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Research Article

PHYSIOLOGICAL PROFILE OF ELITE TRIATHLETES: A COMPARISON BETWEEN YOUNG AND PROFESSIONAL COMPETITORS

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ABSTRACT

The aim of the present work was to compare the cardiorespiratory response of two high level groups of triathletes of different age during a simulation of a cycling-running succession. The two groups, G1 (n=6; age 23.8 ± 5.6 years; weight 71.2 ± 8.7 kg; height 180.0 ± 8.8 cm) and G2 (n=9; age 15.2 ± 0.7 years; weight 60.2 ± 6.8 kg; height 173.6 ± 6.4 cm) performed two tests in a random order. Trial 1 (C-R) consisted of 30 min cycling with a load corresponding to the ventilatory threshold previously calculated, followed by a 3000 m run at the highest possible intensity around a 400 m track. Trial 2 (R), consisted of a 3000 m run at the maximum intensity possible only. The G1 subjects took less time to complete the distance (591.2 compared to 669.1 s for the G2 subjects in the C-R setting, and 584.6 vs. 645.5 s in the R setting). In addition, the G1 subjects showed a more adapted cardiorespiratory response than the G2 subjects. In conclusion, the results show a profile in terms of cardiorespiratory response and performance for senior and young triathletes highly trained.

Key words: *Cycling-running trial, comparative study, metabolic cost, cardiorespiratory response, performance.*

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INTRODUCTION

The Olympic triathlon is an endurance sport that involves three immediately successive components: 1.5 km swimming, 40 km cycling, and a 10 km run. The duration of the event is around two hours (Rowlands and Downey, 2000; Vleck et al., 2006). The capacity to produce the maximum amount of energy per unit time is one of the main markers of performance in this sport (O'Toole and Douglas, 1995). The event also requires high technical performances in and rapid physiological adaptation between each component (Millet and Vleck, 2000).

It has been suggested that the importance of the transition between the swimming and cycling components is mainly tactical in nature (Millet and Vleck, 2000). Those participants who are not among the first to abandon the water see their chances of winning decline since cycling alone is associated with increased fatigue (Hausswirth et al., 1999; Hausswirth et al., 2001). The cycling-running succession, however, has an important physiological component: it is difficult to adapt to running after cycling (Díaz et al., 2009). Certainly, the times recorded for this last phase of the event are those that show the greatest variation (Landers et al., 2000) or a great correlation with overall performance (Vleck et al., 2006). Triathletes who show the best overall performance are therefore those for whom the cycling component least affects running (Hue et al., 1998).

A number of studies have compared groups of different performance level in simulations of cycling-running trials (Hue et al., 2001b; Hue et al., 2000; Millet et al., 2000). However, few have compared groups of different age. Bunc and coworkers, using incremental running test, reported certain requisites to be met by young triathletes if they wished to compete at international level. Also they showed high maximal oxygen uptake (VO_{2max}) and similar characteristics between triathletes and middle distance runners (Bunc et al., 1996). Millet and Bentley used a protocol which combined runing-cycling-runing and indicated that performance in the running component might be more important than the VO_{2max} in the detection of talented competitors (Millet and Bentley, 2004). These authors showed that young triathletes are different from senior ones in terms of peak power output during cycling or speed at the ventilatory threshold, which are lower for youngers. Both works carried out tests where the subjects were not able to select the intensity or pacing strategy, that are know to be realted to performance (Foster et al., 1994; Vleck et al., 2008)

Taking in account the aforementioned studies, more research is needed to asses differences between young and senior triathletes during specific cycling-running succession. Thus, the aims of the present work was to compare the cardiorespiratory response and performance during a cycling-running trial of high level triathletes of different age, using a test where the intensity is self-selected by the subject.

MATERIAL AND METHODS

Subjects

The study subjects were 15 elite triathletes who taked part in the study voluntarity. These were divided into two groups: G1 – senior elite triathletes (n=6) belonging to the Spanish National Triathlon Team, and G2 – young triathletes (n=9) selected by the Spanish Triathlon Federation as the best in their category (under 16). Table 1 shows the main characteristics of the two groups.

All subjects had undergone a medical test in the previous months. All were explained (verbally and in writing) the tests to which they would be subjected, the aims of the experiment, and the risks involved. All provided written consent to be included (permission was provided by the parents/guardians of the G2 subjects) in accordance with the guidelines of the Helsinki Declaration (as revised in Hong Kong 1989 and Edinburgh 2000) regarding human experimentation.

Experimental protocol

All subjects underwent an incremental exercise test (25 $W \cdot min^{-1}$) on a cycle ergometer (Cardgirus, G&G Innovación S.A., Spain) in order to determine their VO_{2max} and ventilatory threshold (Th_{vent}) using a previous described method (Beaver et al., 1986).

The next tests were performed in Madrid (Spain) for the senior elite group or in Soria (Spain) for the young triathletes. The wind was calm, and the environmental conditions stable (temperature 22 ± 2.4 ºC, relative humidity 58 ± 3.8%, atmospheric pressure 702 ± 12 mmHg). The two groups of subjects underwent two tests in the field in random order and with a day's rest between them. Test C-R involved: a) a 10 min warm-up period of cycling and running, followed by b) 30 min of cycling on a Cardgirus® (G&G Innovación S.A., Spain) cycle ergometer at a load corresponding to the Thvent (mean = 3.5 $W \cdot kg^{-1}$), and finally c), after a maximum allowed transition period of 1 min, a 3000 m run at the maximum intensity possible around a 400 m Tartan track (7.5 laps). Test R involved a) a 10 min warm-up period (running only) followed by b) a 3000 m run at the maximum intensity possible. The heart rate (HR) was measured in both tests using a Polar® pulsometer (Polar Electro, Kempele, Finland); no information on this variable was provided to the subjects during the tests. All subjects were constantly encouraged to give their maximum performance. All tests were performed at the same time of day. The subjects were not allowed to compete in any organised event or train during the experimental period.

During the first 20 min of the cycling component of the C-R test, the subjects received 250 ml of cool water. A portable gas analyser (Jaeger Oxycon Mobile®, Erich Jaeger, Viasys Healthcare, Germany), which usefulness has been confirmed (Díaz et al., 2008), was then used to record the subjects' cardiorespiratory variables (ventilation rate [VE], the ratios VE/VO_2 and VE/VCO_2, the respiratory exchange ratio [RER], inspiration time [T_i], expiration time [T_e] and total breathing cycle time [T_{tot}]) over the rest of the test period. During the R test the gas analyser was used over the duration of the run. In both cases, lap and 15 s means were calculated for all variables recorded.

Metabolic cost

The metabolic cost (MC) of runing in the C-R test and R test was determined using the following equation (di Prampero, 1986):

$$MC\ (ml\ O_2 \cdot kg^{-1} \cdot km^{-1}) = VO_2\ (ml \cdot kg^{-1} \cdot h^{-1})\ x\ 60\ /\ speed\ (km \cdot h^{-1})$$

Statistical analysis

After confirming the normal distribution of the variables measured, the paired Student *t* test was used to compare the within-group results of the C-R and R tests. The Student *t* test for independent samples was used to examine the differences between the two groups of subjects. Significance was set at $p<0.05$. All calculations were performed using SPSS software v. 12.0 for Windows® (SPSS Worldwide Headquarters, Chicago, IL).

RESULTS

The results are presented as means ± standard deviation. Table 2 shows the differences between the groups in both tests. The G1 subjects showed a higher HR during the C-R test than the R test, while the G2 subjects showed greater values for the ventilation variables measured (VE, VE/VO_2, VE/VCO_2, RER) (table 1). The T_i, and T_{tot} of the G2 subjects were always smaller in the C-R than in the R tests.

Table 1. *Mean ± standard deviations for the main characteristics of the two groups.*

	G1	G2
Age (years)	23.8 ± 5.6	15.2 ± 0.7
Weight (kg)	71.2 ± 8.7	60.2 ± 6.8
Height (cm)	180.0 ± 8.8	173.6 ± 6.4
VO_{2max} ($ml·min^{-1}·kg^{-1}$)	78.2 ± 4.0	77.1 ± 5.4
Th_{vent} (%VO_{2max})	65.1 ± 3.2	62.0 ± 5.8

VO_{2max} is maximal oxygen uptake measured during an incremental cycle ergometer test; Th_{vent} is the ventilatory threshold (Beaver, et al., 1986).

Table 2. *Means ± standard deviations for the variables measured in the two tests; figures are supplied for both subject groups.*

	C-R				R			
	G1		G2		G1		G2	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
VO_2 ($ml·min^{-1}$)	4730	± 727	4222	± 520 [a]	4691	± 1064	4350	± 707 [a]
VO_2/kg ($ml·min^{-1}·kg^{-1}$)	66.4	± 10.5	69.2	± 5.3	65.8	± 15.2	71.2	± 10.9 [a]
VCO_2 ($ml·min^{-1}$)	5186	± 468	3615	± 298 [a]	5145	± 720	3639	± 604 [a]
VE ($l·min^{-1}$)	155.5	± 21.8	132.5	± 16.8 [a]	151.3	± 26.4	127.2	± 24.3 [a b]
VE/VO_2	38.1	± 7.1	35.0	± 4.0 [a]	37.6	± 8.2	32.3	± 2.8 [a b]
VE/VCO_2	29.2	± 3.2	35.6	± 3.7 [a]	28.6	± 2.0	34.0	± 3.3 [a b]
V_T (l)	2.8	± 0.4	2.3	± 0.3 [a]	2.7	± 0.4	2.3	± 0.4 [a]
f ($resp·min^{-1}$)	56	± 7	57	± 10	56	± 9	55	± 11
HR (ppm)	175	± 10	186	± 8 [a]	171	± 12 [b]	181	± 12 [a b]
T_i (s)	0.53	± 0.06	0.55	± 0.17	0.55	± 0.09	0.58	± 0.18 [b]
T_e (s)	0.56	± 0.09	0.54	± 0.09	0.56	± 0.10	0.57	± 0.12 [b]
T_{tot} (s)	1.09	± 0.14	1.09	± 0.25	1.11	± 0.19	1.15	± 0.29 [b]
RER	1.02	± 0.09	0.87	± 0.04 [a]	1.02	± 0.10	0.85	± 0.04 [a b]
MIF ($l·s^{-1}$) (mean inspiratory flow)	5.28	± 0.71	4.49	± 0.76 [a]	5.09	± 0.88	4.30	± 0.97 [a]
IDC (inspiratory duty cycle)	0.49	± 0.02	0.50	± 0.04	0.49	± 0.01	0.50	± 0.03
MC (ml $O_2·min^{-1}·km^{-1}$)	220.4	± 35.2	256.9	± 24.7 [a]	214.2	± 48.5	257.8	± 42.0 [a]
Vel ($km·h^{-1}$)	18.1	± 1.2	16.3	± 1.1 [a]	18.5	± 1.9	16.7	± 0.7 [a b]
Time to complete run (s)	591.2	± 25.8	669.1	± 23.8 [a]	584.6	± 30.4	645.5	± 15.8 [a b]

[a] *indicates differences with respect to G1 results,* [b] *indicates differences with respect to C-R results ($p<0.05$).*

The MC for the G1 subjects was always lower than that for the G2 subjects, but not significantly so; neither were any differences seen between the MC values for the two tests. The G1 subjects returned better run times, maintaining a greater mean speed than the G2 subjects ($p<0.05$), in both tests. In addition, the G2 subjects showed a loss of performance in the C-R running component (compared to the R test) greater than that seen among the G1 subjects (table 2).

DISCUSSION

The C-R test was associated with an acute cardiorespiratory response in the younger athletes (G2) that was not seen in the professionals (G1). This explains the loss of performance seen in these younger competitors in terms of the time to complete the run and the mean speed maintained.

Kreider and coworkers (Kreider et al., 1988) reported a much lower cardiovascular, hemodynamic and thermal response for the triathlon components when practised alone than when performed successively. This response in the successive component setting is characterised by a progressive increase in the VO_2, VE and HR (Guezennec et al., 1996; Hue et al., 1998). The cycling-running trial would therefore seem to be associated with a clear cardiorespiratory response – known as cardiovascular and ventilatory drift (Dempsey et al., 1988; Rowell, 1974). However, in the present work, this was only seen in the younger athletes. The factors invoked in the explanation of this response include the depletion of glycogen deposits by the cycling component (Guezennec et al., 1996; Hausswirth et al., 1996; Hue et al., 1998), respiratory muscle fatigue (Hue et al., 1998), partial dehydration and a rise in body core temperature (Guezennec et al., 1996; Hausswirth et al., 1996; Hausswirth et al., 1997; Kreider et al., 1988), and a reduction in lung expandability due to exercise-induced hypoxemia (Caillaud et al., 1995).

One study reported an increase in the mobilisation of fatty acids at the end of the triathalon (Van Rensburg et al., 1986). However, in the present work the RER of the G2 subjects increased significantly in the C-R test compared to the R test. Therefore, the cardiorespiratory response seen in these subjects cannot be explained by a movement towards fat metabolism. It should be remembered, however, that the present tests were shorter than both real competitions and the tests used in other studies (Guezennec et al., 1996; Hausswirth et al., 1996); longer exercise times might be associated with an increase in the importance of this factor.

Respiratory muscle fatigue has been reported when exercise intensity involves 85% of the VO_{2max} (Johnson et al., 1993). During the triathlon, such fatigue can be caused by the intensity of exercise but also by the typical position adopted in cycling which causes a loss mechanical efficiency in the diaphragm (the main respiratory muscle) (Hill et al., 1991). Different authors have assessed respiratory muscle fatigue during cycling-running trials and report it to be specific for this succession (Boussana et al., 2003; Boussana et al., 2001). In the present work the ratio VE/VO_2 was greater during the C-R test in both groups (38.1 ± 7.1 vs. 37.6 ± 8.2 for the G1 subjects, and 35.0 ± 4.0 vs. 32.3 ± 2.8 for the G2 subjects), while the behaviour of VE/VCO_2 was similar in both (29.2 ± 3.2 vs. 28.6 ± 2.0 for the G1 subjects, and 35.6 ± 3.7 vs. 34.0 ± 3.3 for the G2 subjects). In the G2 subjects, the increased VE/VO_2 and VE/VCO_2 ratios in the C-R test compared to the R test, along with the reduction seen in T_i and T_{tot} (i.e., hyperventilation), might also be related to metabolic acidosis, even though some authors suggest otherwise (Hue et al., 2001b; Hue et al., 2000). The present results indicate that respiratory muscle fatigue only occurred in the G2 subjects (table 2).

The increase in partial dehydration with core body temperature may be an important factor in the cardiorespiratory response during the cycling-running trial (Guezennec et al., 1996; Hausswirth et al., 1996; Hausswirth et al., 1997; Kreider et al., 1988). In the present study all subjects were allowed 250 ml of cool water during the first 20 min of the cycling component of the C-R test, yet the HR increased significantly. This indicates that this volume was insufficient to prevent cardiovascular drift. In addition, cardiovascular drift has been associated with increased blood osmolarity (Hamilton et al., 1991); thus, rehydrating with water alone may not prevent it.

The cardiorespiratory response seen in the G2 subjects was more acute than that seen in the G1 subjects. The G1 subjects took 1.2% longer to complete the running component of the C-R test than to complete the R test (591.2 ± 25.8 compared to 584.6 ± 30.4), compared to 3.7% longer for the G2 subjects (669.1 ± 23.8 vs. 645.5 ± 15.8). This loss of performance was only significant for the younger subjects (table 2), which must be related to the greater cardiorespiratory response shown. A greater cardiorespiratory response has been associated with the C-R test by other authors (Guezennec et al., 1996; Hue et al., 2001b; Hue et al., 2000; Hue et al., 2001c). It is possible that the G1 subjects have a better adapted cardiorespiratory response given the longer accumulation of specific training over their sporting lives; certainly it has been shown that training in cycling-running blocks improves performance (Hue et al., 2001a; Hue et al., 2002).

In addition to their effect on cardiorespiratory response, differences in MC could also contribute to differences in performance. Several studies have shown differences in MC related to age (Ariens et al., 1997; Krahenbuhl et al., 1989; Sjodin and Svedenhag, 1992); although training might accentuate these differences (Daniels, 1985); age appears to be the most important factor.

Finally, other factors related to muscular activity might explain the differences, since cycling mainly involves concentric contractions while running involves largely eccentric contractions (Bijker et al., 2002). Several studies have related an increase in MC with variations in an athlete's running pattern following the cycling phase (Hausswirth et al., 1997; Hausswirth et al., 2000; Millet et al., 2000), although these variations appear be present for no more than the first six minutes of the race (Millet et al., 2001). In agreement with these authors, G1 triatheletes are able to more rapidly stabilise their running pattern, contributing to a greater performance and lower MC.

Finally, the results provide a performance profile of elite triathletes for the cycling-running trial (table 2) in the post-cycling running component under the present C-R test conditions. Despite this, it should be take in account that the evaluation of the groups were performed in different moments of the training season (final stage of the preparatory period for senior elite and the star of the competitive period for young triatheltes). Then, differences between groups could be even higher if the cardiorespiratory response or performance change throughout a season, although this phenomenon needs more research.

CONCLUSION

In summary, the second transition of the triathlon is a key moment of the competition, and the present work shows that performance during the cycling-running succession is better in more senior elite rather than in younger athletes, despite their both competing at high level. The results provide a performance profile of elite triathletes for the cycling-running trial in the post-cycling running component under the present C-R test conditions. If monitoring the loss of performance in running between the C-R and R tests may be helpful in the detection of talented triathletes is still unclear.

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