ERGOMETRY FOR BOXERS AND CARDIOTRAINING_CIDC IN THE POST COVID-19 ERA

ERGOMETRÍA PARA BOXEADORES Y CARDIOTRAINING_CIDC EN LA ERA POS COVID-19

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Responsibilities (A Research design; B Data collection; C Edition; D Statistical processing; E Financial support; F Original idea and coordination of the whole research)

Received 3 May 2022
Accepted 27 June 2022
DOI: 10.24310/riccafd.2022.v11i2.14654
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ABSTRACT

Introduction: Sports ergometry performed on boxers allows the assessment of physiological parameters, used as indicators of physical performance. Objective: Redesign specific ergometric protocols for boxing and apply the CARDIOTRAINING_CIDC software, for the benefit of individualized sports planning. Material and methods: Quasi-experimental study, between April 2020 and April 2021; sample: 14 boxers from the Cuban National Team; Age: 24 to 31 years old, all male. Two types of maximum stress tests on treadmills were carried out: one conventional and the other specific for boxing. Software, CARDIOTARINING_CIDC, an Excel VBA macro, was used to calculate and store heart rate values. Results: The following were recorded in the first and second ergometries: maximum heart rate and its percentage with respect to the estimated one; maximal oxygen consumption (means: 45 and 61.4 mL/kg/min), myocardial oxygen consumption (30.3 mL/min and 41.8 mL/min), and metabolic equivalent (means: 12.8 METS and 17.6 METS). Three of these indicators had a statistically significant relationship ($p<0.01$) in the ergometry designed for the study, compared to the conventional one. Conclusions: The specific ergometry for boxing was more effective in performing maximum cardiopulmonary stress tests.

KEY WORDS: ergometry, sports, boxing, heart rate, *software*.

RESUMEN

Introducción: La ergometría deportiva realizada a los boxeadores permite valorar los parámetros fisiológicos, utilizados como indicadores del rendimiento físico. Objetivo: Rediseñar protocolos ergométricos específicos para el boxeo y aplicar el *software* CARDIOTRAINING_CIDC, en beneficio de la planificación deportiva individualizada. Material y métodos: Estudio cuasi-experimental, entre abril de 2020 y abril de 2021; muestra: 14 boxeadores del Equipo Nacional cubano; edad: 24 a 31 años, todos del sexo masculino. Se realizaron dos tipos de pruebas de esfuerzo máximas sobre tapiz rodante: una convencional y otra específica para boxeo. Se utilizó un software, el CARDIOTARINING_CIDC, una macro VBA de Excel, para calcular y archivar los valores de la frecuencia cardíaca. Resultados: Se registraron en la primera y segunda ergometrías: la frecuencia cardíaca máxima y su porcentaje respecto a la estimada; el consumo máximo de oxígeno (medias: 45 y 61,4 ml/kg/min), el consumo miocárdico de oxígeno (30,3 ml/min y 41,8 ml/min) y el equivalente metabólico (medias: 12,8 METS y 17,6 METS). Tres de estos indicadores tuvieron relación estadística significativas ($p<0{,}01$) en la ergometría diseñada para el estudio, respecto a la convencional. Conclusiones: La ergometría específica para el boxeo resultó más efectiva en la realización de las pruebas de esfuerzo máximas cardiopulmonares.

PALABRAS CLAVE: ergometría, deportes, boxeo, frecuencia cardíaca, *software*.

INTRODUCTION

The ergometric test is a fundamental procedure for the evaluation of the physiological parameters modified as the body's response to a load imposed during effort.1 It is a widely used medical tool in both clinical cardiology and sports medicine, with special emphasis on functional capacity, which allows analyzing the electrocardiographic and hemodynamic response to exercise. Ergometry constitutes a non-invasive diagnostic test, which can also facilitate the evaluation of physical capacity, tolerance to exertion and its usefulness for the prescription of physical activity.2

The cardiopulmonary stress test in the sports environment is performed with multiple and important purposes, especially to assess individual capacity in performing dynamic exercise and to evaluate the responses of different systems to stress (cardiocirculatory, respiratory, metabolic, others).3 In the case of boxing, a sport classified within the combat area, the functional evaluation of the athlete based on the cardiorespiratory parameters obtained during the ergometry is of vital importance, if one takes into account that the boxer requires extensive development of various physical abilities, such as strength, endurance, power, among others. These qualities demand a high level of cardiovascular demand, which can be measured and assessed through stress tests performed on boxers. They are very useful in the prognosis of cardiovascular integrity, as a reliable predictor of mortality and can even be used as an indicator of performance fitness, to modify and improve individual training plans.4

It is necessary to carry out sports ergometry from a careful perspective, subject to the new normality imposed after the COVID-19 pandemic, with the necessary compliance with hygienic-sanitary measures within the stress test laboratory and with modern approaches based on in science.5 That is why this study proposes as objectives to redesign the most specific ergometric protocols for boxing and to apply the CARDIOTRAINING_CIDC software, for the benefit of individualized sports planning through heart rate and the ranges of the training zones. These alternatives may be of great interest within the renovations and modifications that are assumed in medicine based on sports after the long pause conceived in Cuba and in the world in favor of the health of humanity, in favor of the athletic movement and the athletes.

MATERIAL AND METHODS

Type of study

A quasi-experimental study was carried out at the Cuban Sports Research Center between April 2020 and April 2021.

Sample

Intentional selective, made up of 14 boxers from the Cuban National Team, eight as the case group and six as the control group.

All participants were male, aged between 24 and 31 years old. Each one of them was taken: weight (in kilograms), height (in meters), blood pressure at rest, at the end of each stage during the ergometries and during recovery (measured in millimeters of mercury) using the TANGO digital blood pressure monitor, as well as the measurement of the heart rate (HR) and the electrocardiogram from rest to full recovery, through the ERGOCID software.

For the direct measurement of gas exchange, the METALYZER sensor was used, with which the maximum oxygen consumption (VO2max) was determined. Effort was also measured through the metabolic equivalent (in METS); This parameter represents the metabolic capacity that the body has from the basal level, to meet the energy needs demanded by physical activity, according to its intensity.[6] Likewise, myocardial oxygen consumption (MVO2) was calculated, resulting from the formula: (maximum DP x 0.14 x 0.01) – 6.3, where: DP is the double product.[7,8] This is a parameter that is evaluated during the stress test, which is obtained by multiplying the blood pressure maximum systolic by maximum heart rate. The value of the double product expresses myocardial oxygen consumption, which as such represents the energy expenditure of the heart during physical exercise or activity with a certain intensity.[9]

Before starting each effort test, the study subjects were informed of its purpose and way of developing it; likewise, voluntary consent was obtained for participation in the study from the athletes.

As a criterion for ending the test, the applied protocol was completed, or it was interrupted at the request of the boxer due to fatigue or lower limb fatigue.

For the renewal of the modes of action regarding the sports ergometric protocols, the known standards for carrying out stress tests were taken into account:[1,10,11]

1. Effort protocols used for athletes must be incremental.

2. They start at low loads with smooth and progressive increases to allow adaptation to the ergometer and serve as a warm-up.

3. Optimal duration between 8 and 12 minutes, with a maximum time of up to 20 minutes.

4. They must always be maximal tests: protocols designed so that the subject can reach their limit capacity of effort or reach exhaustion, which must coincide with a value above 90% of the estimated theoretical maximum heart rate (HRME).

The protocol redesign of sports ergometries (gesture-specific) was proposed, based on the following aspects:

1. Adjustments associated with the special needs of the athlete, by imitating the specific biomechanical movements or gestures of their sport.

2. Simulation of the competition times of the sports modality to establish the steps within the ergometric protocol.

3. Use of ergometers, which are the equipment or devices on which the individual can perform the ergometry, which are close to the sports gestures of the athlete studied, modified to achieve greater comfort in carrying out the effort and, therefore, ergometric results more efficient.

4. Possibility of using facilitating sports implements, similar to others used during sport-specific training or innovated for ergometric purposes.

Ergometry protocol 1 (conventional) on ERGOCID AT-PLUS treadmill, applied to the control group:

• Initial warm-up of three minutes at 10 kilometers per hour (km/h); start of the first step with 11 km/h.

• Increase of two km/h every three minutes in the next three steps of the protocol, with the treadmill at one percent incline.

• Increase in subsequent steps of one km/h every minute, until exhaustion; the mat with a three percent incline.

• For recovery: the race was held for the first minute at nine km/h, then the athlete could sit down.

Ergometry protocol 2 (redesign) on ERGOCID AT-PLUS treadmill, applied to the group of cases (experimental):

• An initial warm-up of three minutes was carried out on the mat, at a speed of 11 kilometers per hour (km/h), with zero slope.

• The test was divided into stages, each lasting three minutes, during which it started at 12 km/h and increased by one km/h as it moved towards the next step, until reaching the maximum speed of 21 km/h, without slope.

• Between each three-minute stage, there was a one-minute recovery break between them, in which the boxer walked on the mat at a speed of 4.5 km/h.

• For recovery: walk for the first minute with a speed of 4.5 km/h, then the boxer could sit down.

• The work protocol tried to emulate a fight during international competition, based on the times and requirements of the regulations of the International Boxing Federation.

The software in EXCEL VBA macro format, called CARDIOTRAINING_CIDC, created by the author, was used to facilitate the automatic determination of the maximum heart rate (HRmax) predicted by the Tanaka formula: 206 – 0.7 x [age];[12] it was selected this equation out of 56 analysed,[13,14] due to the accurate predictive capacity of HRmax, especially that of athletes of both sexes with resistance training, and because they are high-performance trained athletes. The same software also calculated the values of the 60, 70, 80 and 90 percent of the HRmax obtained during the ergometric test, and these results correspond to the limits of the ranges of the different training zones. It also generated a database that stores all this information, to which was added: name(s) and surname(s) of the subject, age, date of performance of the test and the HRmax of the ergometry, data that could be consulted with posteriority.

The estimated HRmax (HRME) was calculated according to the Karvonen formula (220 - age), computed automatically by the ergospirometer software (ERGOCID), in addition to the result of the Tanaka formula, which was computed by the CARDIOTRAINING_CIDC software. A submaximal ergometric test was considered when the value of the calculated percentage of the HR exceeded 85%, and a maximum test, when this parameter exceeded 90%.

Some variables of descriptive statistics were expressed, which were stated through the means, standard deviations and percentages of the statisticians. Pearson's correlation coefficients were calculated and the t-Student test was applied to evaluate relationships between variables. The statistical treatment of the results was carried out through the PSPP program, version 1.0.1, and some of the results were offered in tables and figures for better presentation.

RESULTS

During the two ergometries carried out, both in the conventional one and in the redesigned one, the following aspects were essentially measured: HRmax, VO2max, MVO2, as well as the tolerated metabolic equivalent (in METS).

The values of the HRmax obtained in the ergometries 1 and 2 are presented below, together with the HRME according to the Karvonen and Tanaka equations, as well as the minimum and maximum ranges of each of them, the standard deviation (SD) and the percentage that the HRME represent with respect to the HRmax reached in the stress tests (Tables 1 and 2). During the first stress test, the correlation coefficient between the maximum frequencies reached and the one predicted according to Karvonen was -0.39; the calculated between HRmax and that estimated according to Tanaka was -0.42. Regarding the second exercise test, the values were 0.71 and 0.75, for the correlations between the HRmax achieved and those predicted according to Karvonen and Tanaka, respectively.

Table 1. Heart rate behavior during Ergometry 1 for the control group

Variable	Sample	Maximum	Minimum	Mean	SD	% HR max
HRmax (bpm)	6	200	149	171	19,6	-
HRME according to Karvonen (bpm)	6	196	191	193	2,0	88,6
HRME according to Tanaka (bpm)	6	189	185	187	1,5	91,4

Legend: SD: standard deviation; %HR max: corresponding percentage according to the maximum heart rate obtained in the ergometry; HRmax: maximum heart rate; HRME: estimated maximum heart rate.

Table 2. Heart rate behavior during Ergometry 2 for the experimental group

Variable	Sample	Maximum	Minimum	Mean	SD	% HR max
HRmax (bpm)	8	204	169	190	10	-
HRME according to Karvonen (bpm)	8	199	188	193	3,9	98,4
HRME according to Tanaka (bpm)	8	191	183	187	2,7	101,6

Legend: SD: standard deviation; %HR max: corresponding percentage according to the maximum heart rate obtained in the ergometry; HRmax: maximum heart rate; HRME: estimated maximum heart rate.

The VO2max ranges during exercise test 1 were between 35.2 and 54.5 ml/kg/min, with a mean of 45 ml/kg/min and standard deviation of ±7.3, while in exercise test 2 the minimum value was 53.9 and the maximum 72.8 ml/min/kg, mean of 63 and standard deviation of ±7.9 (figure 1). The relationship between the means had a value of p=0.002.

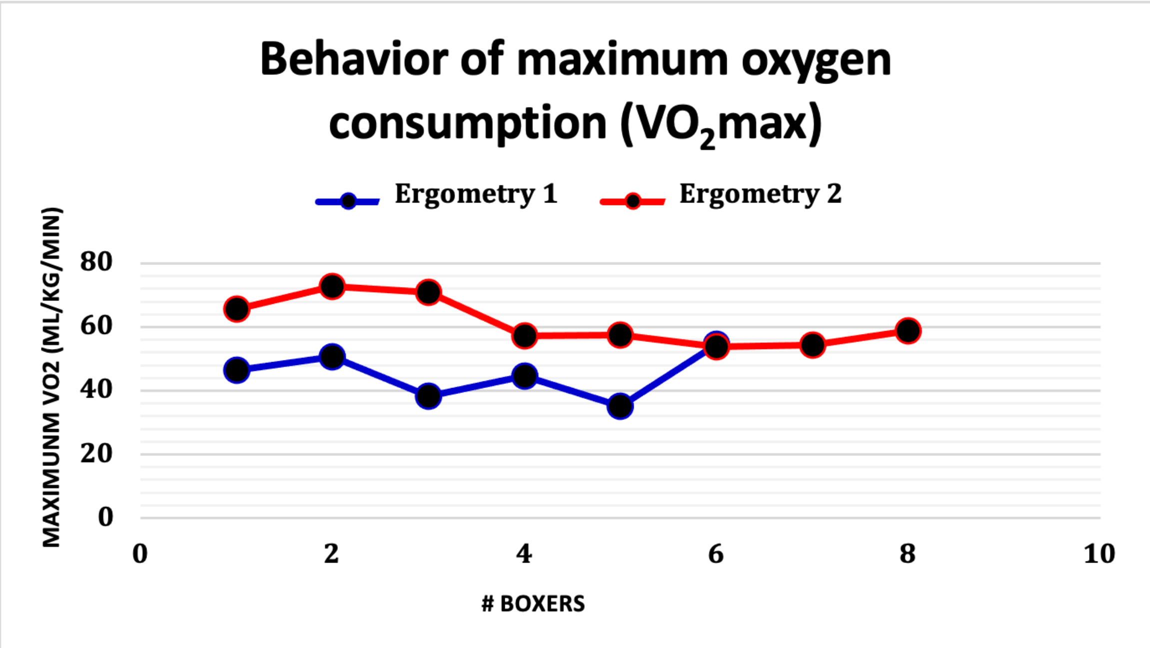

Figure 1. Behavior of maximum oxygen consumption. Ergometry 1: control group; ergometry 2: experimental group.

It is noteworthy that each boxer performed a maximum test, exceeding 90% of the FCME according to Tanaka, in both ergometries. The energy requirement during the first stress test ranged between 10 and 15.6 METS, with a mean of 12.8 and a standard deviation of ±2.1 METS, while in the second it was between 15.4 and 20.8. METS, mean of 17.6 and standard deviation of ±2.1 (p=0.002) [figure 2].

Regarding myocardial oxygen consumption, the values were between 11 and 42 ml/min, the mean was 30.3 and the standard deviation ±11.3 ml/min for conventional ergometry; in the redesigned exercise test, the range was between 34 and 47 ml/min, with a mean of 41.8 and a standard deviation of ±4.6 (p=0.06).

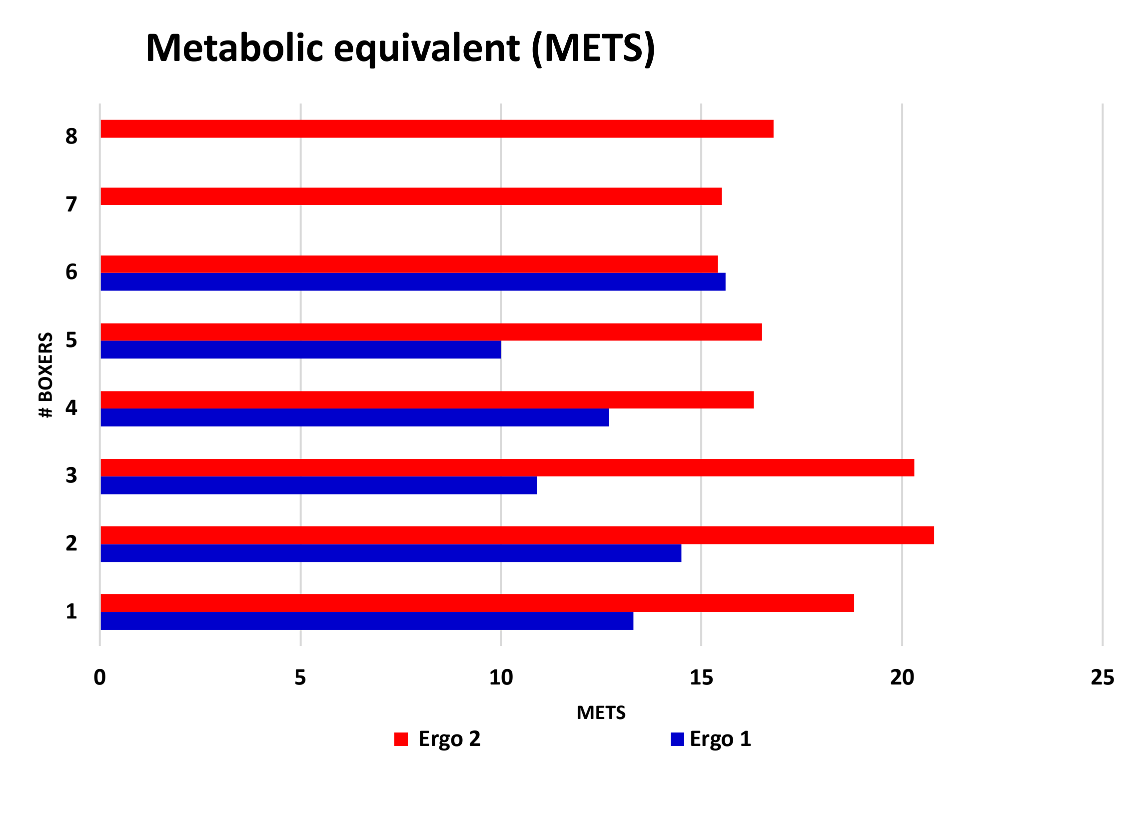

Figure 2. Metabolic equivalent in both ergometries. Ergo 1: ergometry in a group of cases; ergo 2: ergometry in experimental group

DISCUSSION

In the analysis of the two stress tests performed on each boxer, the HRmax exceeded 85% of the HRME calculated according to the Tanaka (91.4%) and Karvonen (88.6%) equations; however, in the second stress test, redesigned to be more specific, the percentages were around 100% of the HRME (98.4 according to Karvonen and 101.6% compared to Tanaka). These values show a greater intensity during the performance of the gesture-specific ergometries, to promote the elevation of the HRmax closer to the expected one, which speaks in favor of the fact that the similarity to the movements and times of the sport, can achieve a greater increase in HRmax in the ergometry.[15] As the laboratory test is more similar to the combat periods of boxers, with intermediate pauses, the adaptation to the steps is also done in a more physiological way and has an impact on a better result at the end of maximum effort.

It was evidenced when looking at VO2max that higher values were reached in the second ergometry, with a significant difference in the relationship between the means, compared to the conventional stress test ($p=0.002$; $p<0.01$); When comparing the ranges of each test, the superiority of the second ergometry with respect to the first is manifested (figure 1). The foregoing may represent that, while superior results are reached in parameters such as HRmax, these are positively correlated with the best achievement of VO2max in the effort,[16] in addition to allowing the greater efficiency of the gesture-specific tests, designed to be inferred boxing, considering that VO2max is the best indicator of cardiorespiratory fitness and functional exercise capacity.[11,17]

Regarding the metabolic equivalents expressed as energy requirement, as shown in Figure 2, the second ergometry stood out with respect to the conventional one, due to the superiority in the values of the cardiopulmonary parameters of the redesigned test compared to those recorded during the first test. In the same sense, myocardial oxygen consumption behaved, slightly higher during the second test with respect to the first, although the statistical difference of this indicator between the stress tests did not become significant, when establishing the comparison between them ($p= 0.06$). This can be explained because since MVO2 is a way of representing the energy consumption of the heart in the face of a physical demand of any intensity, and since the subjects of the study are high-performance athletes, with well-trained hearts to withstand heavy workloads, there is no there were differences when performing different intensities of effort; Myocardial oxygen consumption increased directly and proportionally to the increase in intensity of effort, without affecting the heart muscle.

The ergometric test that was redesigned for boxing was significantly superior ($p<0.01$) to the conventional one after the analysis of three of its main indicators: maximum heart rate, maximum oxygen consumption, and metabolic equivalent; Myocardial oxygen consumption represents cardiovascular hemodynamic integrity, between the effective supply of oxygen volume and the correct function of the myocardium, for which it is a good sign that there have been no significant differences between both ergometries (conventional and redesigned), and speaks in favor cardiovascular health of the boxers studied.[8,9]

The use of the CARDIOTRAINING_CIDC software allowed obtaining the estimated maximum heart rate according to the Tanaka equation, whose values during the first test, the conventional one, were correlated with the HRmax obtained and turned out to have a negative relationship (-0.4); the same happened with that predicted according to the Karvonen formula (-0.3). However, the correlation of the HRmax values during the gesture-specific ergometries with that predicted according to Karvonen was positive (0.71), as was the result of the relationship according to that predicted by Tanaka (0.75); this allows us to assert that in the stress tests redesigned for boxing, the results according to the predicted HRmax were closer to the real one obtained during the maximum ergometry tests, and that this correlation turned out to be strong.[18] The software was also used as a basis for data for the successive readjustments in the sports preparation of the boxers who participated in the research, because they were provided with the ranges of the training zones from the heart rate, to evaluate not only in the ergometry laboratory, but also during each training session, under the supervision of medical and technical sports personnel. It was very useful for the physiological control of training through heart rate, through the prediction of the HRME and for the precision of the training zones in an individualized way, for which it is estimated that it can be a practical tool for both athletes and athletes. for heart patients undergoing rehabilitation and healthy individuals, regarding the planning of physical activity in a personalized way.

Therefore, the extension of this study regarding the effectiveness of gesture-specific ergometry is recommended, to assess not only high-performance boxers, but also to study youth categories, cadets, schoolchildren and even during the evaluation of sports talents for the specialty of boxing.

CONCLUSIONS

The redesign of the gesture-specific maximum effort test in boxing was significantly more effective than conventional ergometry, because its design resembles the times of boxing competition and the technical movements of pugilism.

The use of the CARDIOTRAINING_CIDC software allowed the automatic obtaining of the estimated maximum heart rate very close to the real one obtained in stress tests, and it can be used as a database for successive readjustments in sports preparation, by facilitating the ranges of the zones training based on heart rate.

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