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Original Article

Obtaining a formula that improves maximum oxygen consumption estimation in cycle ergometer exercise tests☆

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ABSTRACT

Objectives: To evaluate if the estimation of the maximal oxygen consumption (MO_2C) in METs (metabolic equivalents) by means of the table proposed in the guidelines of the Spanish Society of Cardiology is a sufficiently reliable method when applied to the bicycle exercise test.
Material and methods: The MO_2C in METs was obtained by gas-exchange analysis on bicycle ergometer tests in 97 healthy subjects (group I). It was compared with the estimate of METs using the table in which only watts and patient's weight were included. A better-adjusted formula was validated in 289 subjects with normal exercise myocardial perfusion gated-SPECT (group II) using the introduction of clinical and ergometric variables.
Results: In group I individuals a good correlation between METs estimated with the table and those obtained through gas-exchange analysis (CCI: 0.93) was observed. However, the best adjusted formula to estimate METs in group II subjects included watts, body mass index (BMI), age and gender (METS = 11.820 – 0.054 × age – 0.189 × BMI + 1.031 × gender + 0.020 × watts) (women: 0, men: 1). This formula allowed the reclassification of 46.9% of group II subjects into the category <5 METs versus the estimation by table.
Conclusions: Estimating the METs with the conventional table is reliable. However, the best adjustment in subjects with normal bicycle exercise SPECT was obtained when, in addition to watts and BMI, age and gender were also considered.

Obtención de una fórmula que mejora la estimación del consumo máximo de oxígeno en las pruebas de esfuerzo con bicicleta ergométrica

Palabras clave:
Prueba de esfuerzo
MET
Estimación del consumo de oxígeno
Gated-SPECT

RESUMEN

Objetivos: Valorar si la estimación del consumo máximo de oxígeno (CMO_2) en MET (unidad metabólica) mediante las tablas propuestas en las guías de la Sociedad Española de Cardiología (SEC) es un método suficientemente fiable cuando se aplica a las pruebas de esfuerzo con bicicleta ergométrica.
Material y métodos: Se obtuvo el CMO_2 en MET por consumo de gases en bicicleta ergométrica en 97 sujetos sanos (grupo I) y se comparó con la estimación de los MET obtenida mediante tabla en la que solo intervienen los vatios y el peso del paciente. Mediante la introducción de variables clínicas y ergométricas se obtuvo una fórmula con mejor ajuste para el cálculo de los MET validándose en 289 pacientes (grupo II) con gated-SPECT de perfusión miocárdica normal.
Resultados: En los individuos del grupo I se observó una buena correlación entre los MET estimados con la tabla y los MET obtenidos mediante consumo de gases (CCI: 0,93). Sin embargo, la fórmula con mejor ajuste para la estimación de los MET en los pacientes del grupo II incluyó los vatios, el índice de masa corporal (IMC), la edad y el sexo (MET = 11,820 – 0,054 × edad – 0,189 × IMC + 1,031 × sexo + 0,020 × vatios) (mujer: 0, hombre: 1). Esta fórmula permitió la reclasificación de un 46,9% de los individuos del grupo II en la categoría <5 MET con respecto a la estimación por tabla.
Conclusiones: La estimación de los MET mediante la tabla convencional es fiable, aunque el ajuste óptimo, cuando se aplica a sujetos con *gated-SPECT* de perfusión miocárdica de esfuerzo normal, se obtiene al considerar, además de los vatios, el IMC, la edad y el sexo.

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Introduction

It has been more than 90 years since the first ergometric tests were performed,[1–5] and exercise tests associated or not with imaging techniques continue to be fundamental diagnostic and prognostic studies in clinical cardiology.[6–15] Maximum oxygen consumption (MO_2C) is generally estimated in metabolic units (MET) using tables including only exercise load and patient weight.[16,17]

In the stress myocardial perfusion gated SPECT it has been observed that if a determined level of tachycardization (80% compared to theoretical maximum) and MO_2C (5 MET) is not achieved, the test should not be considered as diagnostic since its sensitivity and negative predictive values are very low.[18] On the other hand, the MET achieved in the stress test and scintigraphic criteria of severity play an important role in the risk stratification by mycocardial perfusion gated SPECT.[8] Thus, correct estimation of this parameter is essential from both a diagnostic and prognostic point of view.

On the other hand, different physiopathological studies have demonstrated that MO_2C not only depends on exercise load and the weight of the patient but also on other parameters such as age and gender.[10–12] The aim of this study was to evaluate whether the estimation of MO_2C in MET obtained using the table recommended in the Guidelines of the Spanish Society of Cardiology (SEC) for bicycle ergometer stress tests is sufficiently reliable compared to direct measurement of gas consumption in healthy individuals. We also analyzed whether other variables, in addition to watts achieved and patient weight, allow better adjustment in patients with a suspected diagnosis of ischemic heart disease but with myocardial perfusion gated SPECT with normal effort.

Material and methods

We performed a prospective observational study including 97 healthy subjects (Group 1) (25.1%) and 289 individuals with a suspected diagnosis of ischemic heart disease but with normal stress-rest myocardial perfusion gated SPECT (group II). All the subjects included performed a maximum stress test on an ergometer bicyle with continuous electrocardiographic and blood pressure monitoring. All the patients provided informed consent to participate in the study.

In Group I MO_2C was analyzed by the study of respiratory gases and was compared with the mean of the estimation of the MET by 3 observers using the table recommended by the SEC (Table 1).[17] Interobserver variability in the estimation using the MET table was analyzed. Thereafter, we identified clinical and ergometric parameters to develop a formula with the best adjustment for the estimation of the MET. This formula was then validated in the 289 subjects in Group II with a maximum subjective negative stress test and with a normal gated-SPECT (with no evidence of ischemia and with a left ventricular ejection fraction >50%).

In the 97 subjects in Group I (mean age: 45.6 ± 19.7 years; 42.3% women) the study was performed with an ergometer bicycle with an airflow transducer (Neumotac de Pitot), O_2 and Co_2 gas exchange analyzer, 12-lead electrocardiography, sphigmomanometer and pulsioximeter. Exercise began without workload and further increased in 10–30 W/min, maintaining a speed of 60–70 revolutions per minute until the test was discontinued due to the inability to maintain the workload. Once the MO_2C had been obtained by gas exchange analysis, the MET were calculated by dividing O_2 consumption in mlO_2/kg/min by 3.5. Three experienced observers blinded to the MET obtained by gas exchange analysis, independently estimated the MET achieved using the table recommended by the SEC (Table 1).[17] With the use of multiple linear regression analysis the best equation of regression was established for the calculation of MET using different clinical variables (age, gender, body mass index [BMI]) and ergometric data (watts achieved, maximum heart rate, maximum percentage of tachycardization, maximum systolic blood pressure and the product of maximum heart rate by maximum systolic blood pressure). Finally, we analyzed the concordance between the MET values estimated by the 3 observers and that obtained by gas exchange and the MET estimated by linear regression.

The study of the 289 subjects in Group II (mean age 62.7 ± 11.6 years; 38.1% women) included an ergometer bicycle, 12-lead electrocardiograph and sphigmomanometer. Exercise began with an initial workload of 50 watts with increase in workload of 25 watts every 3 min. maintaining a speed of 60–70 revolutions per minute until discontinuation of the test due to inability to maintain the workload. The MET achieved were then estimated using the table recommended by the SEC (Table 1).[17]

Heart rate and blood pressure values were determined for all the ergometric tests every 3 min, at the end of the exercise and at the first, third and fifth minute post-exercise. The percentage of maximum tachycardization achieved was calculated in relation to the maximum theoretical tachycardization according to subject age (maximum heart rate/220 − age).

Statistical analysis

Continuous variables are expressed as the mean with standard deviation (±) and categorical variables are expressed as percentages. The continuous variables were compared using the Student's t test for unpaired samples. For the analysis of the best equation of multiple linear regression (method ENTER; inclusion criteria $p = 0.05$; exclusion criteria $p = 0.10$) in Groups I and II, macro ALLSETS[19] were used with 5 different indices: *Mallows' Prediction*

Table 1
Estimation of the MET for the bicycle ergometric stress test in relation to the weight and watts achieved according to the SEC guidelines.

	Work performed in watts by ergometric bicycle												
Weight (kg)	12	25	50	75	100	125	150	175	200	225	250	275	300
20	4.0	6.0	10.0	14.0	18.0	22.0							
30	3.4	4.7	7.3	10.0	12.7	15.3	17.9	20.7	23.3				
40	3.0	4.0	6.0	8.0	10.0	12.0	14	16.0	18	20.0	22.0		
50	2.8	3.6	5.2	6.8	8.4	10.0	11.5	13.2	14.8	16.3	18.0	19.6	21.1
60	2.7	3.3	4.7	6.0	7.3	8.7	10.0	11.3	12.7	14.0	15.3	16.7	18.0
70	2.6	3.1	4.3	5.4	6.3	7.7	8.8	10.0	11.1	12.2	13.4	14.0	15.7
80	2.5	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0
90	2.4	2.9	3.8	4.7	5.6	6.4	7.3	8.2	9.1	10.0	10.9	11.8	12.6
100	2.4	2.8	3.6	4.4	5.2	6.0	6.8	7.6	8.4	9.2	10.0	10.8	11.6
110	2.4	2.7	3.4	4.2	4.9	5.6	6.3	7.1	7.8	8.5	9.3	10.0	10.7
120	2.3	2.7	3.3	4.0	4.7	5.3	6.0	6.7	7.3	8.0	8.7	9.3	10.0

Source: Ruano Pérez et al.[14]