Aerobic Threshold for Exercise Prescription

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ABSTRACT

The Aerobic Threshold (AerT), is an aged cardiovascular parameter not commonly used to evaluate the heart’s performance in athletes. It indirectly evaluated by ventilator parameters during Cardio Pulmonary Test (CPT). Considering that exercise as prescription therapy “for the diseases, includes training normally established around at the 40% of the peak VO$_2$, this parameter could be taken in care as initial level for the effort prescribed. The aim of the study was to estimate the behavior of the AerT and also Anaerobic Threshold (AT), VO$_2$max in sedentary people. A group of athletes coming from different sports at the same and highest dynamic component were enrolled as control. A group of 41 athletes (16 soccer, 10 basket and 15 cyclists) and 9 healthy subjects were submitted to a CPT. The AerT, AT (assessed by V-slope method) and VO$_2$max were evaluated. The statistical analysis was performed with T student test ($P < 0.05$ significant). As expected in sedentary all the values were lower than athletes, however for Aer T value appears to be not significantly inferior respect of this one , with the exclusion of the comparison with the cyclists. In sedentary the AerT measure seems to give additional information in evaluating the cardiovascular performance. The VO$_2$max and AT remain the main parameters in defining the athletes performance. Therefore we cannot exclude any further utility of the AerT in normal subject but regularly trained.

Keywords: Sedentary, Exercise as Prescription, Intensity of Exercise, Cardio Pulmonary Test

1. Introduction

The Cardio Pulmonary Test (CPT) is currently considered the best tool to determine the production of physical energy by the measurement of the aerobic metabolism.

Several variables are usually considered in the CPT, however among them the main parameter for the assessment of the heart performance, is the maximum oxygen uptake (VO$_2$max) expressed in ml/kg/min [1].

Particularly in athletes this parameter is used to estimate the physical performance and different values of this one normally typify diverse kinds of sports [2].

The degree of the VO$_2$max depends in fact on the cardiovascular workload that is strictly related to a specific sport discipline. The regular training determines a progressive enhancement of the parameters directly associated with the athletes performance and therefore the sports are consequently classified in a major“ static or dynamic“component [3].

Literature reports however some other parameters derived from CPT, like the anaerobic threshold (AT) [4] and the aerobic threshold (AerT) [5] expressed as a percentage of VO$_2$max.

While the AT determination is employed particularly in athletes to classify the fitness level and to follow the effects of physical training [6], on the contrary the AerT is not currently used in athletes population for the poor relationship with an high performance level, but it is use among the deconditioned patients where the 20% to 40% of their VO$_2$max should be the initial intensity of exercise [7].

The last one has been recently considered in evaluating non-athletes subjects, even if regularly trained, where the physical exercise is prescribed as therapy to contrast the risks factors derived from an improper life style.

2. Aim

The main aim of this study it is to compare VO$_2$max, AT and AerT values of the three different kinds sports, included into the same class, in order to better discover any possible difference among them.

3. Materials and Method

Sample: The study was conducted on a sample of 9 healthy non-athletes subjects (6 male, 3 female) similar for the general characteristics (Table 1) matched with a control group of 41 subjects athletes from three different kinds of sport (16 soccer players, 15 cyclists and 10 basketball players).
Following the Sport Classification [3], cycling, basketball and soccer are all included in the group with high dynamic component, with static component at high level for the first, moderate level for the second and low level for the third. Therefore global cardiovascular load shows some slight differences for each sport [3].

Experimental design: All the examinations were performed at the Sports Medicine Centre, of the University of Florence - Italy. All the subjects enrolled, following our ethical internal committee, gave their oral consent to participate to the study; the research protocol was approved by the Ethics Committee of the Faculty of Medicine and Surgery of Florence. Every subject enrolled has undergone to a incremental and maximal cardiopulmonary test (CPT).

For the football players, basketball players and the healthy subjects the treadmill test was used, while for cycling the cycle ergometer was preferred considering the specificity of athletic movements [8].

Before to start, all the subjects were examined by a physician using a dynamic spirometry test and electrocardiogram (ECG) performing to confirm normal lung and heart function.

The respiratory gas measurements were obtained using a Schiller Cardiovit Ergo-Spiro CS 200 (Schiller AG, Baar, Switzerland). Calibrations of flow transducer and gas analysers were performed daily. The transducer with mouthpiece detecting breath by breath registrations of oxygen uptake (VO₂), expired CO₂ (VCO₂), minute ventilation (VE).

The treadmill test: The CPT was performed by he Schiller Cardiovit Ergo-Spiro CS 200 treadmill (Schiller AG, Baar, Switzerland). During exercise the slope and the velocity of the ramp increase at a lower workload than the standard test.

The cycle ergometer test: The cycling exercised on a Schiller Cardiovit Ergo-Spiro CS 200 cycle ergometer (Schiller AG, Baar, Switzerland). During exercise the cadence should be held at a constant 70 rep/min, the first workload was 25 W and increasing 25 W every 2 minutes to subjective exhaustion.

AerT measurement: As literature reports the presence of two points of discontinuities during an incremental effort correspond to the AerT and AT. These discontinuities are observed in ventilator curve response or in the lactate plasma level curve response (correspond 2 mmol and 4 mmol respectively).

They substantially are the transition from aerobic to anaerobic metabolism [5,10].

The first of these points of the curve discontinuities is coincident with AerT. It is associated with the correspondent workload value and it is coincident with the first sustained increase in VE (expressed L/min) as a response of increasing of exercise intensity [11]. AerT were also evaluated that 2 mmol of blood lactate [12]. However few data are now available in literature about the current employment of the AerT, and few results are present about the comparison of this one with the other parameters obtained during CPT, mainly if it is measured in normal subjects but regularly trained [13].

The second discontinuities corresponds to the AT. It is an equilibrium period between the lactate production and the lactate elimination (maximal lactate steady state, MLSS) [14], and it is generally associated with the blood lactate concentration of 4 mmol [12].

Measure of Aerobic Threshold: Following the literature, the AT values were obtained during the CPT by V-Slope method: this method identify AT as the VO₂ at which the change in slope of the relationship of VCO₂ to VO₂ occurs [15]. VO₂max measurement: Achieving a clear plateau in VO₂ has traditionally been used as the best evidence of VO₂max. VO₂max is the best index of aerobic capacity and the gold standard for cardio respiratory fitness. It represents the maximal reachable level of oxidative metabolism involving a large group of mus-

### Table 1. Anthropometrics measures of sample

<table>
<thead>
<tr>
<th>Age</th>
<th>Weight ± SD</th>
<th>Height ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>30.11 ± 5.66</td>
<td>74.47 ± 20.51</td>
</tr>
<tr>
<td>Basket</td>
<td>23.80 ± 7.00</td>
<td>92.00 ± 12.55</td>
</tr>
<tr>
<td>Soccer</td>
<td>24.94 ± 2.89</td>
<td>77.25 ± 5.84</td>
</tr>
<tr>
<td>Cycling</td>
<td>17.80 ± 3.10</td>
<td>62.40 ± 7.95</td>
</tr>
</tbody>
</table>

Note: Anthropometrics data are expressed as mean and SD for each group analyzed. None statistical difference among them for these parameters.

### Table 2. Modified Bruce test protocol

<table>
<thead>
<tr>
<th>Step</th>
<th>Time(min)</th>
<th>Speed (km/h)</th>
<th>Slope(%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0</td>
<td>2.74</td>
<td>10%</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4.02</td>
<td>12%</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
<td>5.47</td>
<td>14%</td>
</tr>
<tr>
<td>4</td>
<td>9</td>
<td>6.76</td>
<td>16%</td>
</tr>
<tr>
<td>5</td>
<td>12</td>
<td>8.05</td>
<td>18%</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>8.85</td>
<td>20%</td>
</tr>
<tr>
<td>7</td>
<td>18</td>
<td>9.65</td>
<td>22%</td>
</tr>
<tr>
<td>8</td>
<td>21</td>
<td>10.46</td>
<td>24%</td>
</tr>
<tr>
<td>9</td>
<td>24</td>
<td>11.26</td>
<td>26%</td>
</tr>
<tr>
<td>10</td>
<td>27</td>
<td>12.07</td>
<td>28%</td>
</tr>
</tbody>
</table>

Note: The example of the modified Bruce protocol where the slope and the velocity of the ramp increase at a lower workload than the standard test.
cles. However, mainly in some clinical testing situations, a clear plateau may not be achieved before symptom limitation of exercise [16,17].

The value of maximum oxygen uptake (VO\(_{2\text{max}}\)), anaerobic threshold (AT), aerobic threshold (AerT) are expressed in ml/kg/min.

Statistical analysis was performed using the SPSS 13.0 package for Windows XP. All data are expressed as mean ± Standard Deviation (SD). The groups were compared using ANOVA test. A probability value (p) of < 0.05 was considered statistically significant.

Confidence intervals of 95% percent for difference between methods were calculated.

4. Results
All the values of the AT and AerT are expressed in mlO\(_2\)/kg/min and in percent of VO\(_{2\text{max}}\) (Table 3).

The results show an increase of the parameters calculated either in sedentary or in control subjects.

Particularly for the AerT, the averaged value is 18.36 ± 3.35 mlO\(_2\)/min/kg in sedentary, 22.76 ± 5.34 mlO\(_2\)/min/kg in basketball, 24.00 ± 4.72 mlO\(_2\)/min/kg for soccer and 28.47 ± 7.52 mlO\(_2\)/min/kg for cycling. These values correspond around to a 40% of VO\(_2\max\) in all sample and they are significantly higher in the cyclist group compared to the healthy one (p < 0.05).

On the other hand the AT value is a percent of VO\(_2\max\) estimated around the 70% of VO\(_2\max\) for basket and soccer, around 76% VO\(_2\max\) for cycling while it is around 65% for sedentary subjects. It demonstrates the same trend of AerT parameter, with a lower value in healthy subjects, highest in cycling and approximately in the middle for basketball and soccer.

The AT values are statistically higher in athletes vs. sedentary (p < 0.01), however no difference is evident between soccer and basketball group (p = 0.25).

Table 3. Data of AerT, Aerobic Threshold; AT, Anaerobic Threshold by V-slope method; VO\(_{2\text{max}}\), maximum oxygen uptake of samples

<table>
<thead>
<tr>
<th></th>
<th>AerT</th>
<th>Anaerobic Threshold (AT)</th>
<th>VO(_{2\text{max}})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sedentary</td>
<td>18.36 ± 3.35</td>
<td>27.62 ± 6.15</td>
<td>43.25 ± 9.30</td>
</tr>
<tr>
<td>%VO(_2\max)</td>
<td>43.0</td>
<td>63.9</td>
<td>100</td>
</tr>
<tr>
<td>Basket</td>
<td>22.76 ± 5.34</td>
<td>40.46 ± 9.37</td>
<td>58.23 ± 5.25</td>
</tr>
<tr>
<td>%VO(_2\max)</td>
<td>39.1</td>
<td>69.5</td>
<td>100</td>
</tr>
<tr>
<td>Soccer</td>
<td>24.00 ± 4.72</td>
<td>43.98 ± 5.27</td>
<td>61.96 ± 5.94</td>
</tr>
<tr>
<td>%VO(_2\max)</td>
<td>38.7</td>
<td>70.9</td>
<td>100</td>
</tr>
<tr>
<td>Cycling</td>
<td>28.47 ± 7.52</td>
<td>55.43 ± 8.64</td>
<td>72.40 ± 9.65</td>
</tr>
<tr>
<td>%VO(_2\max)</td>
<td>39.3</td>
<td>76.6</td>
<td>100</td>
</tr>
</tbody>
</table>

Note: data of the AT and AerT are expressed in mlO\(_2\)/kg/min and in percent of VO\(_2\max\); all the values increase during the effort either in sedentary or in control group (athletes). The behaviour of the AerT showed in the former a particular trend to enhance respect of the other parameters that remedains significantly lower than in athletes.

As expected the VO\(_{2\text{max}}\) parameter reports a progressive and significant increase (p < 0.01) of the values in athletes globally considered (64.20 ± 6.95 mlO\(_2\)/min/kg) respect of the healthy group (43.25 ± 9.30 mlO\(_2\)/min/kg).

However, in addition to this feature, the selected analysis of the behaviour of VO\(_{2\text{max}}\) for each sport considered in the study, demonstrates a statistical difference among them (VO\(_{2\text{max}}\) in basket is 58.23 ± 5.25 mlO\(_2\)/min/kg, in soccer 61.96 ± 5.94 mlO\(_2\)/min/kg, in cycling 72.40 ± 9.65 mlO\(_2\)/min/kg with p = < 0.05) with the exclusion of the comparison between soccer and basketball (p = 0.12).

5. Discussion
There are practical reasons for assessing a subject by CPT. AerT, AT and VO\(_{2\text{max}}\) are the main indexes of exercise intensity to provide guidelines for exercise training. The intensity of training resulting from these parameters may optimize the intensity-duration relationship. AT is highly related to the performance in a various endurance activities, in many cases the relationship is stronger than those between VO\(_{2\text{max}}\) and performance [18].

AerT actually is less frequently considered during an incremental effort because CPT is mainly used in evaluating patient with heart disease where a decrease of VO\(_{2\text{max}}\) is considered as a universal marker of reduced exercise capacity and therefore it represents the onset in assessing the reduction of the exercise tolerance [19]. It is note that athletes may attain values of VO\(_{2\text{max}}\) over 20 times their resting values [20].

On the contrary the AerT, enclosing a restricted application in athletes, it has been more commonly linked to a people with a low intensity of physical activity, in fact the intensity of effort required for treatment is generally between 60% and 80% of the maximum heart rate. The results of this study show the AerT has a peculiar trend in healthy subject’s respect of athletes, supporting the hypothesis to play an important role to set protocols training for people where the physical activity can be used as a therapy. We cannot therefore exclude any further importance of the AerT in normal subject regularly trained where this parameter could be appreciated as the minimum intensity of the effort executed. This could be crucial point to decide the term of the “exercise as prescription”.

The VO\(_{2\text{max}}\) and AT remain however the main parameters in defining the athletes performance. Cyclist have the highest value for every CPT parameters, the static component of the effort may have an additional role in the chronic cardio – pulmonary sport adaptation.

Moreover particularly for the general population where the exercise can be prescribed with therapeutical impact the AT could represent the upper limit of the working range.

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6. Limits of the Study

The study involves a quite small cohort of subjects and therefore the results obtained cannot be considered definitive. The correct use of the AerT instead of AT in non-athletes subjects to establish the degree of physical exercise, will need further assessment of a possible relationship of this parameter with other factors characterizing the body composition. Moreover to verify the effectiveness clinical utilization of these parameters on the general population in terms of exercise as prescription, it will need more investigations in future.

7. Acknowledgements

None founding sources were used to obtain the results of the present study and the data do not constitute endorsement.

REFERENCES