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Anaerobic Threshold Level in Cyclic and Acyclic SportsProcedures

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Abstract

Purpose: The Anaerobic Threshold (AT) and VO_{2max} are both indistinctly used to evaluate the athlete's cardiovascular performance however; they do not correspond to the same metabolic modifications. Despite this aspect could partially depends on the different static and dynamic work-load of the sports practiced, it can also derive from the training variety, where the "cyclic and acyclic" component can be diversely represented. The aim of this study is to evaluate any possible difference of these parameters, among sports at different dynamic and static component undergoing to a diverse kind of training with prevalent cyclic or acyclic preparation.

Methods: A group of 44 athletes from three different sports was submitted to a Cardio Pulmonary Test (CPT) and to a 2D echocardiography exam calculating the AT and VO_{2max} and the standard heart systo-diastolic parameters. The statistical analysis was performed using Anova Test ($P< 0.05$ significant).

Results: Only in cyclists, at high dynamic component and cyclic training, both the parameters were statistically highest ($p<0.01$). In soccer players, at the lowest static class and practicing an acyclic training, the values of AT and VO_{2max} were higher than the basketball. A negative relationship of CMI and CPT parameters has been found in them.

Conclusions: The results support the hypothesis that both AT and $VO_{2max,}$ resulted to be strongly related to the dynamic component of the sport practiced while the AT value can partially depends on the kind of the cyclic or acyclic training. This single parameter can therefore be employed particularly during the follow–up of the athletes training.

Keywords: Athletes heart performance; Cardio pulmonary test

Introduction

The Cardio Pulmonary Test (CPT) is currently considered the best instrument to estimate the production of physical energy by the measurement of the aerobic metabolism. Currently among the parameters usually evaluated during the cardiopulmonary exercise test, the main factor for the assessment of the heart performance, is considered the maximum oxygen uptake (VO_{2max}) expressed in ml/kg/min [1]. However, parallel to this one, the Anaerobic Threshold (AT) is often employed to adjust the fitness level and to follow the effects of physical training [2], directly associated with the athlete's performance. In athletes the AT, as well as VO_{2max}, are generally indistinctly used even if they do not exactly correspond to the same metabolic modifications [3].

The scale of these parameters depends on the cardiovascular workload that is strictly related to a specific sport discipline and consequently the sports are classified in term of "major static" or dynamic component" [4].

Following the Sport Classification [4], cycling, basketball and soccer are all included in the same class with high dynamic component. On the contrary, the static component results to be high only in cyclist, while it is moderate in basketball and low in soccer. The global cardiovascular morphological and functional patterns show some slight differences among the diverse kinds of sports [4]. It is reasonable to think also that some metabolic differences can be found if we considered the sports from another point of view that distinguish these ones as "cyclic or acyclic" for their athletic motion [5,6]. It is note that cyclic sport involves repetitive movements, with prevalent aerobic charge, while acyclic sport, where the aerobic and anaerobic components are balanced, consists on sequential and therefore integrated functions.

The aim of this study it is to compare, during an acute effort, the VO_{2max} and the AT values among three different kinds sports, included into the same dynamic component, but with different static class [4], and various for the cyclic or acyclic feature of the athletic motion in order to better discover any possible difference among them.

Materials and Methods

Experimental design

All the examinations were performed at the Sports Medicine Centre, of the University of Florence, Italy. Following our ethical internal committee, the subjects enrolled, gave their oral consent to participate to the study and the research protocol was approved by the Ethics Committee of the Faculty of Medicine and Surgery of Florence.

The study was conducted on a cohort of 44 athlete's subjects from three different kinds of sports: 18 soccer players, 16 cyclists and 10 basketball players. They were professional athletes and therefore regularly trained, for almost four times a week either for the competition or for the regular season during at least 10 months a year. The anthropometric parameters were compatible with the general characteristics of the sports considered (Table 1) and therefore the major values were found in basketball player's respect of soccer and cyclists.

Every subject has undergone to an incremental and maximal cardiopulmonary test (CPT) conducted up to the maximal effort. For

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	Age (years)	Weight (Kg)	Height (cm)	BMI (Kg/cm²)
Basket	24.22 ± 7.12	92.33 ± 12.33	195.78 ± 9.11	24.02 ± 2.17
Soccer	25.28 ± 3.21	78.67 ± 6.21	182.20 ± 4.52	23.68 ± 1.60
Cycling	18.96 ± 2.95	62.04 ± 8.10	174.36 ± 9.58	20.37 ± 1.16

Table 1: Anthropometrics measures of the three groups of athletes.

the football players, basketball players the treadmill test was used, while for the cyclists the cycle ergometer was preferred in reason of the specificity of athletic movements [7].

Before starting with the CPT they were all submitted to a dynamic spirometry test, electrocardiogram (ECG) and Echocardiogram to confirm the normal pulmonary and cardiac function.

The echocardiographic exam was performed following the AHA guidelines and conducted by two experienced board-certified cardiologists. The two cardiologists had worked together for more than 5 years, and therefore no formal reliability verification of the studies (inter- or intra-tester) for the parameters analyzed was considered necessary.

The respiratory gas measurements during the CPT test were obtained using a Schiller Cardiovit Ergo-Spiro CS 200 (Schiller AG, Baar, Switzerland). Calibrations of flow transducer and gas analysers were normally performed daily. The transducer calculates several parameters with mouthpiece detecting breath by breath registrations of oxygen uptake (VO_2), expired CO_2 (VCO_2), minute ventilation (VE), Respiratory Exchange Ratio (RER).

The treadmill test

For the CPT the Schiller Cardiovit Ergo-Spiro CS 200 treadmill (Schiller AG, Baar, Switzerland) was used. The exercise test followed a modified Bruce protocol. In this text the slope and the velocity of the ramp increase at a lower workload than the standard test. The protocol has been appositely modified to guaranty a progressive enhancement of the effort.

The first two stages of the Modified Bruce Test are performed at a 2.7 km/h and 0% grade and 2.7 km/h and 5% grade, and the third stage corresponds to the first stage of the Standard Bruce Test protocol (Table 2).

The ramp treadmill protocol offers also the advantage of steady gradual increases in work rate to better estimate the global functional capacity [8]. The test was conducted up to the exhaustion.

The cycle ergometer test

The cycling exercised on a Schiller Cardiovit Ergo-Spiro CS 200 cycle ergometer (Schiller AG, Baar, Switzerland) was conducted following the same protocol of the treadmill one. During exercise the rate per minute was constant at 70 rep/min. The first workload was 25 W and increasing 25 W every 2 minutes up to subjective exhaustion.

Measure of anaerobic threshold and maximum oxygen uptake

As literature reports, the presence of two points of discontinuities during an incremental effort are normally observed either in ventilator curve response [9] or in the lactate plasma level curve [10].

The former of these points correspond to the Aerobic Threshold (AerT=2 mmol lactate) [10] that is not routinely used in athletes in reason of the poor correspondence to the sport performance [11].

The latter discontinuity of the curve represents the AT, i.e. in other words, substantially the transition from the aerobic to the anaerobic metabolism [3,12].

Step	Time (min)	Speed (km/h)	Slope (%)
1	0	2.7	0
2	3	2.7	5
3	6	2.7	10
4	9	4.0	12
5	12	5.4	14
6	15	6.7	16
7	18	8.0	18
8	21	8.8	20
9	24	9.6	22
10	27	10.5	24

Table 2: Modified Bruce test protocol.

The lactate production and the lactate elimination are, during the AT, balanced. This time is normally called maximal lactate steady state, MLSS [13] and the blood lactate concentration is 4 mmol [10]. According to previous studies [14], the AT value has been anyway in this investigation indirectly calculated by the gas-analysis V-Slope method, where this parameter is generally identified as the VO_2 value related to the change of slope of the VCO_2/VO_2 ratio [14].

Echocardiography study

The echocardiographic study was performed at rest, by two experienced board-certified cardiologists, using a My Lab 50 echocardiograph (Esaote-Italy) equipped with a 2.5 MHz probe.

According to the AHA Guidelines [15], the standard 2D (two-dimensional) systolic-diastolic and Doppler echocardiographic parameters were calculated. They included the interventricular septum (IVS) and posterior wall (PW) thickness, left ventricular end diastolic diameter (LVEDd), left ventricular end systolic diameter (LVESd), left atrium dimensions (LAD) and aortic root (Aor) dimensions, peak velocities of pulsed wave Doppler transmitral flow during early diastole (E) and atrial systole (A), deceleration time (DTc) of early diastolic flow, and the isovolumic relaxation time (IVRT). The analysis of the diastolic parameters was performed in the presence of a stable R-R interval from a series of three measurements. The evaluation of the left ventricular cardiac mass index (CMI g/m2) was obtained using the Devereux procedure [16], and the ejection fraction (EF) (%) was calculated from the formula [(LV end-diastolic3 -LV end-systolic3) / LV end-diastolic3] × 100 (%). LV Relative Wall Thickness (RWT) was calculated as the ratio of the posterior and septum wall thickness to end-diastolic diameter, according to the formula: [2 × (PWTd+IVSd)/LVDd]. A RWT value of 0.40 was considered as the cut-off point [17].

Statistical analysis

For the Statistical analysis the SPSS 13.0 package for Windows XP as been used. All data are expressed as mean ± Standard Deviation. The groups were compared using ANOVA test. A probability value (p) of <0.05 was considered statistically significant. The two correlations between the CMI, and VO_{2max} or AT were possible by R-regression analysis.

Results

The values obtained, related to the body surface area, were expressed as mean as SD. As expected, in consequence of the different anthropometrics general characteristics of the athletes investigated, the BMI values were higher in the basketball group than in soccer and cyclist one (Table 1).

All the echocardiographic standard parameters were within the normal range: the CMI resulted to be higher in cyclists and soccer respect of basketball players, while the RWT parameter, as expression of a possible diverse morphological pattern of the athlete's heart, was anyway similar in all, confirming the substantial homogeneous remodelling of the myocardial morphology in them. Among the diastolic parameters, particularly the DT value, related to the first phase of the diastolic function, resulted to be little shorter in cyclists than in the other groups.

No more significant modification of the heart performance was evident among the groups analyzed: the EF was in fact normal among the three groups (Table 3, Figure 1).

Regarding the cardiopulmonary test data, the VO_{2max} was expressed in mlO_2/kg/min, also the AT was expressed in mlO_2/kg/min and in percent of VO_{2max} (Table 4).

The results obtained during the effort have shown an increase of these parameters in the three groups of athletes with the highest values for both only in cyclists. In basketball and soccer the values remain normal despite at lower level of the range on behalf of the athletes.

The AT value as percent of VO_{2max}, was estimated around the 70% of VO_{2max} for basketball and soccer and around 75% VO_{2max} for cyclists athletes. These data correspond to values of 41.57 ± 9.28 ml O_2/min/kg for basketball, 44.02 ± 5.32 mlO_2/min/kg for soccer and for cyclist is 54.62 ± 8.45 ml O_2/min/kg (Table 4). No significant difference was found for the AT parameter between soccer and basketball groups (p= 0.23), while a strong difference was evident comparing soccer and cyclist players (p=0.02) and also basketball and cyclist (p<0.01) one.

The VO_{2max} values were in basketball 57.28 ± 5.42 ml O_2/min/kg, in soccer 62.03 ± 6.04 ml O_2/min/kg, without any significant variation, while a strong difference was evident comparing soccer and cyclist players (71.87 ± 9.52 ml O_2/min/kg) (p<0.01) and also basketball and cyclists (p<0.01).

No relationship was found between the CMI values and the CPT parameters (VO_{2max} and AT values) in all the groups (r CMI-AT=0.29; r CMI–VO_{2max}=0.33) (Table 5).

	Soccer	Cyclist	Basket	p value
HR	62,33	61,78	66,89	NS
SAP	119,67	113,46	121,67	0,002
DAS	77,00	71,54	76,11	0,041
IVS	10,65	10,24	10,40	NS
PW	10,05	9,69	10,08	NS
LVDD (mm)	55,80	53,74	54,56	NS
LVSD (mm)	34,73	32,50	34,00	NS
EF %	62,67	70,31	58,14	NS
E peak (cm/s)	76,47	91,07	77,63	NS
A peak(cm/s)	46,13	40,86	45,13	NS
IVRT(ms)	71,80	66,79	76,00	NS
DT(ms)	177,33	149,29	188,38	0,0036
LA(mm)	37,33	36,96	37,11	NS
RVDD	23,62	25,24	26,23	NS
Aorta	32,47	32,60	33,63	NS
RWT	0,37	0,36	0,37	NS
CMI	134,79	138,36	110,67	0,0161

Table 3: Echocardiograph parameters of the three groups of athletes investigated HR: Heart Rate; SAP: Systolic Arterial Pressure; IVS: Inter Ventricular Septum; PW: Posterior Wall; LVDD: Left Ventricular Diastolic Diameter; LVSD: Left Ventricular Systolic Diameter; EF: Ejection Fraction; E peak: E peak velocity; A peak: A peak velocity; IVRT: Isovolumic Relaxation Time; DT: Deceleration Time; LA: Left Atria.

	Anaerobic Threshold (AT)	Maximum Oxygen Uptake (VO_{2max})
Basket	41.57 ± 9.28	57.28 ± 5.42
% VO_{2max}	69.8	100
Soccer	44.02 ± 5.32	62.03 ± 6.04
% VO_{2max}	70.7	100
Cycling	54.62 ± 8.45	71.87 ± 9.52
% VO_{2max}	75.8	100
p value	<0.01	<0.01

Table 4: Data of AT, VO2 max of samples (expressed in ml O2/Kg/min) and p values.

R	Anaerobic Threshold	VO_{2max}
CMI Cyclist	0.17	0.28
CMI Basket	-0.005	-0.20
CMI Soccer	-0.03	0.13
CMI Total	0.29	0.33

Table 5: Correlation between CPT parameters and CMI values for each group of athletes.

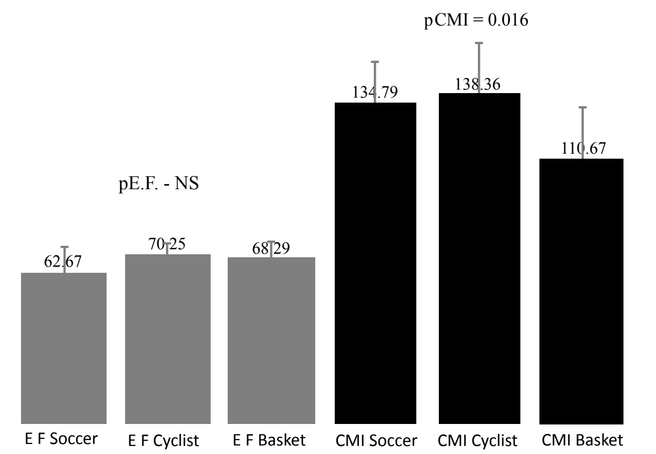

Figure 1: Data of CMI and EF of the three groups of athletes.

Limit of the study

The study has been conducted in a relative small cohort of athletes, the results obtained are anyway strongly suggestive for a not complete harmony between the values of the AT and VO_{2max} as previously supposed in the aim of the study.

A poor relationship between the CPT parameters and the CMI has been also found. This aspect, apparently in contrast with the common physiological knowledge supports anyway the hypothesis of an exclusive responsibility of the different kind of sports on metabolic parameters that seem to be independent from the CMI value.

Regarding the evaluation of a blood lactate sample to demonstrate the achieving of an anaerobic metabolic energy-substrate during the exercise, it has not been feasible in consequence of a negative consent on behalf of the athletes enrolled.

Discussion

The assessment of the cardio-pulmonary performance in athletes is currently identified with the evaluation of the VO_{2max} and AT. There are practical reasons for assessing the performance in athletes by the CPT.

The AT and the VO_{2max} are the main index of exercise intensity to better provide the strategy and to improve the plan of the physical training. The athletes may attain values of VO_{2max} over 20 times their resting values [18] and it is noted that the degree of training expressed on behalf of these parameters may address to a higher intensity-duration ratio. The AT parameter is highly related to the performance in a various endurance activities and in many cases the relationship is stronger than those between VO_{2max} and performance [19]. Despite these parameters are both currently used indistinctly, they do not correspond to the same metabolic modifications and therefore their behaviour during the CPT, might partially depends from various metabolic factors related with different work-load of the sports practiced.

The results of the echocardiography parameters show that high heart performance in all the athletes analyzed where a myocardial physiological hypertrophy at rest condition is evident, and normal systolic-diastolic function is preserved. These results obtained do not anyway support an expressed correlation among the CMI and the CPT values. It is reasonable assumption that among sports at different dynamic and static load, the VO_{2max} and AT behaviour in them can predominantly depend from the pulmonary performance instead of the heart one. In this context further studies will be necessary to better clarify this aspect.

The CPT results obtained from the present study, even if conducted in a small cohort of athletes, show on the contrary a peculiar and diverse trend of AT and VO_{2max} among the three different kinds of sports whose static and dynamic components are not equally represented. Only in a cyclic sport (like cycling), at high dynamic and static work-load, the values of both these parameters are significantly higher than in basketball and soccer (acyclic sport) while, the AT values of soccer players, whose static component is the lowest among the groups of athletes analyzed, results to be near to the upper limits of the normal range: it is in fact around 70%, expressed in percentage of VO_{2max}. This peculiar behavior of the AT found exclusively in soccer players, is suggestive for a particular sensibility in describing the athlete's performance practicing sport at low static component even if in presence of high dynamic one. The AT could be therefore considered to be the main helpful parameter to better follow the athlete's performance in case of acyclic sports where the static component is low.

It is therefore reasonable to think that in this kind of sports, particularly if "acyclic", the onset of intracellular metabolism and the mechanisms of O_2 transfer remain only slightly influenced by the exercise intensity, while this one could be more affected in consequence of the impact of the exercise or on the quantity of the muscles involved. On the contrary, in case of "cyclic sports" with high static and dynamic work-load, both the components contribute to determine a progressive enhancement either of the VO_{2max} or the AT, without any particular specificity. The comparison between soccer and basketball (both acyclic sports) didn't show in fact any statistical differences regarding the AT and VO_{2max} values. It is therefore possible to suggest that prevalent static component, may have nonetheless an additional role on the chronic cardiopulmonary global adaptation, whose quantification is better evaluated by the VO_{2max} values.

Conclusion

In conclusion, the results obtained support the hypothesis of a possible exclusive utilization of the AT, to evaluate the degree of the athlete's performance, in case of acyclic sports with low static component. Nonetheless, it could be practical to use the VO_{2max} value (expressed in term of AT) as the main parameter to assess the athletes performance at the onset of the yearly training , while during the seasonal physical exercise preparation, a submaximal intensity test of the AT, could be proposed to more conveniently obtain a new adequate program .

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