Ventilatory Threshold and Maximal Oxygen Uptake in Present Triathletes

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Abstract/Résumé

The aim of this study was to determine the physiological profile of young triathletes who began triathlon competition as their first sport. Twenty-nine male competitive triathletes (23 regionally and nationally ranked triathletes and 6 elite, internationally ranked triathletes) performed two tests, one on a cycle ergometer (CE $\dot{V}O_{2max}$) and one on a treadmill (TM $\dot{V}O_{2max}$). Results showed (a) no difference between CE $\dot{V}O_{2max}$ and TM $\dot{V}O_{2max}$ in the triathletes (69.1 ± 7.2 vs. 70.2 ± 6.2 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively), (b) values of CE $\dot{V}O_{2max}$ and TM $\dot{V}O_{2max}$ in elite triathletes (75.9 ± 5.2 and 78.5 ± 3.6 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively) that were comparable to those reported in elite single-sport athletes in these specialities, and (c) although the ventilatory threshold (Th_{vent}) were similar in CE and TM, TM Th_{vent} was consistently lower for triathletes than TM Th_{vent} usually reported for runners.

Le but de cette étude était de déterminer le profil physiologique de jeunes triathlètes qui ont choisi le triathlon comme premier sport de compétition. En tout, 29 triathlètes masculins ont participé à cette étude (23 de niveau régional ou national et 6 de niveau international,

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i.e., élite). Ils ont effectué deux tests d'exercice maximal, l'un sur tapis roulant (TM), l'autre sur cycloergomètre (CE). Les résultats sont que (a) il n'existe pas de différence significative entre les valeurs de $\dot{V}O_{2max}$ relevées sur TM et CE; (b) les valeurs de $\dot{V}O_{2max}$ relevées chez les triathlètes d'élite sont comparables à celles relevées chez des coureurs ou des cyclistes d'élite; et (c) les seuils ventilatoires sont similaires en CE et en TM, mais le seuil ventilatoire en TM est significativement plus faible chez les triathlètes que chez les coureurs de même niveau.

Introduction

Maximal oxygen uptake and anaerobic threshold have been measured for most groups of elite athletes (Bunc et al., 1987; Withers et al., 1981) who train and compete in only one sport, such as running (Powers et al., 1983; Tanaka et al, 1984) or cycling (Coyle et al., 1991; Lucia et al., 1998). In these single sports, values of $\dot{V}O_{2max}$ have been correlated with training distance and competitive results: the athletes who developed the highest $\dot{V}O_{2max}$ were those who averaged the highest mileage per week, and, generally, the athletes who had the highest $\dot{V}O_{2max}$ also had the best results (Hagan et al., 1981; Krebs et al., 1986). Furthermore, the ventilatory threshold (Th_{vent}), validated as being concomitant to the anaerobic threshold (Wasserman et al., 1973) has been demonstrated as being a better predictor of distance running and cycling performance than $\dot{V}O_{2max}$ (Coyle et al., 1991; Powers et al., 1983).

Training induces central adaptations that are important in the development of $\dot{V}O_{2max}$ (Clausen et al., 1973). However, although in recreational single-sport athletes, testing with a treadmill (TM) usually elicited 6–11% higher $\dot{V}O_{2max}$ values than with a cycle ergometer (CE) (Astrand, 1970), elite athletes who train only in a single sport have shown a higher $\dot{V}O_{2max}$ and Th_{vent} in their speciality (Hagberg et al., 1978), indicating that peripheral adaptations (resulting from training specific to the muscle groups used) are also important in the $\dot{V}O_{2max}$ development (Clausen et al., 1973).

Numerous studies (Table 1) have reported $\dot{V}O_{2max}$ and Th_{vent} values for running and cycling in male triathletes. Th_{vent} in running, expressed as a percentage of $\dot{V}O_{2max}$, has been noted consistently higher in running than in cycling for triathletes (Schneider et al., 1990). The mean $\dot{V}O_{2max}$ of male triathletes ranged from 57.4 to 75.4 $mL \cdot kg^{-1} \cdot min^{-1}$ in running and from 54.4 to 70.3 $mL \cdot kg^{-1} \cdot min^{-1}$ in cycling (O'Toole et al., 1989a, 1995; Schneider et al., 1990) with the difference between TM $\dot{V}O_{2max}$ and CE $\dot{V}O_{2max}$ for triathletes (3–6%) less than the difference for single-sports athletes (6–11%). The additive benefits from participation in multisports are commonly referred to as "cross-training" adaptations (Schneider et al., 1990).

Because earlier studies were conducted on triathletes (Delistraty and Noble, 1987; Kohrt et al., 1987; O'Toole et al., 1989) that tended to be older than those of most groups of elite swimmers (Trappe, 1997), cyclists (Wilber et al., 1997), and runners (Robinson et al., 1991) and were initiated to triathlon competition following years of competition in a single sport (Roalstad, 1989), it is unclear if the smaller differences between CM and TR $\dot{V}O_{2max}$ resulted from physiological adaptations derived from the additive benefits elicited by triathlon training.

The aim of the present study was to examine the metabolic and cardiorespiratory data in triathletes who began the triathlon as their first sport. Our hypothesis

Table 1 Physical/Physiological Characteristics of Triathletes Reported in Some Previous Studies

Study	N	Age (yr)	Height (cm)	Weight (kg)	Cycle ergometry $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	Treadmill running $\dot{V}O_2$ ($ml \cdot kg^{-1} \cdot min^{-1}$)
Albrecht et al. (1986)	9	28.7	181.6	73.8	56.3	57.7
Hue et al. (1998)	7	20.8	180.4	69.7	65.4	62.1
Kohrt et al. (1987)	8	27.6	179.4	72.8	57.9	60.5
Kreider (1998)	9	27.6	179.4	72.8	64.3	68.1
Miura et al. (1997)	17	26.5	171.1	62.8	61.1	63.8
O'Toole et al. (1989)	8	30.5	178.8	74.7	66.7	68.8
Roalstad (1989)	10	30.5	181.9	76.6	64.3	67.2
Schneider et al. (1990 [elite]	10	27.6	179.3	72.0	70.3	75.4
Sleivert and Wenger (1993)	18	27.7	180.0	76.2	60.1	63.7

was that in such triathletes, because of simultaneous training in cycling and running, (a) TM $\dot{V}O_{2max}$ and CE $\dot{V}O_{2max}$ would be equal, and (b) cycling and running Th_{vent} would occur at a similar % $\dot{V}O_{2max}$. Moreover, we further hypothesized that the $\dot{V}O_{2max}$ values in elite triathletes would be similar to those of elite single-sport athletes, despite lower training distance per week in each sport, which suggest general cross-training adaptations in triathletes.

Materials And Methods

SUBJECTS

Twenty-nine male competitive triathletes participated in the present study. Twenty-three were regionally and nationally ranked triathletes, and 6 were elite triathletes who had been chosen to represent France in the International Triathlon Union World Championship. All were students at the School of Physical Education at the University of Montpellier, France, and they were members of the University Athletic

Team, which has been a French national champion in the triathlon for four consecutive years. The subjects had been competing in triathlon for 6.0 (± 2.3) years and were in the competitive period at the time they were tested. Anthropometric and training regimen data are reported in Table 2. All subjects were informed of the purpose of the study and gave written consent in accordance with the regional Ethics Committee before participating.

TESTING PROTOCOL

The tests were performed by every triathlete who entered the School of Physical Education at the University of Montpellier, France, between 1993 and 1997. Each subject randomly completed two incremental tests that took place over two consecutive weeks. The tests were done at the same time of day and the same day of the week to minimize the influence of the effects of personal training on the study. The subjects were asked to maintain their training schedule for the duration of the study but were not allowed to compete in a triathlon during the testing period. During experiment days, the subjects were asked to abstain from training. The incremental treadmill (Gymroll 1800, Gymroll, Roche La Molière, France) test began at 5 km · h^{-1} for one minute at 0% grade. The speed was then increased by 1 km · h^{-1} every minute up to 18 km · h^{-1}. The slope was then increased by 1% every minute to exhaustion. The incremental cycle (Monark 864, Monark-Crescent AB, Varburg, Sweden) test was performed on an electronically braked cycle ergometer. After 3 min of cycling at 30 W, the power was then increased by 30 W every minute to exhaustion.

GAS EXCHANGE MEASUREMENT

The following cardiorespiratory data were measured every minute using a mass spectrometer breath-by-breath automated system (MGA-1100, Marquette, NY, USA): ventilation ($\dot{V}_E$), oxygen uptake ($\dot{V}O_2$), carbon dioxide output ($\dot{V}CO_2$), respiratory equivalents for O_2 ($\dot{V}_E/\dot{V}O_2$) and CO_2 ($\dot{V}_E/\dot{V}CO_2$), respiratory exchange ratio (*R*), breathing frequency (f_R), and tidal volume ($\dot{V}_T$). Heart rate (HR) was measured

Table 2 General Physical Characteristics and Training Regimens for the Triathletes (N = 29) and the Subgroup of Elite Triathletes (N = 6)

Swim (N)	Age (yr)	Height (cm)	Weight (kg)	Mean training distances (km · wk^{-1}) Swim	Bike	Run
29	20.9 ± 2.6	176.9 ± 8.0	68.0 ± 7.8	13.5 ± 5.5	222.0 ± 100.8	38.5 ± 14.1
6	21.8 ± 2.4	178.8 ± 7.8	69.9 ± 7.3	16.3 ± 2.4	345.0 ± 52.4	55.8 ± 5.8
P values	NS	NS	NS	NS	0.008	0.007

Note. Training distances are average weekly values representing training volumes at the time subjects were tested. NS indicates that the mean value for elite triathletes was not significantly different from the value obtained for all triathletes using a telemetry system (Polar Racer, Polar Electro, Kempele, Finland). To ensure that $\dot{V}O_{2max}$ was attained, at least three of the following four criteria had to be met: (a) an increase in $\dot{V}O_2$ lower than 100 ml with the last increase in work rate ("leveling off" criterion); (b) attainment of age-predicted maximal HR, 210 – (0.65 × age) ± 10 % (Spiro, 1977); (c) R >1.10; and (d) an inability to maintain the required running speed or the minimal pedaling frequency (= 50 rpm) despite maximal effort and verbal encouragement. The ventilatory threshold (Th_{vent}) was automatically determined using the V-slope method of Beaver et al. (1986). This method involves the analysis of $\dot{V}CO_2$ as a function of $\dot{V}O_2$ and assumes that the Th_{vent} corresponds to the break point in the $\dot{V}CO_2$-$\dot{V}O_2$ relationship. As shown in Figure 1, this method is similar to Wasserman et al. (1973) in which the Th_{vent} is indicated by an increase in $\dot{V}_E/\dot{V}O_2$ without a marked increase in $\dot{V}_E/\dot{V}CO_2$.

STATISTICAL ANALYSIS

The results are expressed as mean ± SD. Maximal exercise data, as well as the metabolic and cardiorespiratory values obtained at the Th_{vent} during cycle ergometry and treadmill running, were compared using a Student's paired t-test. Statistical significance was defined at $P < 0.05$. Simple linear regressions were used to determine the relationship between $\dot{V}O_{2max}$ differences between CE and TR (CE $\dot{V}O_{2max}$ – TM $\dot{V}O_{2max}$) and differences in training schedule between cycling and running (cycling training schedule - running training schedule, h^{-1}) for each triathlete and between cycling and running training schedule and CE and TM $\dot{V}O_{2max}$.

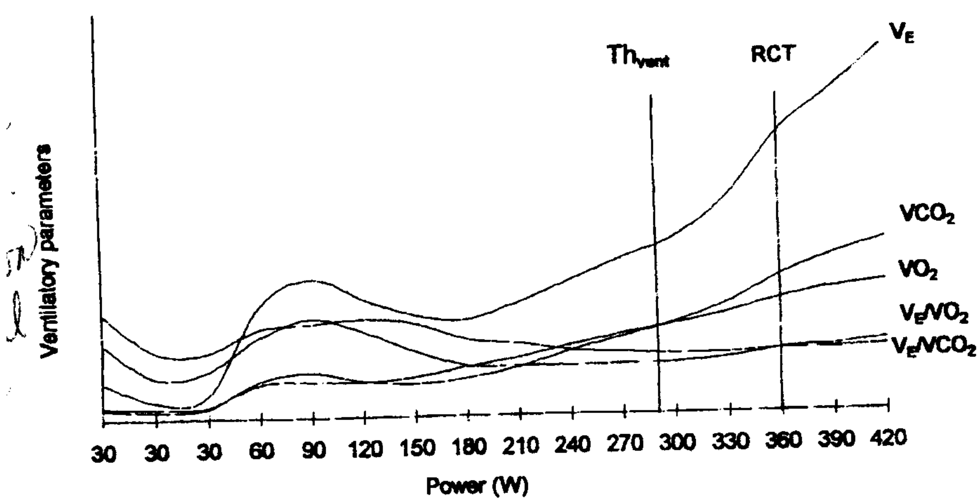

Figure 1. The detection of ventilatory threshold (Th_{vent}) for a representative subject. One can see that both the methods of Beaver et al. (1986) and Wasserman et al. (1973) induce the same Th_{vent}. One could also see on this figure the approximate respiratory compensation threshold RCT detection based on the non linear rise in $\dot{V}_E$ and in $\dot{V}_E/\dot{V}O_2$, associated with a rise in $\dot{V}_E/\dot{V}CO_2$.

Results

Maximal metabolic and cardiorespiratory values obtained during cycle ergometry and treadmill running are presented in Table 3. There were no differences between CE $\dot{V}O_{2max}$ and TM $\dot{V}O_{2max}$. Maximal HR was significantly lower ($P < 0.001$) for CE than for TM. The maximal V_T reached for CE was significantly higher ($P < 0.05$) than for TM. The maximal f_R was significantly ($P < 0.01$) lower for CE.

Table 4 presents the mean and standard deviation values for the metabolic and cardiorespiratory variables measured at Th_{vent} for both modes of exercise. The Th_{vent} occurred at the same level for both TM and CE. HR at Th_{vent} was significantly lower ($P < 0.05$) for CE. Tidal volume at Th_{vent} was significantly higher ($P < 0.001$) and f_R at Th_{vent} was significantly lower ($P < 0.001$) for CE than for TM.

We found nonsignificant correlations ($r = 0.37$, $P = 0.32$) between $\dot{V}O_{2max}$ differences (CE $\dot{V}O_{2max}$ – TM $\dot{V}O_{2max}$) and training schedule (cycling training schedule - running training schedule, h^{-1}) or between training schedule and $\dot{V}O_{2max}$ ($r = 0.56$, $P = 0.13$ and $r = 0.45$, $P = 0.23$, for cycling and running, respectively).

Table 3 Maximum Metabolic and Cardiorespiratory Values Obtained During Incremental Cycle Ergometry and Treadmill Running for All Triahletes (T) and the 6 Elite Triathletes (E)

Variables	Population	Cycle ergometry	Treadmill running	P values
$\dot{V}O_2$ ($L \cdot min^{-1}$)	T	4.70 ± 0.49	4.81 ± 0.42	NS
	E	5.30 ± 0.36	5.49 ± 0.25	NS
$\dot{V}O_2$ ($mL \cdot kg \cdot min^{-1}$)	T	69.1 ± 7.2	70.2 ± 6.2	NS
	E	75.9 ± 5.2	78.5 ± 3.6	NS
HR ($beats \cdot min^{-1}$)	T	180 ± 11	188 ± 7	0.000
	E	174 ± 3	184 ± 5	0.000
R	T	1.16 ± 0.04	1.10 ± 0.04	0.008
	E	1.14 ± 0.04	1.11 ± 0.04	NS
$\dot{V}_E$ ($L \cdot min^{-1}$)	T	143.4 ± 22.3	144.0 ± 18.4	NS
	E	135.5 ± 22.0	140.1 ± 17.8	NS
$\dot{V}_T$ (L)	T	3.00 ± 0.55	2.60 ± 0.41	0.01
	E	3.02 ± 0.59	2.77 ± 0.34	NS
f_R ($breaths \cdot min^{-1}$)	T	48.8 ± 7.6	57.4 ± 11.1	0.01
	E	45.3 ± 4.1	51.1 ± 6.4	0.02

Note. P: Comparison between values obtained on cycle ergometer and treadmill running.

Table 3 Maximum Metabolic and Cardiorespiratory Values Obtained During Incremental Cycle Ergometry and Treadmill Running for All Triahletes (T) and the 6 Elite Triathletes (E)

Variables	Population	Cycle ergometry	Treadmill running	*P* values
$\dot{V}O_2$ ($L \cdot min^{-1}$)	T	3.01 ± 0.55	3.17 ± 0.55	NS
	E	3.42 ± 0.76	3.55 ± 0.30	NS
$\dot{V}O_2$ ($mL \cdot kg \cdot min^{-1}$)	T	45.1 ± 8.2	46.7 ± 4.1	NS
	E	49.0 ± 10.9	50.9 ± 4.3	NS
% $\dot{V}O_{2max}$	T	65.3	66.4	NS
	E	64.5	64.8	NS
HR (beats $\cdot min^{-1}$)	T	141 ± 16	150 ± 10	0.04
	E	138 ± 13	145 ± 8	NS
$\dot{V}_E$ ($L \cdot min^{-1}$)	T	64.3 ± 10.3	71.5 ± 13.6	NS
	E	63.3 ± 11.2	75.9 ± 12.6	0.03
$\dot{V}_T$ (L)	T	2.43 ± 0.41	1.90 ± 0.27	0.000
	E	2.42 ± 0.30	1.96 ± 0.31	0.001
f_R (breaths $\cdot min^{-1}$)	T	27.7 ± 3.3	41.2 ± 8.7	0.000
	E	26.6 ± 3.8	39.9 ± 5.5	0.000

Note. P: Comparison between values obtained on cycle ergometer and treadmill running.

Discussion

PHYSICAL CHARACTERISTICS

The physical characteristics of triathletes have been reported by several investigators (Table 1). Our results are comparable to those reported in previous studies (O'Toole and Douglas, 1995; Roalstad et al., 1989) concerning height, which was reported to be the same as in single-sport athletes (Coyle et al., 1991; Robinson et al., 1991; Trappe et al., 1997), and weight, which tended to be less than the weight of swimmers (Trappe et al., 1997) but greater than that of cyclists (Coyle et al., 1991) and runners (Robinson et al., 1991). The average age of our triathletes was lower than the values usually reported (O'Toole and Douglas, 1995; O'Toole et al., 1989; Roalstad, 1989) but similar to that of most groups of swimmers, cyclists, and runners with the same characteristics of training. This similarity in age could be explained by the fact that our triathletes had chosen the triathlon as their first sport and not following years of competition in a single sport.

PHYSIOLOGICAL CHARACTERISTICS

Maximal oxygen uptake. CE and TM (see Table 3) are in accordance with mean values reported in previous studies: Schneider et al. (1990) reported values that ranged from 54.4 to 66.7 mL · kg^{-1} · min^{-1} for cycling and 57.4 to 72.0 mL · kg^{-1} · min^{-1} for running in recreational triathletes. The mean running $\dot{V}O_{2max}$ of 70.8 mL · kg^{-1} · min^{-1} compared favourably with the values previously reported for highly trained male distance runners (Powers et al., 1983; Tanaka et al., 1984). Moreover, the mean running $\dot{V}O_{2max}$ of 78.5 mL · kg^{-1} · min^{-1} noted in the elite triathletes agrees with the range of 75.4–85.0 mL · kg^{-1} · min^{-1} reported in high-level triathletes (Schneider et al., 1990; Sleivert and Rowlands, 1996, respectively) and was comparable to the value of 79.3 mL · kg^{-1} · min^{-1} reported in Olympic runners (Martin et al., 1986). The cycling $\dot{V}O_{2max}$ of 69.1 mL · kg^{-1} · min^{-1} for the triathletes was 7–10% higher than the values reported for other competitive male cyclists (Simon et al., 1986; Withers et al., 1981) and comparable to the value of 71.1 mL · kg^{-1} · min^{-1} reported by Folinsbee et al. (1983) for seven elite cyclists. Moreover, the cycling $\dot{V}O_{2max}$ of 75.9 mL · kg^{-1} · min^{-1} noted for the elite triathletes was comparable to the value of 74.0 mL · kg^{-1} · min^{-1} reported by Burke (1980) for 23 members of the U.S. national cycling team. Since the triathletes of the present study trained less in any one sport than single sport athletes (Table 5) and had not turned to triathlon competition after years of competition in a single sport, the achievement of $\dot{V}O_{2max}$ values that are comparable to those of elite single-sport athletes may demonstrate an additive effect between sport activities, commonly called "cross-training effect" (O'Toole et al., 1989; Schneider et al., 1990).

For most groups of athletes that train and compete in only one sport, such as running or cycling, the TM test usually elicits higher $\dot{V}O_{2max}$ than the CE test, with the TM $\dot{V}O_{2max}$ values reported to be 6–11 % higher (Astrand, 1970). This has also been reported in triathletes but with a smaller difference (3–6%) between TM $\dot{V}O_{2max}$

Table 5 Training Regimen Reported in Some Previous Studies for Triathletes Training for Classic Distance Triathlon

Etude	N	Distance	Swimming (km · wk^{-1})	Cycling (km · wk^{-1})	Running (km · wk^{-1})
Hue et al. (1998)	7	CD	14.7	264.3	44.3
Kreider (1988)	9	CD	6.3	180.0	54.0
Schneider et al. (1990)	10	—	12.4	269.3	54.9
Anderson Jones et al. (1992)*	12	—	59.5	—	—
Coyle et al. (1991)**	15	—	—	539	—
Robinson et al. (1991)***	13	—	—	—	85

Note. CD: 1.5 km swim, 40 km cycle, 10 km run or for every distance (—), and for swimmers (*), cyclists (**), and runners (***).

and CE $\dot{V}O_{2max}$ (Roalstad, 1989; Schneider et al., 1990). This difference is related to the greater muscle mass used in running versus cycling (Pannier et al., 1980; Pechar et al., 1974). We found no difference in $\dot{V}O_{2max}$ between the two modes of exercise in our study, suggesting general cross-training adaptations due to training in the two sports. These results agree with those of studies comparing the effect of a combined cycle/run training versus a single sport (i.e., running) on $\dot{V}O_{2max}$ (Foster et al., 1995; Mutton et al., 1993). However, these results that reported short-term cross-training effects (O'Shea, 1991) have been noted in low-level subjects that generally train in single sports.

Our study demonstrates a long-term cross-training effect in elite athletes, which to our knowledge has not been reported before. Indeed, elite athletes who train only in a single sport have a higher $\dot{V}O_{2max}$ in their speciality (Hagberg et al., 1978; Withers et al., 1981), which indicates that physiological adaptations are specific to the muscle group recruited (Withers et al., 1981). Also, the magnitude of improvement in $\dot{V}O_{2max}$ in triathletes was reported to depend on the training volume in each of the three components of the sport (Kohrt et al., 1987). Despite these findings, we found nonsignificant correlation between $\dot{V}O_{2max}$ differences (CE $\dot{V}O_{2max}$ – TM $\dot{V}O_{2max}$) and training schedule (cycling training schedule - running training schedule, h^{-1}) for triathletes or between training schedule for each sport and $\dot{V}O_{2max}$ for cycling and running, respectively.

Ventilatory threshold. Many researchers have studied the anaerobic threshold in male athletes who train in only one sport, such as running or cycling (Bunc et al., 1987; Powers et al., 1983). The values of 66.4% and 64.8% of $\dot{V}O_{2max}$ reported in the present study, during TM running for the triathletes and the subgroup of elite triathletes, respectively, are lower than the values usually reported for competitive and elite distance runners (70 to 88% of $\dot{V}O_{2max}$, respectively; Bunc et al., 1987; Schneider et al., 1990; Withers et al., 1981). This may be attributed to the great difference in running volume during training between distance runners and the triathletes, and more certainly to the fact that competitive and elite distance runners train at a higher intensity and do more interval training in running than do triathletes (Korkia et al., 1994; Schneider et al., 1990). This also may be attributed to the method used for the Th_{vent} measurement, which could represent, in some cases (Bunc et al., 1987), the detection of the respiratory compensation threshold (RCT) rather than the Th_{vent}. Our values of 65.3% and 64.5% of $\dot{V}O_{2max}$ during CE for the triathletes and the elite triathletes, respectively, agree with the value of 66.8% of $\dot{V}O_{2max}$ reported by Schneider et al. (1990) in triathletes. These values are also comparable to the 66.3% of $\dot{V}O_{2max}$ detected by Withers et al. (1981) in 10 endurance trained cyclists, while Simon et al. (1986) reported a value of 65.8% of $\dot{V}O_{2max}$ in 6 highly trained cyclists. The lack of difference in Th_{vent} for triathletes and cyclists could be attributed to the highly aerobic character of cycling. Indeed, competitive and elite cyclists are reported to do very little interval training but to have a high training volume, and general training volume of triathletes can be favourably compared with that of cyclists (O'Toole, 1989).

The lack of difference between Th_{vent} in cycling versus running in triathletes agrees with earlier results (Albrecht et al., 1989; Kreider, 1988). In these two studies, values are considerably higher than our values: 78.8% and 79.3% of CE and TM $\dot{V}O_{2max}$, respectively, and 85% and 90% of CE and TM $\dot{V}O_{2max}$, respectively. These high values should be considered with extreme caution. Indeed, RCT has to be distinguished from Th_{vent} (Schneider et al., 1990); RCT usually occurs at a higher percentage of $\dot{V}O_{2max}$ than Th_{vent} does. Also, the studies of Albrecht et al. (1989) and Kreider et al. (1988) exist only in an abstract form with no identification of the methods used for detection of Th_{vent}.

The difference between running and cycling in tidal volume and breathing frequency at $\dot{V}O_{2max}$ agrees with the findings of Bonsignore et al. (1998). These authors have reported that V_T and f were correlated with both the cycle rate and CO_2 production, which indicates that the rhythm of exercise modulated f and V_T.

This study demonstrates for the first time that young triathletes, without prior athletic specialization, have the same $\dot{V}O_{2max}$ for running and cycling. In addition, despite a lower volume of training in each sport, the triathletes and the elite triathletes had cycling and running $\dot{V}O_{2max}$ values that were comparable to those reported for competitive and elite male cyclists and runners. These findings suggest an important general cross-training adaptation due to simultaneous trainings in the two modes of exercise. However, the lower Th_{vent} running value of the triathletes in comparison with that of distance runners supports the need of specific training. Indeed, although triathletes benefit from the effect of cross-training, measurable improvement in one specific sport of the triathlon probably requires a training regimen that is specific to that sport.

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