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ORIGINAL

HEART RATE PROFILE IN HIGHLY TRAINED TRIATHLETES

PERFIL DE LA FRECUENCIA CARDIACA EN TRIATLETAS ALTAMENTE ENTRENADOS

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ABSTRACT

Nine male triathletes ($\dot{V}O_{2max}$: 68.0 ± 2.0 mL·kg⁻¹·min⁻¹, age: 25 ± 1.9 years, weight: 68.3 ± 2.2 kg, height: 177.4 ± 2.2 cm), performed an incremental maximal cycle exercise test on three separate occasions corresponding to the start of the season, pre-competitive period, and competitive period. Maximal oxygen uptake ($\dot{V}O_{2max}$) and ventilatory thresholds (VT₁ and VT₂ respectively) were assessed in each visit. Despite changes in the distribution of training among disciplines, total training time, training time per week, and intensity of the training, PO_{max}, $\dot{V}O_{2max}$, submaximal HR, and lactate concentration remained stable throughout the season. Due to the stability displayed by the heart rate ventilatory thresholds relationship in our sample, we conclude that a single laboratory testing at the start of the season could be enough to prescribe training intensities (at least for cycling) based on heart rate zones in highly trained triathletes. These results should be compared in future studies with longer samples in order to be generalised.

KEY WORDS: performance, longitudinal study, $\dot{V}O_{2max}$, power output, ventilatory thresholds, triathlon

RESUMEN

Nueve triatletas hombres ($\dot{V}O_{2max}$: 68.0 ± 2.0 mL·kg⁻¹·min⁻¹, edad: 25 ± 1.9 años, peso: 68.3 ± 2.2 kg, altura: 177.4 ± 2.2 cm), realizaron un test incremental en cicloergómetro en tres ocasiones correspondientes con el comienzo de la temporada, periodo precompetitivo y periodo competitivo. El consumo de oxígeno máximo ($\dot{V}O_{2max}$) y los umbrales ventilatorios (VT₁ and VT₂ respectivamente) fueron medidos en cada visita. A pesar de los cambios en la distribución del entrenamiento entre disciplinas, tiempo total de entrenamiento, tiempo de entrenamiento por semana, e intensidad del entrenamiento, PO_{max}, $\dot{V}O_{2max}$, FC submáxima, y concentración de lactato permanecieron estables a lo largo de la temporada. Dada la estabilidad mostrada con la relación entre la frecuencia cardiaca y los umbrales ventilatorios en nuestra muestra, concluimos que un único test de laboratorio al comienzo de la temporada podría ser suficiente para prescribir intensidades de entrenamiento (al menos en ciclismo) basándose en zonas de frecuencia cardiaca en triatletas altamente entrenados. Estos resultados deberán ser comprobados además con muestras mayores para poder ser generalizados.

PALABRAS CLAVE: rendimiento, estudio longitudinal, $\dot{V}O_{2max}$, potencia, umbrales ventilatorios, triatlón

INTRODUCTION

An Olympic distance triathlon is an endurance sport where competition time usually surpasses one hour. Therefore, as an endurance sport, maximal oxygen uptake ($\dot{V}O_{2max}$) and the ability to sustain work at a high percentage of $\dot{V}O_{2max}$ for an extended period of time have been shown to be key variables in triathlon

performance (Bentley, Millet, Vleck, & McNaughton, 2002; O'Toole & Douglas, 1995). Different from other endurance sports, triathlon combines into a single event swimming, cycling and running in a consecutive manner. This combination of events dictates increased training time compared to individual modalities athletes. Triathletes will train more hours than their specialist counterparts in only one of the disciplines (Rowlands & Downey, 2000). Moreover, cross-training effects resulting from the combination of training in swimming, cycling and running has been shown in triathlon (Millet, Vleck, & Bentley, 2009), although the mechanisms are not understood. These unique characteristics make the usefulness of specific tests, a challenge for the coaches.

Due to the potential cross-training effects, a proper description of physiological variables throughout the season is needed in order to prescribe and monitor training intensity and adaptations. The scientific literature investigating the extent to which physiological variables, such as VO_{2max} or maximal power output (PO_{max}), change throughout the season in highly trained/elite triathletes is limited. Kohrt et al. (Kohrt, O'Connor, & Skinner, 1989) showed significant improvements in VO_{2max} and lactate threshold throughout a season only during cycling. However, Kohrt's group of triathletes cannot be considered elite or highly trained since they presented VO_{2max} below $60 \text{ mL}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$. In elite cyclists, VO_{2max} and submaximal parameters, such as PO at the ventilatory thresholds or the lactate threshold, increased from the start of the season to the competitive period (Lucia, Hoyos, Perez, & Chicharro, 2000; Zapico, et al., 2007). Despite improvements in VO_{2max} and submaximal parameters, training heart rate zones (HR) remained stable throughout the season, suggesting that a single incremental test at the beginning of the season may be sufficient to establish adequate training prescription for the rest of the year (Lucia, et al., 2000; Zapico, et al., 2007). However, a direct extrapolation of these results to triathletes would be inappropriate due to their different training methods, and the lack of literature concerning highly trained triathletes and the response of specific physiological variables during the training season.

In an attempt to investigate whether one single incremental test at the beginning of the season is sufficient to prescribe training intensities throughout the rest of the year, the objective was to describe the changes/development of physiological variables, at maximal and submaximal intensities, in a group of highly trained triathletes.

MATERIAL AND METHODS

PARTICIPANTS

Nine male highly trained triathletes volunteered to participate in the present study. At the time of the study, all participants were members of the team that placed second at the Spanish National Championships over the Olympic (draft-legal) distance. Through the year of the study, two out of nine subjects competed regularly at international level (European Triathlon Union races) while the rest of the triathletes competed at national level. Their times during Olympic

distance draft-legal triathlons ranged from 1:54:43 and 2:04:36. They were familiarised with laboratory tests, and followed the same training plan under the supervision of an experienced coach. Prior to the study, participants completed a comprehensive clinical examination to detect any condition that would preclude their participation in the study. A detailed verbal and written description of the nature and purpose of the study was given to the participants, and an informed signed consent was obtained. The study protocol was performed according to the Declaration of Helsinki's ethical standards and was approved by the Local University Ethical Committee.

Table I. Characteristics of the participants in each visit.

	Start of the season	Pre-competitive period	Competitive period
Age (years)	25±1.9	25±2.5	26±2.0
Body mass (kg)	68.3±2.2	67.6±2.0	67.8±2.1
Height (cm)	177.4±2.2	177.3±2.1	177.4±2.2
Σ skinfold thicknesses (mm)	47.4±4.4	40.8±3.2	42.8±3.9
Fat free mass (kg)	35.3±1.2	35.0±1.2	35.4±1.2
Body fat (%)	8.0±0.5	7.5±0.5	7.3±0.4

Data are shown as mean ± s.

STUDY PROTOCOL

Each participant was tested at three separate periods throughout the course of a triathlon season in November, February and June. These time point were chosen as representative of the start of the season or preparatory period (from November to January), the pre-competitive period (from February to May), and the competitive period (from June to August).

ANTHROPOMETRIC VARIABLES

Body mass and height were measured following standard procedures (Marfell-Jones, Olds, Stewart, & Carter, 2006). Skinfold thickness was measured at the triceps, subscapular, supraspinale, abdominal, calf and thigh areas. Body fat percentage was calculated from skinfold thicknesses using the equation reported by Yuhasz (1974), (Heyward & Stolarczyk, 1996):

$$\text{Body fat (\%)} = [(\Sigma 6 \text{ skinfold thickness} \times 0.097) + 3.64] / 100$$

$$\text{Fat free mass (kg)} = \text{weight} - \text{fat mass.}$$

INCREMENTAL EXERCISE TEST

Each participant performed a maximal test on an electrically braked cycle ergometer (Jaeger ER800, Erich Jaeger, Germany) until exhaustion. Starting at 0 watts (W), the workload was increased by 25 W·min⁻¹ and pedalling cadence

was kept between 70-90 revolutions/min. The test was considered maximum when two out of the three criteria proposed by Basset and Boulay (2000) were met: respiratory exchange ratio (RER) higher than 1.10, variations in $\dot{V}O_2$ lower than $100 \text{ mL}\cdot\text{min}^{-1}$ despite increases in exercise intensity (i.e. a plateau), and 98% of the maximum HR calculated as $220 - \text{age}$. All the tests were performed under controlled environmental conditions ($21\text{-}24 \text{ }^\circ\text{C}$, 45-55% relative humidity) and participants were instructed to refrain from exhaustive exercise during the previous 24 hours.

Throughout the test, expired gas analysis was carried out breath by breath by means of an automatic gas analyser (Jaeger Oxycon Pro®, Erich Jaeger, Germany), that had been previously validated (Carter & Jeukendrup, 2002; Foss & Hallen, 2005). The system was calibrated prior to the start of each test using a known concentration of gases and a 3 litres syringe following the manufacturer's instructions. Oxygen uptake ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$) and ventilation (V_E) were averaged every 10 seconds for later calculation of $\dot{V}O_{2\text{max}}$ and ventilatory thresholds (VT_1 and VT_2 respectively).

$\dot{V}O_{2\text{max}}$ was calculated as the mean of the two highest averaged values recorded at the maximum workload reached during the test (Hawley & Noakes, 1992). Ventilatory thresholds were calculated by two independent researchers in a double blind process (coefficient of variation between researchers was 1.6%) as reported elsewhere (Rabadán, et al., 2011). VT_1 was determined: i) as the first non-linear increment in V_E (Skinner & McLellan, 1980), ii) as the first rise in the $V_E/\dot{V}O_2$ ratio without any change in the $V_E/\dot{V}CO_2$ ratio (Davis, Whipp, & Wasserman, 1980), and iii) as the break point of the $\dot{V}O_2$ - $\dot{V}CO_2$ relationship (Beaver, Wasserman, & Whipp, 1986). VT_2 was determined: i) as the second non-linear increment in V_E (Skinner & McLellan, 1980) and ii) as the second non-linear increment of the $V_E/\dot{V}O_2$ ratio with a concomitant increase in the $V_E/\dot{V}CO_2$ ratio (Davis, et al., 1980).

In addition, capillary blood samples were taken from the fingertip every other minute during exercise and on the third and fifth minute post exercise. Lactate concentration ($[\text{La}]$) was measured immediately by photometry using a Dr. Lange LP-20 (Bruno Lange, Germany) equipment.

TRAINING RECORDS

Training variables were recorded in a weekly basis throughout the entire season. Each triathlete was provided with a HR monitor (Polar S720i, Polar Electro OY, Finland). The researcher uploaded the maximal exercise test data to the HR monitor to establish training zones and asked the athletes to record HR during their training sessions as well as during their races. Distribution of training among swimming, cycling and running was derived from the coach's plan. Training volume was expressed as time (total hours or hours/week) and training intensity was calculated in hours of training performed at three different heart rate zones (Zapico, et al., 2007): i) below VT_1 , ii) between VT_1 and VT_2 , and iii) above VT_2 . Training stimulus was calculated as TRIMP scores (Banister & Calvert, 1980) using the following equation:

$$w(t) = T \times [(HR_{exer} - HR_{rest}) / (HR_{max} - HR_{rest})]$$

Where $w(t)$ is the training stimulus or TRIMP score, T is the duration of the exercise in minutes, HR_{exer} is the heart rate during exercise, HR_{rest} is the resting heart rate and HR_{max} is the maximum heart rate during the maximal cycle ergometer test .

STATISTICAL ANALYSES

One way repeated-measures analysis of variance (ANOVA) was used to compare the means of the variables recorded over the three periods. Previously, a Mauchly test (Mauchly, 1940) proved the sphericity of the distribution. An adjustment of p -value by Greenhouse-Geisser method (Greenhouse & Geisser, 1959) was then used if the test revealed a non type H covariance structure.

Difference in the distribution of training, training intensity or training time between the two periods defined by the testing (*i. e.* from the start of the season to the pre-competitive period *vs.* from the pre-competitive period to the competitive period) were revealed using a paired t -test.

All statistical analyses were performed using the Statistical Package for Social Sciences (SPSS, v. 15.0 for WINDOWS; SPSS Inc, Chicago). The level of significance was set at 0.05.

RESULTS

Participant's characteristics in each visit are shown in Table 1. Details about training volume and intensity during each period are depicted in Table 2. Total training time increased ($p = 0.02$) from the start of the season to the pre-competitive period. This increase was accompanied by a decrease in training below VT_1 ($p < 0.01$) and a concomitant increase in the time spent above VT_2 ($p < 0.01$). In addition, training distribution among disciplines varied through the course of the season. According to the coach's plan, within the first period of the study (*i.e.* from the start of the season to the start of the pre-competitive period), triathletes spent $36.1 \pm 4.3\%$ of the total training swimming, $43.4 \pm 3.6\%$ cycling and $20.5 \pm 4.1\%$ running. These percentages were altered during the pre-competitive period to the competitive period and triathletes trained $28.6 \pm 5.1\%$ of the time swimming ($p < 0.01$), $45.2 \pm 3.4\%$ cycling (non-significant) and $26.2 \pm 4.3\%$ running ($p = 0.02$).

Table II. Total training and intensity throughout the season.

	Between start of the season and pre-competitive period	Between pre-competitive and competitive period
Total training (hours)	158.7±0.6	166.6±0.7*
Total training (hours/week)	13.7±2.2	14.4±3.8*
Total TRIMP score per week	695±62.0	977.3±69.4*
Training below VT ₁ (% total training)	57.3±0.4	48.3±0.6*
TRIMP score per week below VT ₁	264.7±42.5	251.8±62*
Training between VT ₁ and VT ₂ (% total training)	39.4±0.5	39.3±0.6
TRIMP score per week between VT ₁ and VT ₂	267.2±51.4	292.2±67.8
Training above VT ₂ (% total training)	3.3±0.6	12.4±0.4*
TRIMP score per week above VT ₂	163.1±53.2	433.3±71.3*

Data are shown as mean ± s. * $p < 0.05$ between periods. TRIMP scores were calculated as reported by Banister and Calvert (1980).

Physiological variables recorded during exercise are shown in Table 3. Compared to the start of the season, $\text{VO}_{2\text{max}}$ remained stable during the pre-competitive period but increased at the competitive period ($p < 0.01$). On the other hand, PO, HR and [La] remained stable within the different periods of the season at maximum intensity or at the intensity corresponding to the VT₂. However, at the intensity corresponding to the VT₁, an improvement in PO ($p < 0.01$) and VO_2 ($p = 0.03$) was observed already at the pre-competitive period. This effect was maintained during the competitive period. No significant changes were observed for the HR either at maximum or submaximal intensities.

Table III. Variables recorded during the three visits.

	Start of the season	Pre-competitive period	Competitive period
PO _{max} (W)	383±15.8	396±17.0	402±23.0
PO _{max} (W·kg ⁻¹)	5.6±1.1	5.85±1.3	5.92±1.5
HR _{max} (beats·min ⁻¹)	184±4	182±4	183±5
VO _{2max} (mL·min ⁻¹)	4640±182	4593±125	4929±196
VO _{2max} (mL·kg ⁻¹ ·min ⁻¹)	68.0±2.0	68.1±1.6	72.9±2.0*†
[La] _{max} (mmol·L ⁻¹)	12.1±1.4	10.3±1.4	14.1±1.3
PO _{VT1} (W)	169±12.9	221±12.5*	200±15.5
PO _{VT1} (%PO _{max})	44.1±2.4	55.8±2.6*	49.8±3.0†
HR _{VT1} (beats·min ⁻¹)	128±4	132±4	130±4
VO _{2VT1} (mL·min ⁻¹)	2325±142	2820±130*	2778±200
VO _{2VT1} (%VO _{2max})	50±2.4	61±2.1*	56±2.0†
[La] _{VT1} (mmol·L ⁻¹)	2.4±0.2	2.3±0.2	2.3±0.1
PO _{VT2} (W)	319±12.8	326±10.0	336±13.5
PO _{VT2} (%PO _{max})	83.3±3.0	82.3±2.4	83.6±2.8
HR _{VT2} (beats·min ⁻¹)	168±3	167±4	168±4
VO _{2VT2} (mL·min ⁻¹)	3870±172	3883±121	4247±208
VO _{2VT2} (%VO _{2max})	83.3±2.0	83.2±1.2	86.2±1.6
[La] _{VT2} (mmol·L ⁻¹)	6.7±0.7	5.6±0.7	6.6±0.5

Data are shown as mean ± s. Power output (PO), Heart rate (HR), Oxygen consumption (VO₂), blood lactate concentration ([La]). Subscripts max, VT₁ and VT₂ indicate maximum, first ventilatory threshold and second ventilatory threshold respectively.

* $p < 0.05$ compared with start of the season.

† $p < 0.05$ compared with pre-competitive period.

DISCUSSION

This study provides new insights into the development/changes on physiological variables (measured during cycle ergometer test) throughout a season in highly trained triathletes. The results of the study show that cycling HR remains stable in our sample, despite changes in training distribution, training intensity or changes in PO at the intensity corresponding to the VT_1 . Although there are some triathlon-specific tests available in the academic literature, both lab-based (Hue, Le Gallais, Boussana, Chollet, & Prefaut, 2000; Millet, Dreano, & Bentley, 2003; Millet, Millet, & Candau, 2001) and field-based (Bernard, et al., 2003; Díaz, et al., 2011; Vleck, Santos, Bentley, & Alves, 2005), monitoring and prescribing training intensity in triathletes still represents a challenge for coaches (Vleck, et al., 2005). Therefore, the stability of the cycling HR-ventilatory thresholds relationship throughout the competitive season may imply that a single laboratory test at the beginning of the season might be sufficient to prescribe training (at least in cycling) based on HR zones. This observation agrees with previous research in speed skaters (Foster, Fitzgerald, & Spatz, 1999) and elite cyclists (Lucia, et al., 2000; Zapico, et al., 2007), which reported that HR remains stable throughout the course of the year using the same methods to determine the HR – thresholds relationship (Zapico, et al., 2007).

On the other hand, PO showed an increasing trend (only significant for PO_{VT_1}) from the start of the season to the competitive period (Table III), shifting the HR – PO and PO – thresholds relationships during the course of the season. Consequently, the use of power-meters instead HR to monitor and prescribe training intensities would require several evaluations throughout the season. Nonetheless, the evaluation of the PO – thresholds relationship over the course of one or several seasons may be useful to identify training-induced adaptations. In runners with more than 7 years of training experience the speed at VT_2 has been used to discriminate between long and middle distance runners, suggesting that speed at VT_2 is more sensitive to chronic adaptations (Rabadán, et al., 2011). Maffulli et al. (1991) also addressed this concept by evaluating the relationship between anaerobic threshold and competition speed in 112 runners of various competitive distances. This relationship was only significantly strong in those runners competing over long distances (5000 or 10000 meters). Finally, a meta-analysis study determined that in average, VT_2 is more sensitive to training-induced adaptations than VT_1 (Londeree, 1997). Whether changes in PO at VT_2 or VT_1 may reflect training-induced adaptations in triathletes still remains unclear and requires further investigation, since as opposed to our results, Galy et al. (2003) found a decrease in PO at VT_2 throughout the competitive season.

The PO and VO_{2max} obtained by our participants are comparable with those already reported for elite triathletes by Schneider et al. (1990) and Hue et al. (2000). We found a positive increase of ~6% in $\dot{V}O_{2max}$ from the start of the season to the competitive period. Although these findings agree with previous studies (Kohrt, Morgan, Bates, & Skinner, 1987), the ~6% improvement, is somewhat surprising since elite or highly trained athletes require longer periods of training to reach improvements (Calderon, Díaz, Peinado, Benito, & Maffulli, 2010; Londeree, 1997), and previous studies have reported no seasonal

changes of VO_{2max} in triathletes (Galy, et al., 2003). In our study, the magnitude of training intensity expressed as TRIMP scores for all modalities is similar to the ~800 units per week reported in other endurance disciplines such as in Kenyan runners (Billat, et al., 2003) and Nordic skiers (Seiler & Kjerland, 2006), as well as the distribution of training among disciplines (Basset & Boulay, 2003; Millet, Vleck, & Bentley, 2011). However, in our study training intensity changed from the start of the season to the competitive period, not only by increasing training volume (*i. e.* time of training), but also by dramatically elevating the training time above the VT_2 (Table II). In addition, we recorded a significant decrease of training in swimming concomitant to an increase in running. It is important to note that triathletes may adapt to training different to specialist counterparts due to the cross training effects (Millet, et al., 2009). If the shift of training through the course of the season from swimming to running, together with the shift of training intensities, may affect cycling VO_{2max} remains speculative and furthers studies in which total training remains stable but training distribution is modified are required.

The increase in VO_{2max} at the competitive period was accompanied by a decrease in VO_{2VT1} and a slight, but non-significant increase in VO_{2VT2} . Galy et al. (Galy, et al., 2003) reported a decrease in PO at VT_1 and VT_2 over the course of the season. In contrast, a positive effect of training throughout the season on VO_{2VT1} has been shown previously in cyclists (Lucia, et al., 2000; Zapico, et al., 2007) and triathletes (Kohrt, et al., 1987). Compared to previous studies, we controlled the training in a weekly basis and we observed more time spent above the VT_2 prior to the competitive period. These changes in training throughout the different periods of the season may explain our results. However the lack of significant increase at VT_2 is interesting since Kohrt et al. (1987) reported an improvement of the lactate threshold ($4 \text{ mmol}\cdot\text{L}^{-1}$) from the beginning to the end of the season. In this context, Schneider et al. (1990) observed a lactate threshold ($4 \text{ mmol}\cdot\text{L}^{-1}$) at ~67% VO_{2max} , Kohrt et al. (1987) at ~72-76% VO_{2max} , and Hue et al. (2000) at ~65% VO_{2max} . In our study, the VT_2 was determined at ~6 $\text{mmol}\cdot\text{L}^{-1}$. These differences between studies could be related to the different methodologies used to determine the VT_2 . While previous studies chose a fix lactate concentration of $4 \text{ mmol}\cdot\text{L}^{-1}$, we chose to determine the ventilatory threshold because it has been shown that VT_2 assessment is reproducible (Amann, et al., 2004; Dickhuth, et al., 1999; Weston & Gabbett, 2001) and it is a good predictor for performance in athletes with similar VO_{2max} (Coyle, Coggan, Hopper, & Walters, 1988; Coyle, et al., 1991).

Finally, it is important to know that changes in cycling VO_2 or PO were always accompanied by the stability of the HR. This stability observed at both, maximal and submaximal intensities, has been previously reported in cyclists (Lucia, et al., 2000; Zapico, et al., 2007), however this is the first time that it is presented in highly trained triathletes competing at national and international level. This finding is of major importance, from a practical point of view, since it suggests that a single test at the start of the season (obtaining the individual HR – thresholds relationship) may be sufficient to prescribe and monitor cycling training intensities throughout the rest of the year.

LIMITATIONS

First of all, although training stimulus was similar compared to other endurance disciplines (Billat, et al., 2003; Seiler & Kjerland, 2006), and training distribution is also in agreement with previous works (Basset & Boulay, 2003; Millet, et al., 2011), we were unable to determine the training intensity in each discipline. The results of the present study are also limited due to the fact that our data were obtained only through a cycle ergometer test, whilst triathlon combines three different sports disciplines which affect each other (Millet & Vleck, 2000). Thus, the results obtained with cycling tests might not be the same for running or swimming performance and our results must be confined to cycling.

Nonetheless, a previous study has shown a similar relationship between HR and $\dot{V}O_2$ during running and cycle ergometer tests in triathletes (Basset & Boulay, 2003), which suggest that a test in one of the disciplines may be useful to prescribe training intensity in the other. Moreover, the ventilatory thresholds are submaximal landmarks representing physiological events (Davis, et al., 1980; Meyer, Lucia, Earnest, & Kindermann, 2005; Skinner & McLellan, 1980; Wasserman, Whipp, Koyl, & Beaver, 1973) which are independent of the nature of the test, meaning that the HR – ventilatory thresholds relationship may be also stable in running or swimming. On the other hand, longer samples would be necessary in order to generalise our results.

In addition, the lack of a control group hampers to study the possible changes throughout the season independently of training. However, our data are valuable since the academic literature concerning training intensity throughout the season is limited. We were also successful recording training (~90% of the training session were successfully registered) and testing highly trained triathletes competing both at national and international level.

CONCLUSION

We conclude that the cycling HR – ventilatory thresholds relationship is stable in our sample through the different periods of a competitive season, even occurring increase of some maximal and submaximal parameters. This relationship remains stable even if significant changes in total training intensity or distribution of training among swimming, cycling and running occurs. Therefore, we suggest that single laboratory testing at the start of the season could be sufficient to prescribe cycling training intensity in highly trained triathletes based on HR zones. Since these findings were obtained from cycle ergometer tests, they are not directly applicable for running or swimming training prescription. In order to provide a more integrated picture, future studies should examine longer samples and the stability of this relationship during running and swimming tests.

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