Cardiopulmonary exercise testing - effective method for evaluation and recommendation of individualized exercise training in patients with metabolic syndrome

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Abstract

The present study *aims* to emphasize the role of cardiopulmonary exercise training (CPET) in evaluation and recommendation of individualized exercise training in patients with a metabolic syndrome. *Methods:* We performed a prospective longitudinal study of 9 months. The study group consisted of 28 young patients (21.3±3.1 years old) without contraindications to exercise, previously diagnosed with metabolic syndrome according to NCEP-ATPIII criteria. All patients were evaluating at baseline and after 3 months of intervention and at the end of the study (after 9 months). The evaluation consists in performing a CPET on bicycle ergometer in which subjects were monitored in terms of cardiac and respiratory parameters. The CPET results allow us to establish the range of effort intensity in which the patient should exercise in order to burn calories and achieve the maximum fat oxidation rate. All patients benefit from an intensive interval exercise training programme, supervised and guided by a physical therapist. Exercise training consisted in 50 minutes sessions, 3 times per week, at intensive endurance training zone (in the range of anaerobic threshold), completed by 1 minute interval in the range between anaerobic threshold (AT) and respiratory compensation point (RCP), for every 5 minutes of training. *Results:* After 9 months of intervention we noticed an improvement of abdominal obesity (waist circumference decreased from 98.98±10.14 cm to 89.54±12.32 cm, $p<0.001$), physical fitness (V'O2peak increased from 1.83±0.33 l/min to 2.13±0.4 l/min, $p<0.001$) and endurance (Oxygen uptake in the range of anaerobic treshold increase from 1.27±0.27 l/min to 1.55±0.31 l/min, $p<0.001$). *Conclusions:* Cardiopulmonary exercise testing together with training zones determinations is a useful tool for assessing the exercise capacity and drawing up individual workouts. Active and closely monitored intervention by individualized exercise training programmes leads to improved physical fitness, endurance and central obesity in young patients with metabolic syndrome.

***Key words**: cardiopulmonary exercise test, metabolic syndrome, exercise training.*

Rezumat

Studiul de faţă are ca *scop* evidenţierea rolului testării cardiopulmonare la efort (CPET), în evaluarea şi recomandarea programelor individualizate de antrenament fizic la pacienţii cu sindrom metabolic. *Metode:* Am realizat un studiu

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prospectiv longitudinal pe o perioada de 9 luni. Grupul de studiu a fost alcătuit din 28 pacienți tineri (21,3 ± 3.1 ani), fără contraindicații de a efectua antrenament fizic, diagnosticat anterior cu sindrom metabolic (în conformitate cu criteriile NCEP-ATPIII). Toți pacienții au fost evaluați inițial, după 3 luni de antrenament şi la sfârşitul studiului (după 9 luni). Evaluarea a constat în realizarea unei testări cardiopulmonare la efort la bicicleta ergometrică. Rezultatele CPET au permis stabilirea intensității recomandate a efortului în timpul programelor de antrenament în scopul atingerii consumului caloric maxim şi a ratei maxime de oxidare a grasimilor. Toți pacienții au beneficiat de un program intensiv de antrenament fizic cu intervale, supravegheat de către un kinetoterapeut. Fiecare şedinââ de antrenament a constat în 50 de minute de exercițiu fizic, de 3 ori pe săptămână, în zona de intensitate medie (în jurul pragului anaerob), completat de intervale de câte 1 minut, în intervalul dintre pragul anaerob şi punctul de compensare respiratorie, pentru fiecare 5 minute de antrenament. *Rezultate:* Dupa 9 luni de intervenție am observat o reducere semnificativă a obezității abdominale (circumferința taliei a scăzut de la 98,98 ± 10,14 cm la 89,54±12.32 cm, p <0,001), precum şi o îmbunatatire a condiției fizice (consumul maxim de oxigen a crescut de la 1,83±0,33 l/min la 2,13±0,4 l/min, p<0,001) si anduranței (consumul de oxigen la prag anaerob a crescut de la 1,27±0,27 l/min la 1,55±0,31 l/min, p<0,001). *Concluzii:* Testarea cardiopulmonară la efort, împreună cu determinarea zonelor de antrenament este un instrument util pentru evaluarea capacității de efort şi elaborarea de programe de individualizate de antrenament fizic. Intervenția activă şi monitorizată prin programe individualizate de antrenament fizic, conduce la îmbunătățirea condiției fizice, a anduranței si reducerea obezității abdominale la pacienții tineri cu sindrom metabolic.

***Cuvinte cheie**: testare cardio-pulmonară de efort, sindrom metabolic, antrenament fizic.*

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Introduction

The Metabolic syndrome (MS) is a cluster of cardiovascular risk factors including high blood pressure, dyslipidemia, hyperglycemia, and central obesity [1]. Changes in lifestyle through adopting healthy foods and an increase in energy consumption through physical activity is a key intervention in treating the metabolic syndrome [2,3].

The health benefit of physical activity was demonstrated in many studies. General recommendation of moderate-intensity aerobic physical activity, (approximately 1000 kcal/week) proved to reduce mortality risk from all causes with 20-30% [3]. Cardiopulmonary exercise testing (CPET) is considered the gold standard for exercise capacity assessment [4].

Performing a maximal CPET, in the beginning of an exercise training programme, improves the confidence and safety of the patients and allow the physical therapist to set the right effort intensity in order to achieve the body composition and fitness goals.

Purpose

The present study aims to emphasize the role of CPET in evaluation and recommendation of individualized exercise training in patients with metabolic syndrome.

Methods

We performed a prospective longitudinal study of 9 months. The study group consisted of 28 young patients (21.3±3.1 years old) without contraindications to exercise, previously diagnosed with metabolic sindrome according to NCEP-ATPIII criteria (5). All patients were evaluated at baseline and after 3 months of intervention and at the end of the study (after 9 months). The evaluation consists in performing a CPET (using a Metalyzer 3B gas exchange device) on bicycle ergometer in which subjects were monitored in terms of cardiac and respiratory parameters. We recorded the oxygen uptake at anerobic threshold (AT), and respiratory compensation point (RCP), oxygen uptake ($V'O_2$), oxygen pulse (V'O2/HR – an important indices of cardiac performance in exercise), metabolic equivalents for oxygen and carbon dioxide (V'E/V'O2 and V'E/V'CO2 - important indices of respiratory performance in exercise), minute ventilation (V'E) and breathing frequency (BF). An example of the results parameters is presented in Figure 1.

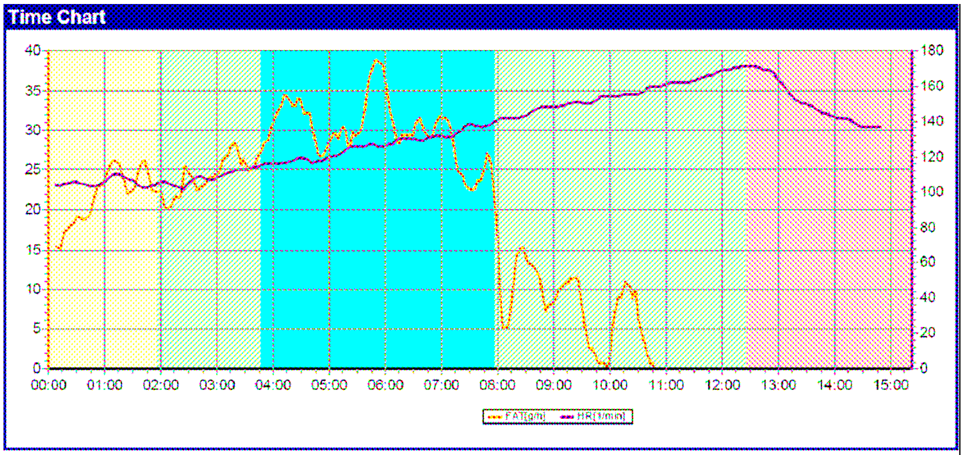
Also, the CPET results allow us to establish the range of efort intensity in which the patient should exercise in order to burn calories and achieve the maximum fat oxidation rate (Figure 2).

The interval exercise training program of each patient was individualized according to these parameters and the training zones was established according to the heart rate achieved at every threshold. An example of recommended training zones is presented in Figure 3.

Parameter	Unit	Rest	AT	AT % V'O2max Meas	RCP	V'O2max	V'O2max % Pred	Predicted	Abs. max. in exercise
Time	[h:mm:ss]	0:01:54	0:07:06	-	0:10:27	0:12:30	-	-	0:12:23
HR	[1/min]	105	131	78	157	168	85	197	171
WR	[W]	20	101	56	151	179	92	194	179
WR/kg	[watt/kg]	0	1	58	2	2	-	-	2
WR/kg_Lean	[watt/kg]	-	-	-	-	-	-	-	-
Dist	[m]	-	-	-	-	-	-	-	-
METS	-	2.9	5.5	66	7.3	8.3	-	-	8.6
V'O2	[l/min]	0.871	1.656	66	2.193	2.513	114	2.204	2.601
V'O2/kg	[ml/min/kg]	10	19	66	25	29	-	-	30
V'O2/kg_Lean	[ml/min/kg]	-	-	-	-	-	-	-	-
V'CO2	[l/min]	0.607	1.286	49	2.075	2.648	-	-	2.778
RER	-	0.70	0.78	74	0.95	1.05	-	-	1.07
V'O2/HR	[ml]	8.3	12.6	85	14.0	14.9	133	11.2	15.2
V'E/V'O2	-	21.1	20.3	72	25.3	28.2	-	-	28.6
V'E/V'CO2	-	30.1	26.1	98	26.7	26.7	-	-	30.7
V'E	[l/min]	19.9	35.2	48	57.7	73.0	439	16.6	76.3
VT	[l]	0.92	1.62	70	2.07	2.31	-	-	2.35
BF	[1/min]	22.2	21.7	68	27.8	31.7	98	32.2	33.1

Figure 1. Example of the summary results in a patient participating to the study project
HR: heart rate; WR: work rate; METS: metabolic equivalents; V'O2: minute oxygen uptake; V'O2/kg: minute oxygen uptake per body kilogram; V'CO2: minute carbon dioxide eliminated; RER: rate of expiratory ratio; V'O2/HR: oxygen pulse; VE/ V'O2: oxygen respiratory equivalent; VE/ V'CO2: carbon dioxide respiratory equivalent; V'E: minute ventilation; VT: ventilation; BF: breathing frequency.

All patients benefit from an intensive interval exercise training (IET) programme. For exercise we used ergometric bicycles, elliptical bicycles, steppers, treadmill devices. IET was supervised and guided by a physical therapist. Exercise training consisted in 50 minutes sessions, 3 times per week, at intensive endurance training zone (in the range of anaerobic threshold), completed by 1 minute interval in the range between anaerobic threshold (AT) and respiratory compensation point (RCP), for every 5 minutes of training.

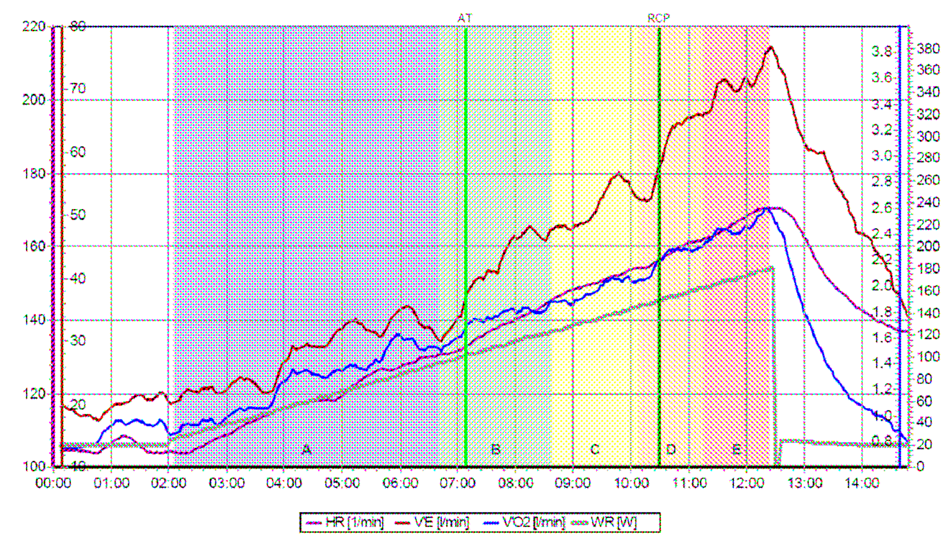


Parameter	Unit	Value
Maximum Fat Oxidation Rate:	g/h	30

Figure 2. Example of the fat oxidation rate evaluation in a patient participating to the study project
FAT: quantity of fat burned per hour; HR: heart rate.

CPX-Testing Device: MetaLyzer 3B - R2
Exercise Device: None
ECG12-Testing Device: GE Healthcare CardioSoft

Ambient Conditions
Temperature: 26.8 °C
Pressure: 1010 mbar



Training Zones

Training Zones Set: Percent of V'O2 at AT (Standard)

The criteria for a maximum exercise test was not fulfilled. Nevertheless the test has been declared as maximum exercise load.

	Zone	HR 1/min	WR W	v km/h	G %
E: >140%	Top Zone	>162	>163	>0.00	>0.0
D: 130-140%	Development Zone	155-162	146-163	0.00-0.00	0.0-0.0
C: 115-130%	Intensive Endurance	146-155	124-146	0.00-0.00	0.0-0.0
B: 100-115%	Extensive Endurance	131-146	95-124	0.00-0.00	0.0-0.0
A: <100%	Compensation Zone	<131	<95	<0.00	<0.0

Figure 3. Example of training zones obtained in a patient after performing CPET; we used for exercise training the extensive and intensive training zones along with short intervals of 1 minute in development zones.
AT: anaerobic threshold; RCP: respiratory compensation point; HR: heart rate; V'E: minute ventilation; V'O2: oxygen uptake; WR: work rate.

For monitoring exercise intensity and caloric consumption we used Polar RS 800 heart rate monitors. We also provide general dietary recommendations to the patients in order to improve their nutritional habits.

After the intermediary evaluation (the first 3 months) we adjust the training programs parameters according the exercise test results.

From total participants to the study, one patient was excluded for low availability to participate in training sessions.

Statistical analysis

Continuous variables are presented as mean and standard deviation. Changes from baseline to follow-up within treatment groups was tested using Anova single factor test. The level of statistical significance was set at $p \leq 0.05$. The statistical analyses were performed with "GraphPad Prism v.5" for Windows.

Results

After 9 months of intervention we noticed an improvement of abdominal obesity (waist circumference decreased from 98.98±10.14 cm to 89.54±12.32 cm, $p<0.001$), physical fitness (V'O2peak increased from 1.83±0.33 l/min to 2.13±0.4 l/min, $p<0.001$) and endurance (Oxygen uptake in the range of anaerobic treshold increase from 1.27±0.27 l/min to 1.55±0.31 l/min, $p<0.001$).

The detailed evoultion of investigated parameters is presented in table I, figures 4-6.

Table I. Parameters evolution – initially, at 3 months and after 9 months from baseline

Parameter	Baseline	3 month	9 month	P value
Waist (cm)	98.98±10.14	94.80±10.90	89.54±12.32	<0.001
VO_2peak (ml/min)	1.833±0.333	1.927±0.335	2.128±0.407	<0.001
VO_2_AT (ml/min)	1.270±0.269	1.336±0.253	1.554±0.315	<0.001

Values are presented as mean ± standard deviation.

VO_2peak: peak oxygen uptake; VO_2_AT: oxygen uptake in the range of anaerobic threshold.

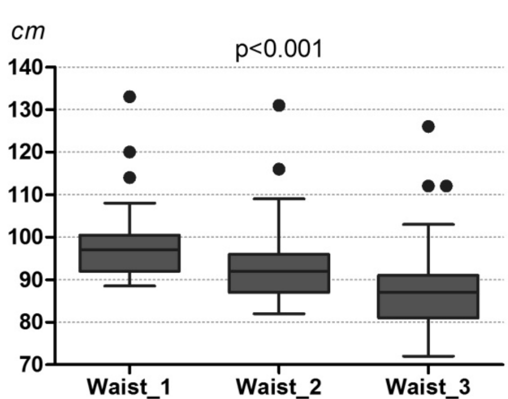


Figure 4. Trend of wais after 3 and 9 months of training Values are presented as median with minimum-maximum whiskers.
Waist_1: Waist at baseline;
after 9 months of training.
Waist_2: Waist after 3 months of training;
Waist_3: Waist after 9 months of training.

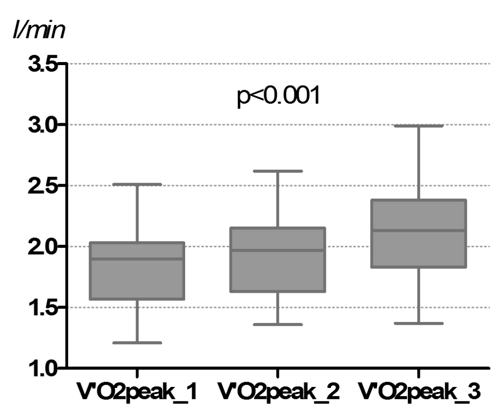


Figure 5. Trend of peak oxygen uptake after 3 and 9 months of training. Values are presented as median with minimum-maximum whiskers
V'O2peak_1: peak oxygen uptake at baseline; oxygen uptake
V'O2peak_2: peak oxygen uptake after 3 months of training;
V'O2peak_3: peak oxygen uptake after 9 months of training.

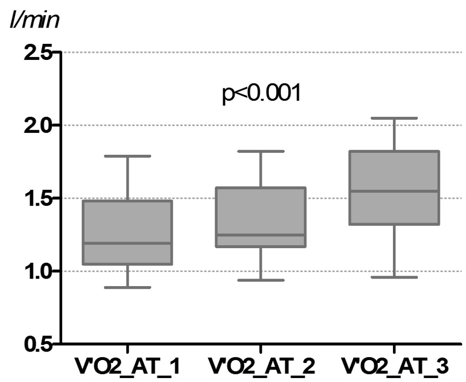


Figure 6. Trend of oxygen consumption oxygen uptake in the range of anaerobic treshold (AT) after 3 and 9 months of training.
Values are presented as median with minimum-maximum whiskers. V'O2_AT_1: oxygen uptake in the range of AT at baseline; V'O2_AT_2: oxygen uptake in the range of AT after 3 months of training; V'O2_AT_3: oxygen uptake in the range of AT after 9 months of training.

Discussions

Individualization of exercise intensity according to maximal fat oxidation rate and training zones, increase the programs efficiency and improves the weight loss effect of exercise training.

Both, physical fitness and physical endurance are significantly increased after 9 months of individualized interval exercise training in patients with metabolic syndrome. These changes are independent of weight loss and central obesity (which were also significantly improved).

Similar results were shown by another recent study in which after 12 weeks of aerobic training (jogging), maximal oxygen uptake increased by 6.2±2.4 ml/kg/min. [6] This results are superior as intervention time (4 months comparing to 9 months in our study), but we consider that outdoor jogging in obese patients may be harmful for musculoskeletal system. Some time due to their need of more energy output to move total body mass, morbidly obese subjects have a reduced aerobic capacity and even brisk walking could reach the anaerobic threshold. Morover, to achieve a healty lifestyle (in term of healthy food and daily exercise) we onsider that a longer intervention is neded.

Conclusions

Cardiopulmonary exercise testing together with training zones determinations is a useful tool for assessing the exercise capacity and drawing up individual workouts.

Active and closely monitored intervention by individualized exercise training programmes leads to improved physical fitness, endurance and central obesity in young patients with metabolic syndrome.

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