Original Article

Maximal oxygen consumption in national elite triathletes that train in high altitude

GILBERTO GONZÁLEZ-PARRA[1], RIGOBERTO MORA [1,2], BERNHARD HOEGER[3]

[1] *Multidisciplinary Mathematics Group (GMM), Faculty of Engineering, University of the Andes, Mérida, Venezuela*

[2] *Management Sports of the University of the Andes, Mérida, Venezuela*

[3] *Department of Physical education, University of the Andes, Mérida, Venezuela.*

ABSTRACT

González-Parra G, Mora R, Hoeger, B. Maximal oxygen consumption in national elite triathletes that train in high altitude. *J. Hum. Sport Exerc.* Vol.8, No. 2, pp. 342-349, 2013. Triathlon is considered an endurance sport composed by the individual disciplines of swimming, cycling and running which are generally completed in this sequential order. It has been suggested that triathlon performance can be predicted by maximal oxygen uptake (VO2max). However, it has also been suggested that some variables such age, gender, fitness, training and ventilator muscles may affect VO2max. It is the aim of this research to measure and analyze the VO2max of 6 national elite triathletes and one national juvenile triathlete, with long experience, training in a high altitude city (1650m). We compare VO2max for female and male groups. We found differences at the VO2max values for these groups. Additionally, we also found high values of VO2max for these young elite triathletes despite their relative short age, but long sport age. **Key words**: VO2MAX, TRIATHLON, LACTATE, GAS ANALYZER, GENDER.

Corresponding author. Multidisciplinary Mathematics Group (GMM), Faculty of Engineering, University of the Andes, Av. 3, Independencia, Mérida, Venezuela.
E-mail: gcarlos999@gmail.com
Submitted for publication June 2012
Accepted for publication November 2012
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.4100/jhse.2012.82.03

INTRODUCTION

Maximal oxygen uptake (VO2max) is currently the most used measure of aerobic capacity. Thus, measuring VO2max is important to predict triathlon performance (Cejuela, 2007). In fact, elite triathletes have significantly higher VO2max values than sub-elite triathletes and high VO2max levels are required for success in triathlons. However, some authors assert that VO2max is a relatively poor predictor of performance in runners due to variations in running and fatigue resistance during prolonged exercise (Noakes, 2003).

There are several methods to measure VO2max including indirect and direct methods. Indirect methods generally are more economical and rely on the use of equations or formulas (Chatterjee, 2010; Niels et al, 2004). One commonly used indirect method is the Bruce protocol which is a maximal exercise test where the athlete works to complete exhaustion as the treadmill speed and incline is increased. The length of time on the treadmill is the test score and can be used to estimate the VO2max value. However, the reliability of indirect methods results are less than the ones offered by direct methods. Nevertheless, the direct measurement of cardiorespiratory endurance (VO2max) itself is difficult, exhausting and often hazardous to perform. The direct method is based on measures regarding expiratory gases from the athlete during exercise.

It is important to remark that VO2max values can improve with training but independently decrease with age. However, the degree of trainability affects VO2max widely; for example, conditioning may double VO2max in some individuals, and will never improve it at all in others (Bouchard, 1999). Also it has been shown that respiratory muscle training does not improve VO2max of triathletes and marathon runners (Amonette & Dupler 2002).

Earlier reviews, conducted in the 1980s, concluded that triathletes possessed lower VO2max values than other endurance athletes (Suriano, 2010). However, some authors state that triathletes are able to obtain similar physiological values as single-sport athletes despite dividing their training time among three disciplines (Suriano, 2010). For instance, VO2max values in elite triathletes have been reported in the range of 70–90 ml/kg/min (Schneider & Pollack, 1991; Basset & Boulay, 2000; Hue et al., 2000). However, VO2max has not been taken as a good predictor of triathlon performance in elite triathletes (O'Toole et al., 1987; Schuylenbergh et al., 2004). Nevertheless, some authors have proposed that VO2max plateau duration has more correlation to triathlon performance than VO2max value (Jianjun, 2009).

Authors also speculate that triathlon training results in general adaptations which enhance maximal oxygen uptake values, whereas anaerobic threshold adaptations occur primarily in the specific muscle groups utilized in training (Schneider, 1991). Additionally, it has been suggested that the exercise testing mode affects the VO2max (Roels, 2005). For instance, it was reported that swimmers exhibited a significantly higher VO2max in swimming than in cycling (58.4 v 51.3 ml/kg/min), whereas the opposite was found for triathletes (53.0 v 68.2 ml/kg/min) (Roels, 2005).

The main aim of this research is to measure and analyze the VO2max of six (6) national elite triathletes and one national juvenile triathlete from the Venezuelan city of Merida. Six of these triathletes have been racing at international triathlons under the regulations of the International Triathlon Union (ITU). The city of Merida was chosen because the majority of the members of the national team train in this high altitude city (1650m). Furthermore, four international elite Olympics triathletes which two of them were former top ten in the ITU world rankings have done their training in this city because its mountain topography and high altitude. We are also interested in comparing VO2max for female and male groups in order to verify the accepted hypothesis that absolute values of VO2max are typically 40-60% higher in men than in women (Hyde & Gengenbach, 2007). Additionally, the relationship between VO2max values with triathlon experience and sport age is studied.

METHODS

Subjects

Seven triathletes (four male elite, two female elite and one female junior) age 22 ± 4.08 years; body mass 61.18 ± 8.44 kg, height 1.67 ± 0.05 m and body mass index 21,66 ± 2,72 kg/m2) volunteered for this study after being informed about the nature and risks involved in participating in the experiments. Five of the triathletes had been consistently involved in triathlon training for at least 5 years and have competed in elite international level prior to participating in this study. They were 21.8 (±0.3) (range: 20.3–22.9) years old and their body weight and height were 179 (±2) cm, and 67.5 (±2.5) kg, respectively.

Experimental Design

We used a treadmill to measure VO2max since in triathletes there is generally no difference in VO2max measured in cycle ergometry and treadmill running (Medelli, 1993). However, data concerning the anaerobic threshold in cycling and running in triathletes is conflicting (Medelli, 1993). This is likely due to a combination of actual training load and prior training history in each discipline.

In order to measure VO2max we performed the Bruce protocol and used expiratory gas analyzer Oxycon Pro of Jaeger (Viasys). Today, the Bruce Protocol is also a common method for estimating VO2max in athletes. The Bruce Protocol was used such that the workload was increased by altering both the incline percent and velocity of the treadmill. The tests were done according to Bruce Protocol, starting at speed 2,74km/hr and grade of 10% and it progressively increased at every 3 minutes until exhaustion (Bruce et al., 1949). During the test the participant breathed via a 2-way valve system. Air came in from the room, however expired through sensors that measure both oxygen concentration and volume. Additionally, the triathlete's heart rates were measured by Polar Vantage NV heart rate monitors (Polar Electro Oy, Kempele, Finland). Forty eight (48) hours prior to the measurements the athletes were asked not to participate in any vigorous training to avoid any possible side effects. The test finished when the VO2max values produced a plateau despite a load increase or the theoretical cardiac frequency was exceeded and the athlete indicated that he was exhausted.

In order to give more reliability to the tests we measured the blood lactate at the start of the Bruce protocol and every three minutes at the end of each stage previous to the workload increase. Finger puncture samples of blood were taken in order to measure lactate every 3 minutes. However, in other researches authors use blood test from the earlobe since it is less pain-sensitive, its skin is thinner and it is easier to dilate ear capillaries as compared to the finger. Most often only a single puncture in the ear is enough to take blood samples for half a day.

Body weight was taken with the triathletes dressed only underpants with sensitive electronic balance. To estimate percent body fat composition, a seven site skinfold thickness technique was used. The anatomical sites used were: chest, abdominal, thigh, triceps, suprailium, subscapular and armpit.

Body Mass Index (BMI) was calculated as the ratio of body weight in kilograms to the square of the standing body height in meters (kg/m2). In order to perform statistical analysis we rely on the statistical program for social sciences version 16.0 (SPSS 10.0).

RESULTS

Seven triathletes (four elite males, two elite females and one junior female) volunteered for this study after being informed about the nature and risks involved in participating in the experiments. The descriptive characteristics of the triathletes under investigation are shown in Table 1. As it can be seen the mean age of female and male groups are under the mean age of international elite triathletes competing in world cups and Olympics.

***Table 1**. Descriptive characteristics and physiological variables for male and female triathletes during treadmill running*

Gender	Age Years	Weight (kg)	BMI kg/m^2	Body Fat%	Lactate mmol/l	VO_2max ml/kg/min	Sport Age Years
Female	26	52.1	19.85	16.08	10.1	73.9	18
Female	20	56.8	18.54	17.05	9.6	74.1	12
Female	15	52.5	18.6	19.77	15.4	64.5	3
Male	25	59.3	22.04	7.2	7.6	79.0	10
Male	25	66.0	24.53	8.44	15.5	81.6	15
Male	24	75.2	25.12	7.77	14.1	66.0	14
Male	19	66.4	22.97	7.69	*	77.4	10

In order to obtain VO2max and blood lactate the Bruce treadmill protocol was implemented. This protocol tended to produce plateau in oxygen consumption during the early stages (Northridge, 1990).

The results regarding maximal oxygen consumption VO2max showed that the female triathlete group had lower values (70.83±5.48 ml/kg/min) than the male group (76.0±6.88 ml/kg/min). These values are in well accordance with values of other elite triathletes around the world and higher than ironman triathletes (Dengel, 1989; Laurenson, 1993; O'Toole et al. 1987; O'Toole 1995; Schabort, 2000; Schneider, 1990). For instance it has been reported group of male triathletes with VO2max mean values of 75.4 ml/kg/min measured on the treadmill and VO2max mean values of 70.3 ml/kg/min during cycle ergometry (Schneider, 1990). Additionally, we checked the hypothesis that absolute values of VO2max are typically higher in men than in women. However, the difference is not in the proposed range of 40%-60% (Hyde & Gengenbach, 2007). In Figure 1 it can be observed the VO2max mean values of the female (lower) and male (higher) triathlete groups.

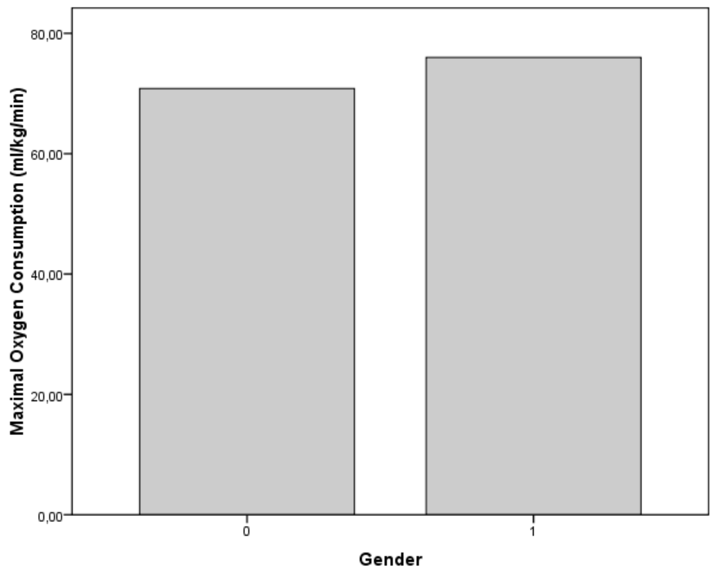

Figure 1. *Maximal oxygen consumption for female (Gender=0) and male (Gender=1) triathletes obtained during the test. As was expected the female group has less maximal oxygen consumption values than the male group*

In regard to the highest blood lactate achieved in the test for each group, female triathlete group has lower values (11.7±3.21 mmol/l) than the male group (12.4±4.21 mmol/l). These values are in the normal range for elite triathletes (Hausswirth, 1999). It is important to mention that the blood lactate of one male triathlete could not be taken. In Figure 2 it can be seen the dynamic behavior of blood lactate for the female triathletes during the test. Notice the steep increase at 11 minutes and the less experienced triathlete obtaining faster and higher blood lactate levels. Additionally, in Figure 3 it can be observed the dynamic behavior of blood lactate for the male triathletes during the test. Notice the steep increase at 14 minutes.

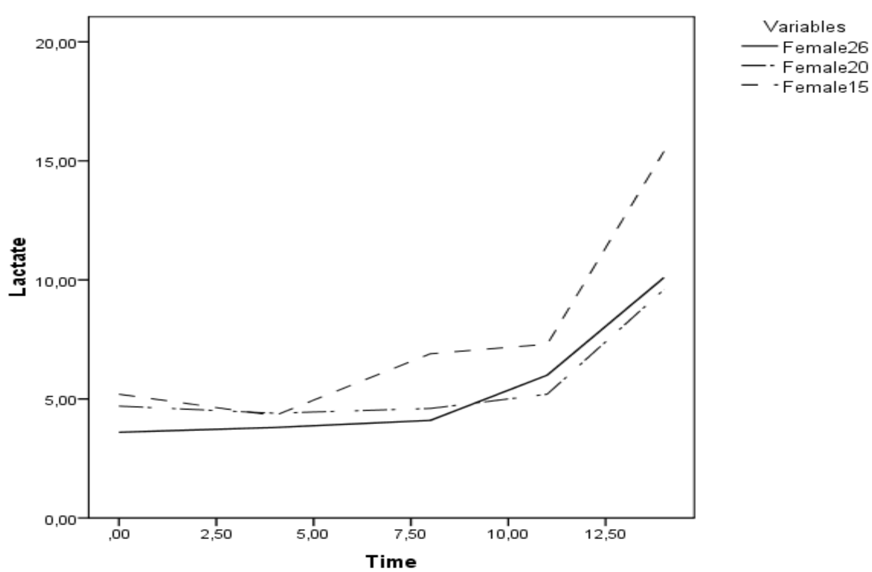

Figure 2. *Dynamic behavior of blood lactate for the female triathletes during the test. Notice the step increase at 11 minutes and the less experienced triathlete obtaining faster and higher blood lactate.*

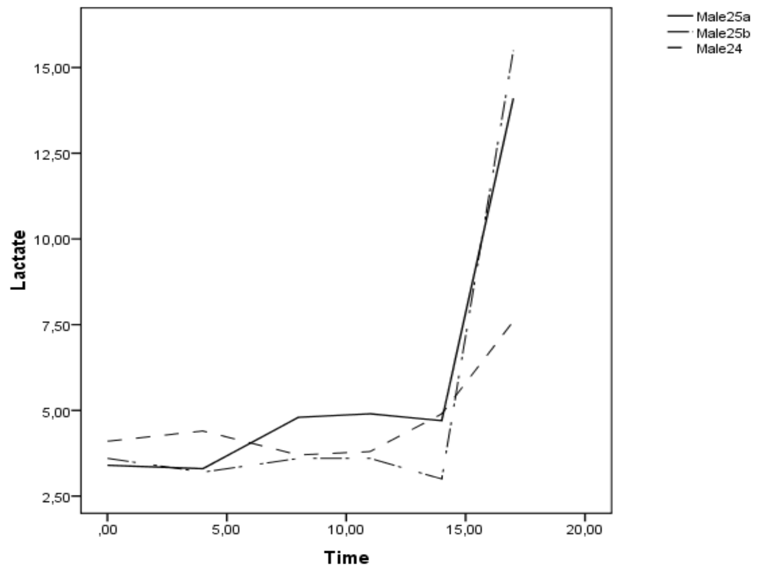

Figure 3. *Dynamic behavior of blood lactate for the male triathletes during the test. Notice the step increase at 14 minutes.*

In order to check possible correlations between VO2max, blood lactate and other physical characteristics of the triathletes we performed Pearson's product moment correlations. For all statistics, a significance level of $P<0.05$ was present. A correlation coefficient of $r=0.73$ was calculated as being significant. The results didn't show any correlation.

DISCUSSION AND CONCLUSIONS

In this research we measured and analysed the VO2max of 6 national elite triathletes and one national juvenile triathlete training in a high altitude city (1650m). We compare VO2max for female and male groups. The results regarding maximal oxygen consumption VO2max showed that female triathlete group had lower values (70.83±5.48 ml/kg/min) than the male group (76.0±6.88 ml/kg/min). Additionally, we found high values of VO2max for these elite triathletes despite their short age, but long sport age. In regard to the highest blood lactate achieved in the test for each group we found that the female triathlete group had lower values (11.7±3.21 mmol/l) than the male group (12.4±4.21 mmol/l).

Finally, it is important to remark that maximum workload achieved depends on many physical (activities the day before) and psychological (ability to agonize oneself, interest in the study) factors. Additionally, the sample size used in this work is not the optimum. However, it is important to mention that several elite triathletes and their coaches have some concerns about this type of test and elite triathletes training in high altitude on regular basis are few. Thus, we are aware that results need to be taken carefully.

REFERENCES

1. AMONETTE WE, DUPLER TL. The effects of respiratory muscle training on VO2max, the ventilatory threshold and pulmonary function. *Journal of Exercise Physiology*. 2002; 5: 29-35.
2. BASSET FA, BOULAY MR. Specificity of treadmill and cycle ergometer tests in triathletes, runners and cyclists*. Eur J Appl Physiol*. 2000; 81(3): 214-221.

3. BASSETT DR JR, HOWLEY ET. Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Med Sci Sport Exer*. 2000; 32: 70-84.
4. BOUCHARD C, AN P, RICE T, SKINNER JS, WILMORE JH, GAGNON J, PÉRUSSE L, LEON AS, RAO DC. Familial aggregation of VO2max response to exercise training: results from the HERITAGE Family Study. *J Appl Psychol*. 1999; 87(3): 1003-1008.
5. BRUCE RA, PEARSON R, LOVEJOY FW, YU PNG, BROTHERS GB. Variability of respiratory and circulatory performance during standardized exercise. *J Clin Invest*. 1949; 28(6 Pt 2): 1431-1438.
6. CEJUELA-ANTA R, PÉREZ-TURPIN J, VILLA-VICENTE J, CORTELL-TORMO J, RODRÍGUEZ-MARROYO J. An analysis of performance factors in sprint distance triathlon. *J Hum Sport Exerc*. 2007; 2(2): 1-25.
7. CHATTERJEE P, BANERJEE AK, DAS P, DEBNATH P. A regression equation for the estimation of VO2max in Nepalese male adults. *J Hum Sport Exerc*. 2010; 5(2): 127-133.
8. DENGEL DR, FLYNN MG, COSTILL DL, KIRWAN JP. Determinants of success during triathlon competition. *Res Q Exercise Sport*. 1989; 60: 234-8.
9. DE VITO G, BERNARDI M, SPROVIERO E, FIGURA F. Decrease of endurance performance during Olympic Triathlon. *Int J Sports Med*. 1995; 16(1): 24-8.
10. HYDE TE, GENGENBACH MS. Conservative Management of Sports Injuries. 2nd ed.; Sudbury, Mass.: Jones & Bartlett, 2007: 845.
11. JIANJUN LI, JIANMIN C, ZHAO FAN Z, HAO S, HAI T. Aerobic Capacity of the Excellent Female Triathlon Athletes in China. *Journal of Shenyang Sport University*. 2009-05.
12. HAUSSWIRTH C, BRISSWALTER J, VALLIER JM, SMITH D, LEPERS R. Evolution of electromyographic signal, running economy, and perceived exertion during different prolonged exercises. *Int J Sports Med*. 2000; 21(6): 429-36.
13. HAUSSWIRTH C, LEHÉNAFF D, DRÉANO P, SAVONEN K. Effects of cycling alone or in a sheltered position on subsequent running performance during a triathlon. *Med Sci Sport Exer*. 1999; 31(4): 599-604.
14. HUE O, LE GALLAIS D, CHOLLET D, BOUSSANA A, PREFAUT C. The influence of prior cycling on biomechanical and cardiorespiratory response profiles during running in triathletes. *Eur J Appl Physiol O*. 1998; 77(1-2): 98-105.
15. HUE O, LE GALLAIS D, CHOLLET D, PREFAUT C. Ventilatory threshold and maximal oxygen uptake in present triathletes. *Can J Appl Physiol*. 2000; 25: 102-13.
16. HUE O, VALLUET A, BLONC S, HERTOGH C. Effects of multicycle-run training on triathlete performance. *Res Q Exercise Sport*. 2002; 73(3): 289-95.
17. LAURENSON NM, FULCHER KY, KORKIA P. Physiological characteristics of elite and club level female triathletes during running. *Int J Sports Med*. 1993; 14(8): 455-9.
18. MEDELLI J, MAINGOURD Y, BOUFERRACHE B, BACH V, FREVILLE M, LIBERT JP. Maximal Oxygen Uptake and Aerobic-Anaerobic Transition on Treadmill and Bicycle in Triathletes. *Jpn J Physiol*. 1993; 43: 347-60.
19. MIURA H, KITAGAWA K, ISHIKO T. Characteristic feature of oxygen cost at simulated laboratory triathlon test in trained triathletes. *J Sport Med Phys Fit*. 1999; 39(2): 101-6.
20. NIELS U, SØRENSEN H, OVERGAARD K, PEDERSEN PK. Estimation of VO2max from the ratio between HRmax and HRrest--the Heart Rate Ratio Method. *Eur J Appl Physiol*. 2004; 91(1):111-5.
21. NOAKES TD. Physiological models to understand exercise fatigue and the adaptations that predict or enhance athletic performance. *Scand J Med Sci Spor*. 2000; 10:123-45.
22. NOAKES TD. The Lore of Running. (4th edition) Oxford University. 2003.

23. NORTHRIDGE DB, GRANT S, FORD I, CHRISTIE J, MCLENACHAN J, CONNELLY D, MCMURRAY J, RAY S, HENDERSON E, DARGIE HJ. Novel exercise protocol suitable for use on a treadmill or a bicycle ergometer. *Brit Heart J*. 1990; 64: 313-316.
24. O'TOOLE ML, DOUGLAS PS, HILLER WDB. Lactate Oxygen Uptake and Cycling Performance in Triathletes. *Int J Sports Med.* 1989; 10(06): 413-418.
25. O'TOOLE ML, HILLER WDB, CROSBY, LON O, DOUGLAS PS. The ultraendurance triathlete: a physiological profile. *Med Sci Sport Exer*. 1987; 19(1): 45-50.
26. ROELS B, SCHMITT L, LIBICZ S, BENTLEY D, RICHALET JP, MILLET G. Specificity of VO2max and the ventilatory threshold in free swimming and cycle ergometry: comparison between triathletes and swimmers. *Brit J Sport Med*. 2005; 39: 965-968.
27. SCHABORT EJ, KILLIAN SC, ST. CLAIR GIBSON A, HAWLEY JA, NOAKES TD. Prediction of triathlon race time from laboratory testing in national triathletes. *Med Sci Sport Exer*. 2000; 32(4): 844-849.
28. SCHNEIDER DA, LACROIX KA, ATKINSON GR, TROPED PJ, POLLACK J. Ventilatory threshold and maximal oxygen uptake during cycling and running in triathletes. *Med Sci Sport Exer*. 1990; 22(2): 257-64.
29. SCHNEIDER DA, POLLACK J. Ventilatory Threshold and Maximal Oxygen Uptake during Cycling and Running in Female Triathletes. *Int J Sports Med*. 1991; 12(04): 379-383.
30. SCHUYLENBERGH R, VANDEN EYNDE B, HESPEL P. Prediction of sprint triathlon performance from laboratory tests. *Eur J Appl Physiol*. 2004; 91(1): 94-99.
31. SURIANO R, BISHOP D. Physiological attributes of triathletes. *Journal of Science and Medicine in Sport*. 2010; 13(3): 340-347.

