steps and estimated at RQ of 1.15.

Capillary blood samples for the determination of lactate concentration were obtained two minutes after reaching volitional exhaustion.

The two minutes recovery period was passive.

This methodology has been chosen accordingly to Donald A. Schneider *et al.*[8] and also not to effect the evolution of testing. It is also to be considered that during the first 2 minutes of passive recovery blood lactate accumulation is maximal.

During each exercise test, the subject breathed through a mouthpiece attached to a turbine device. The respired gas was continuously sampled by a Sensor Medics 2900 C metabolic cart for breath—by breath determination of metabolic and ventilatory variables. The use of non-invasive techniques to determine the ventilatory threshold has been described by Wasserman *et al.*[9]

The ventilatory threshold was indicated as the work-rate or $\dot{V}O_2$ at which the ventilatory equivalent for oxygen ($V_E/\dot{V}O_2$) increased without a marked rise in the ventilatory equivalent for carbon dioxide ($V_E/\dot{V}CO_2$). The anaerobic ventilatory threshold (T_{vent}) is one of the objective measurements which indicated a circulatory-metabolic limitation to exercise.

Results

Maximum metabolic and cardiorespiratory values obtained during cycle ergometry and treadmill running are presented in Table II.

Table III presents the mean and standard deviation values for the metabolic and cardiorespiratory values measured at the T_{vent} for both modes of exercise.

Table IV Case Report presents the principal physiological parameters of the Italian champion, related to a racing situation, to investigate power output at the transition from running to cycling and back to running again.

TABLE IV.—*Case report. Principal physiological parameters in the duathlon champion under racing conditions, investigating power output at the transition from running to cycling and back to running.*

Age	Weight	Height	Duathlon experience	Duathlon completed	Mean training distances (km.wk)
34	172.5	181	2 yrs	12	run 80 cycle 300

Variables	Cycle ergometre	Treadmill running	Cycle ergometre (after 5 km run)	Treadmill running (after 5 km run and 30 km cycle)
$\dot{V}O_{2max}$ (l min-1)	5.122	5.435	4.959	4.810
$\dot{V}O_{2max}$ (ml kg-1 min-1)	72.84	76.23	69.08	66.97
$\dot{V}O_2$ T_{vent}	61.91	67.08	56.64	50.22
%$\dot{V}O_{2max}$	85%	885%	82%	75%
HRmax	168	176	165	172
HR T_{vent}	158	166	155	160
Power output (W)/Speed km·h-1	420	22	380	19
Power Tvent/Speed km h-1	360	19	310	18

The first running and cycling sections were performed at anaerobic threshold speed.

Discussion

Maximal oxygen uptake has been measured and reported for most groups of élite athletes who train and compete in single sport such as running or cycling.[1 3 4 6 10-13]

The mean running $\dot{V}O_{2max}$ of 71.1 ml· kg-1· min-1 compared favourably with the values previously reported for highly trained male distance runners.[1 3 11 14]

The running $\dot{V}O_{2max}$ for the duathletes was 10% less than the value of 79.3 ml·kg-1·min-1 reported by Martin *et al.*[9] for nine élite male runners training for the 1984 Olympic Games.

Moreover, the mean $\dot{V}O_{2max}$ value of 66.3 ml·kg-1·min-1 for cycle ergometry was 6% less than the value of 71.1 ml·kg-1·min-1 reported by Folinsbee *et al.*[6] for seven élite cyclist and by myself on professional cyclist.

The cycling $\dot{V}O_{2max}$ for the duathletes was 10% less than the $\dot{V}O_{2max}$ of 74.0 ml·kg-1·min-1 reported by Burke for 23 members of the US national Cycling team.[10] Thus these differences are significant in determining performance capabilities in single sport competitors, they should be considered relatively small for athletes training in a multidisciplines event like duathlon and triathlon, considering that the duathletes trained less in any one sport than single-sport athletes. Nonetheless, the achievement of high $\dot{V}O_{2max}$ values may demonstrate a true cross-training effect.

Previously reported $\dot{V}O_{2max}$ values for running in male triathletes ranged from 57.4 to 72 ml·kg-1·min-1, while the values reported for cycling ranged between 54.4 and 66.7 ml·kg-1·min-1.

Thus, the duathletes in the present study had average running and cycling $\dot{V}O_{2max}$ values that were greater than those previously reported for male triathletes.

This could suggest that more is the number of disciplines, lower is the $\dot{V}O_{2max}$ for any single sport.

Maximal oxygen uptake values are usually highest when the largest muscle mass in used in the test.[15 16]

Researchers have found that the $\dot{V}O_{2max}$ for cycle ergometry is typically 8-11% less than the value obtained for treadmill running.[15 16]

These relationships have been shown to change significantly with endurance training.[3 7] Most previous studies have focused on athletes who train and compete in only one sport. For example, Hagberg *et al.*[7] observed that competitive cyclist had a $\dot{V}O_{2max}$ for cycling that was about 4% higher than for treadmill running. A study by Withers *et al.*[3] found that competitive male