Original article

Measurement of oxygen consumption during stress tests in child footballers

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SUMMARY

Introduction

Cardiorespiratory, neuromuscular, and metabolic fitness to perform a physical activity lasting several minutes and involving the participation of large muscle masses can be known by continuously and directly measuring certain physiological variables during a stress test.

Objectives

To measure VO_2 mL/kg/min in different stages in a new continuous and progressive stress test in 60 boys, divided into three groups according to age and ventilatory efficiency (VE/VCO_2) at anaerobic threshold. To obtain peak values of VO_2 L/min, VE L/min, VCO_2 L/min, and R coefficient for each of the groups.

Material and method

Twenty healthy boys aged 8 to 10 (Group A), twenty aged 11 to 13 (Group B), and twenty aged 14 to 16 (Group C), who do football training, underwent treadmill tests. The continuous breath-by-breath analysis of exhaled gas was carried out with the open-circuit method (
CPX Plus/
SQL System Cybermedics, Collins, Boston).

Results

Every child completed the test. VO_2 mL/kg/min was measured in each stage, increasing throughout the test, and significantly between the 1st and the 2nd minute, and between the 6th and 7th minute in the three groups. Significant differences were found in VO_2 mL/kg/min during the stress in the 1st minute between groups A and C ($p<0.021$), in the 6th minute between groups A and B ($p<0.015$) and between A and C ($p<0,001$), and after running between groups A and C ($p<0.012$).

For each group, maximum values of the variables studied VO_2 L/min, VCO_2 L/min, HR, respiratory quotient (R) VE L/min, and VE/ VCO_2 at anaerobic threshold were obtained, expressed as mean and standard deviation. The means obtained were analyzed with ANOVA test and Tukey's post-hoc test.

Conclusions

All groups showed significant differences among them, which justify their differentiation.

VO_2 increased during the test, with a further increase in the run.

For each group, peak values of the variables under study (expressed as mean and SD) were obtained.

Key words: *Oxygen consumption, ergospirometry, children, stress test, treadmill, energy cost, football.*

Abbreviations:

VO_2: Oxygen consumption.
VO_2: Peak oxygen consumption.
VCO_2: Carbonic Anhydride Production.
R: R coefficient.
VE: Minute ventilation.
HR: Heart rate.
VE/VCO_2: Ventilatory efficiency

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INTRODUCTION

The main function of the heart is to provide energy and oxygen through circulatory transportation to cells in proportion to their metabolic needs.[1] Exercise tolerance testing has been acknowledged as a useful method to assess the physical activity capacity in children, either healthy or with cardiorespiratory disorders.[2-5]

Cardiorespiratory, neuromuscular, and metabolic capacity to perform a physical activity lasting several minutes and involving the participation of large muscle masses can be known by continuously and directly measuring certain specific physiological variables —such as oxygen consumption— during stress.[6] In the case of children and adolescents doing sports training, it is necessary to adjust the type of physical work, its intensity and duration, to the anthropometric and functional characteristics, as well as the habits and limitations of human beings in their period of growth and development.

Previous studies[1, 2, 7-10] have established that the most reliable way to know a person's physical capacity is to measure his/her oxygen consumption during a continuous and progressive test for several minutes. Even though individual differences among people of the same sex and with a similar body size and age are recognized, training and playing one or two football matches a week increases their aerobic capacity levels and contributes to homogenizing functional values in a treadmill stress test.

This study aimed at directly measuring VO_2 mL/kg/min in child footballers, using a new protocol for 7.5 minute-long treadmill stress tests, which was devised at Ricardo Gutiérrez Children's Hospital (HNRG), and presented on various papers at Argentine Cardiology Congresses in 1993[11] and 2002[12], respectively, and included in the Consensus on Graduated Stress Tests in 2010,[13] in trained male footballers from 8 to 16 years of age.

MATERIAL AND METHODS

Sixty healthy boys doing football training, divided according to their levels of growth and development into three groups of twenty boys, from 8 to 10 years of age (Group A); twenty of 11 to 13 (Group B); and twenty of 14 to 16 (Group C), underwent a continuous treadmill stress test. It consisted of 6 minutes of walking, starting at a 0 per cent incline, for one minute, and increasing the incline level by 4 per cent every minute. With the 20 per cent incline, they ran for 90 seconds. The walking speed varied according to the group: 2.5 mph for A; 3 mph for B; and 3.5 mph for C. The final running period was 4 mph, 4.5 mph, and 5 mph, respectively.

The breath-by-breath analysis of exhaled gas was carried out with the open-circuit method (CPX Plus/SQL System Cybermedics, Collins, Boston), and the heart function was recorded with a continuous 12-lead ECG (Cardio Perfect 540). A motor-driven sliding race table was used (Technogym).

For the statistical analysis, the SPSS 17 software, Worldwide Headquarters, Chicago, USA, was used. All the values were recorded as mean +/- standard deviation, and confidence intervals. *p* <0.05 was considered as significant. In addition, to analyse the significant difference as regards the groups, ANOVA was used. Tukey's procedure was used as a post-hoc test to find specific differences among the groups.

RESULTS

Table 1 displays the averages of all the anthropometric data of each group, showing a significant difference in the Weight variable between A and B (p<0.0000), between A and C (p<0.0000), and between B and C (p<0.006) (Group A: 35.15+-7.35 kg, Group B: 50.95+-6.73 kg, and Group C: 57.95+-6.5 kg); in the Height variable between A and B (p<0.005), and between A and C (p<0.006), with no significant difference between B and C (Group A: 138.85+-8.82 cm, Group B: 160+-5.14 cm, Group C: 167.35+6 cm).

All the boys completed the test. The progressive increase in the exercise intensity determines the VO_2 change patterns recorded in mL/kg/min on *Table 2.* The data from the 3 groups were analysed with the ANOVA method, the mean values and confidence interval of VO_2 mL/kg/min and Tukey's post-hoc test were recorded, finding significant differences in the 1st minute —when exercise begins— between Group A and Group C (p< 0.021), in the 6th minute —when walking stops— between Groups A and B (p< 0.015), and between Groups A and C (p< 0.001), and in the 7th and a half minute —when the run ends— between Groups A and C (p<0.012). The reason for stopping the test was the completion of the Protocol.

Graph 1 shows the mean values and the VO_2 mL/kg/min confidence interval of each group in each stage of the test. Significant differences were found for each group between the 1st and the 2nd minute —when they start walking— (p< 0.025), and between the 6th and the 7th minute —when they start running— (p<0.001).

Graph 1. Mean values and VO2 confidence interval for each group in each stage of the test.

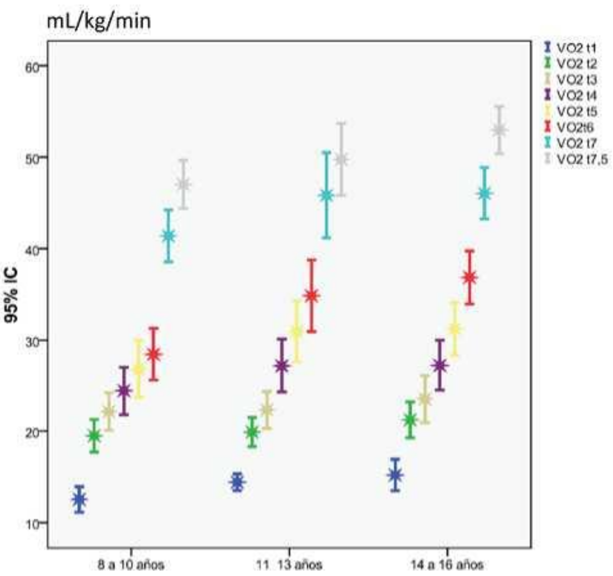

Table 1 Anthropometric data

Group	A	B	C
n	20	20	20
Weight, kg	35.15+-7.35	50.95 +- 6.73	57.95+- 6.5
Height, cm	138.85+-8.82	160+-5.14	167.35+-6

Table 2. VO2 mL/kg/min increase throughout the test

	M	**I**	**N**	**U**	**T**	**E**		
GROUP	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**7.5**
A	**12.5**	**19.5**	**22.1**	**24.4**	**26.8**	**28.5**	**41.4**	**47.1**
SD	**2.7**	**3.4**	**4.02**	**5.1**	**6.2**	**5.3**	**5.5**	**5.1**
B	**14.4**	**19.9**	**22.3**	**27.2**	**30.9**	**34.9**	**45.8**	**49.8**
SD	**1.7**	**2.98**	**3.81**	**5.5**	**6.3**	**7.4**	**8.7**	**7.4**
C	**15.2**	**21.2**	**23.5**	**27.3**	**31.2**	**36.9**	**46.1**	**53.0**
SD	**3.7**	**4.2**	**5.6**	**5.9**	**6.1**	**6.2**	**6.0**	**5.5**

Table 3. Means and SD of peak values of FC l/min, VO2 L/min, VCO2 L/min, VE *L/min, VE/VCO2, and R coefficient*

PEAK VALUES	**A**	**B**	**C**
FC l/min	**180.2+-8.4**	**180.5 +- 8.7**	**176.1+-11.2**
VO2 L/min	**1.5+-1.54**	**2.7 +- 0.65**	**3.03 +- 0.58**
VCO2 L/min	**1.7 +- 0.86**	**3.29 +- 0.85**	**3.46 +- 0.63**
VE L/min	**63.23 +-19.79**	**102.6 +- 26**	**97.15+- 20.03**
VE/VCO2	**34.7 +- 4.27**	**30.15 +- 2.88**	**25.82 +- 2.91**
R coefficient	**1.11+- 0.1**	**1.21 +- 0.08**	**1.22 +- 0.07**

Table 3 shows the results for the peak mean values when ending the protocol for HR l/min (Heart Rate), VO_2 L/min (Oxygen Consumption), VCO_2 L/min (Carbonic Anhydride Production), VE L/min (Pulmonary Ventilation), VE/VCO_2 (Pulmonary Ventilation / Carbonic Anhydride Production or Ventilatory Efficiency) and R Coefficient (VCO_2/VO_2).

DISCUSSION

Response to exercise shows changes throughout growth and development, resulting in increased physical performance, which is enhanced after puberty, and it is greater in men.[14] In addition, the design and development of tests to measure the physical work capacity of healthy children and adolescents requires consideration of the necessary collaboration of a subject in the various moments of the test. This avoids the early termination of stress determined by psychological factors, such as fear and anxiety. A slight hyperpnoea is usually recorded at the beginning of the test, of a potential psychological origin.[6]

The training effects have been extensively studied in adults, but in sports children and adolescents, the topic of aerobic training is controversial.[15] The increase in maximum O_2 consumption is also associated with circulatory adaptations, as heart, plasma, haemoglobin, erythrocyte concentration, and O_2 transport capacity volumes per minute increase.[16-18]

Baltaci has recorded a 20 per cent difference between the maximum VO_2 in 9- to 11-year-old swimmers with respect to non-sports children of the same age.[19]

Stress tests are complementary studies which are widely used in Paediatric Cardiology to assess the response to exercise of the variables measured (Functional Capacity, HR, BP), with precise indications in normal and sports children, in children with various types of arrhythmias and conduction disorders, in the assessment of either operated or unoperated congenital heart defects, heart valve diseases, cardiomyopathies, electrocardiographic disorders, etc.

Conventional stress tests assess the response to exercise of Heart Rate and Blood Pressure, and indirectly Functional Capacity in METs, where 1 MET equals 3.5 mL/kg/min, but, in this type of test, METs are inferred.

Stress tests with a direct measurement of oxygen consumption yield real values of this consumption, in addition to other data that have been assessed in this study, such as:

- Peak VO_2 mL/min.
- Peak VCO_2 mL/min.
- R coefficient defined as the quotient between VCO_2/VO_2 (when the exercise is highly intensive, VCO_2 exceeds VO_2, its ratio is 1 or more than 1). A peak value of > 1.1 is accepted as excellent physical stress.
- Peak pulmonary ventilation (VE).
- The VE/VCO_2 ratio at the anaerobic threshold considered as ventilatory efficiency, whose normal value must be below 30 in adults, and up to 35 is accepted in prepubescent children.

In this research, it is seen how the values of such ratio decrease in protocols B and C (pubescent and post-pubescent children), as well as the value of peak VCO_2 L/min, which contributes to a better physiopathological understanding of our patients' response to exercise.

The protocol on a treadmill which is most widely used in paediatrics is the Bruce protocol, and according to the percentiles developed at the Ricardo Gutierrez Children's Hospital,[20] a 6-year-old boy reaches the 50th percentile in 3 and a half stages (equivalent to 10 minutes and 45 seconds); a 15-year-old boy in 4 stages and a half (13 minutes and 55 seconds); a 6-year-old girl in 3 stages and a third (10 minutes); and a 15-year-old girl completes the 50th percentile in 4 stages of the Bruce protocol (12 minutes). Considering these values, these three Protocols A, B, and C were devised.

The three protocols used in this experimental study were adequate to the clinical-diagnostic purpose, according to the figures reported in the last decade in the Cardiology Service of the HNRG, where around 7,000 studies were performed under these protocols, in healthy children, and children with arrhythmias and mild heart defects. Their design seems adequate to motivate and reassure patients as the increase in the stress intensity by gradually increasing the incline postpones the increase in speed, and only 90 seconds are used in this condition. Thus, the testing time is shortened, which is very valuable, to obtain greater collaboration from children, and it is also innovative to offer children and young people a shorter time which makes it possible to better reproduce their usual physical activity, i.e., short runs. Even though the design of the protocols is predetermined as it ends at 7 and a half minutes, it is worth noting that almost all children reached 90 per cent of the maximum Heart Rate expected (it should be considered that these are trained children), and the VO_2 mL/kg/min values were similar to those found by other authors.[21, 22]

The differences between Group A with respect to B and C are more significant as A includes children of exclusively prepubescent age, while B and C include pubescent and post-pubescent children. Although the differences in terms of values of the different variables studied between groups B and C are not so significant, their differentiation is justified so as to be able to reach a maximum or submaximum heart rate in protocols that are predetermined in patients with more physical training.

CONCLUSION

The groups showed significant differences among them, which justify their differentiation.

VO_2 increases during the test, with a higher increase during the run.

For each group, peak values of the variables studied, expressed as mean and standard deviation, were obtained.

Every protocol was biomechanically well adapted to participants.

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ADDENDA

Table 4. VO2 for protocols A, B, and C in all the stages of the test

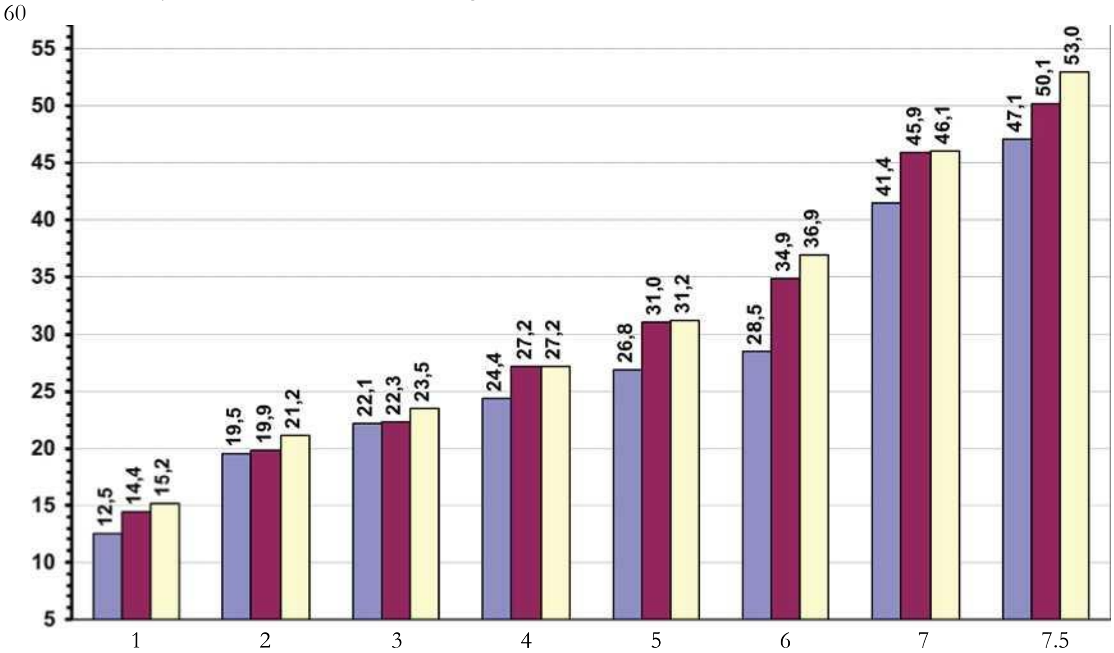

Table 5. METs for protocols A, B, and C in all the stages of the test

GROUP A

1	2	3	4	5	6	7	7.5
3.92	5.74	6.28	6.98	7.67	8.14	13.01	13.44
1.1	1.2	1.1	1.5	1.8	1.6	1.3	1.5

GROUP B

1	2	3	4	5	6	7	7.5
4.00	5.35	6.80	7.75	8.98	10.11	13.44	14.79
0.5	1.2	1.5	1.6	1.8	2.1	2.4	1.9

GROUP C

1	2	3	4	5	6	7	7.5
4.34	5.87	6.73	7.77	8.92	10.54	13.09	15.14
1.0	1.2	1.6	1.6	1.8	1.8	1.8	1.6