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Proposal and reproducibility of a specific test for amateur boxing

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Key words: exercise test, sports, exercise, physical fitness, athletic performance

Abstract
Background and Aim. Based on the assumption that a specific test for boxing would assist in the evaluation of athletes and in the selection of training based on actions within the ring, this study intends to propose a test and evaluate its reproducibility, intending to be physiologically alike an official fight, and providing estimates of performance.
Methods. 12 boxers were evaluated on two different days with an interval of 48 hours between the test and retest. The evaluation consisted of a specific test where the evaluator guided the athletes for three rounds in repeated actions of attack, defense, and movement. During the test, variables of maximum heart rate (HR), lactate concentration (LA), rating of perceived exertion (RPE) and fatigue (ROF) at rest were evaluated at the end of rounds, and at five and ten minutes after the test; in addition, the test was filmed for performance analysis (number of actions). The reproducibility of the test was verified by scientifically rigorous methods.
Results. The specific test was proven to be alike an official fight with Mean Action/seg between 1.69±0.2 – 1.87±0.2 and mean values of HR of 190 bpm, RPE of 17.92 points and LA of 8.42 mmol/L, at third round). There was reproducibility of the physiological and performance variables, except for HR and Mean Evaluator Error.
Conclusion. The proposed specific test for amateur boxing has characteristics and physiological responses similar to an official fight and presents reproducibility in the analyzed variables, providing an estimate of performance; however, HR and Mean Evaluator Error did not prove to be reproducible.

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1. Introduction

Boxing is an Olympic combat sport where athletes use their fists with the intention of taking down their opponent, and because of this, it is difficult to reproduce its specificity, in putting together both attack and defense, while conducting tests, principally which use sensible equipment [Arseneau *et al.* 2011].

There are already some proposals for specific boxing tests such as the work published by Smith *et al.* [2000], who proposed the creation of a specific dynamometer where boxers dealt straight blows (jab and cross) in sequence, or single blows according to the verbal assignment. Halperin *et al.* [2016] used a similar method with a dynamometer, but the athletes were instructed to throw 12 blows at maximum strength, three jabs, three crosses, three hooks with the lead hand and three with the rear hand, with five seconds of an interval between each punch. Hall *et al.* [2001] measured the performance of boxers using a 4x2min circuit, consisting of burpees and arm push-ups.

Wasik *et al.* [2018] state, that when the maximum velocity of a punch occurs closer to the moment of hitting a target, the higher it will be in the moment of that hit. Other authors evaluated punch speed [Kimm, Thiel 2015] and strength of punch [Pilewska *et al.* 2017] using an accelerometer. The speed was measured with the accelerometer inside athletes´ bandages, and the methodology applied was the execution of 20 blows in the air between jabs and crosses. The force was measured with an accelerometer inside a punching bag, and the athletes struck this bag for three sets of three jabs and three crosses.

A good simulated fighting strategy has been the use of focus mitts by an instructor guiding the athlete. In order to investigate metabolic demands in boxing, Davis *et al.* [2014] simulated a fight (based on the analysis of official fights), between an athlete and an instructor who guided the actions to be performed against his gloves; with this method, they were able to analyze the energy demands used in a fight, but also presenting indicators such as number of blows delivered, to compare the number obtained in the test with that of a real fight. Thomson *et al.* [2017] used a similar strategy, a simulated fight against an instructor using focus mitts, but with the actions being given by a voice recording. This study presented results compatible with that of a fight, considering the analyzed physiological aspects. Finlay *et al.* [2018] also used the fight simulation, however, against a punching bag, with actions being guided by voice recording.

Despite some studies that have already proposed different tests, we did not find a specific validated boxing test, which would help the academic and professional fields in the development of studies and tools for the detection of talents and training prescription. Therefore, the aim of this study is to suggest an accessible and low-cost specific test for amateur boxing, which can be reproducible and physiologically like an official fight (measuring athletes' heart rate, blood lactate concentration, the perceived exertion and fatigue and the Rating-of-fatigue scale), providing a performance estimate based on the athletes' actions count (number of error made by athletes or the evaluator).

2. Methods

This experimental, cross-sectional, and quantitative research was approved by the Research Ethics Committee of the Federal University of Sao Paulo (protocol number 1015/2018) and complied with the Helsinki Declaration and all norms related to research studies with humans.

2.1 Participants

For this study, a convenience sample was used, which resulted in a sampling of 19 amateur boxing athletes aged between 18 and 38 years. The inclusion criteria were that they had already participated in at least one competition, being physically active in the six months prior to the test. The exclusion criteria were: to present muscle, bone and/or joint injuries that could prevent the performance of the protocol, and athletes in a period of weight loss to compete (since the dehydration that occurred in this process decreases the athlete's performance [Pallares *et al.* 2016]).

Seven of 19 athletes were affected by the exclusion criteria, 6 were excluded for not being physically active for the last six months prior to the test and 1 presented a knee injury.

The sample consisted of 12 athletes (two women) of different weight classes: two lightweight (56-60 kg); one light welterweight (60-64 kg); one welterweight (64-69 kg); two middleweight (69-75 kg); five light heavyweight (75-81 kg); and one heavyweight (81-91 kg), covering six of the ten weight classes described by the Amateur International Boxing Association (AIBA)[2019].

The athletes participated in different levels of competition, with seven having fought in regional or state competitions, four already having a podium in national competitions and one with podium in continental competition. Table 1 shows other information on the characterization of the athletes.

2.2 Procedures

Volunteers had anthropometric and body composition variables measured and answered a questionnaire about their boxing history. Then, they performed warm-up exercises followed by the boxing-specific test which consisted of three 3-minute rounds with actions alike those in an official fight. They were re-evaluated after a period of 48 to 72 hours, to verify the reproducibility of the test.

The warm-up was done for 10 consecutive minutes and divided into: 2 minutes of ballistic stretching, 3 minutes of moderate running, and 5 minutes with the evaluator performing the actions of the specific boxing test. In this context, the participant was already familiar with the test itself.

2.3 Test and measurements

The evaluations were performed at room temperature between 20°C and 25°C, with a relative humidity between 79% and 84%, to the maintenance of optimal performance, and lower physical wear when compared to high temperatures [Marino *et al.* 2004; Tucker *et al.* 2004].

2.4 Anthropometrics

Body mass was measured on a BC-558 Ironman scale (Tanita Corp., Tokyo, Japan); height was measured with a Sanny stadiometer, with an accuracy of 100 grams (g) and 0.1 centimeters (cm), and wingspan using a Sanny inelastic measuring tape, according to the methodology described by LOHMAN *et al.* [1988].

2.5 Body composition

Body composition was analyzed using the bioelectric impedance method, with the BC-558 Ironman Segmental Body Composition Monitor (Tanita Corp., Tokyo, Japan) equipment, considered to be a fast, non-invasive, and economically viable method to indirectly estimate the values of fat-free mass, fat mass, total body water, and basal metabolic rate [Sergi *et al.* 2017].

2.6 Physiological assessments

The specific boxing test was held in a 4 x 4 m ring. Athletes were evaluated continuously from the warm-up exercises until ten minutes after the third round, through heart rate using a heart monitor (Polar A300) positioned around the athlete's chest, and with the reader placed on the edge of the ring. This data was automatically saved to the device's memory and then analyzed.

The volunteer had collected capillary blood samples from the earlobe to determine blood lactate concentration [Forsyth *et al.* 2012] (Accutrend Plus, Roche), and also indicated the athlete's perceived exertion and fatigue on the Borg Scale of Perceived Exertion [Foster *et al.* 2001] and the Rating-of-fatigue scale [Micklewright *et al.* 2017] respectively, at rest, after the end of each round, and at five and ten minutes after the last round.

2.7 Specific boxing test

The specific boxing test was structured based on analyses of the activity profile of 2015 World Boxing Championship matches, performed by Davis *et al.* [2018]. It was done by professionals with experience in the sport, which evaluated the average, per round, of each action in sequences of attack, defense, and movement that are common to boxers.

Our proposed test required the athlete's personal equipment (gloves, shoes and bandage), an evaluator (with experience in boxing training), focus mitts, and a ring. A maximum of 3 tests per day were performed to avoid possible fatigue of the evaluator and therefore differences in intensity.

The test consisted of two sequences (illustrated in Figure 1): in the first sequence the athletes performed attack actions, movement and defense and, in the second sequence, they performed attack, movement, defense, and clinch (immobilization of the opponent). These two sequences were called a cycle and were repeated during the round and counted as a form of performance evaluation. The evaluator requested the execution of the actions within the shortest possible interval, but it was up to the volunteer to increase the pace of execution. For countability, the number of actions in a cycle (31) were made into decimal numbers, being able to generate a consistent number when the last cycle ended.

The specific test consisted of three rounds of three minutes with an interval of one minute between each round, as in an official fight [Amateur International Boxing Association, 2019]. In this study, samples were collected during the intervals (one minute), at the end of the last round and after five and ten minutes at the end of the third round. Data were collected on lactate concentration, perceived exertion, fatigue, and maximum round heart rate.

2.8 Performance analysis

The specific test was recorded in 2160p resolution with a rate of 30 frames per second; the camera (Asus Zenfone 3) was positioned next to the red corner obtaining a full view of the ring, with no blind spots [Dunn *et al.* 2019]. The resulting footage was analyzed in the VLC media player version 2.2.8 (VideoLAN Project) software using the "slower" speed option, and the same evaluator checked each video three times in order to verify possible counting changes. The video analyses were performed to account, on each cycle, the number of actions per second (dividing the total actions by the total round time), and the number of errors made by the athletes (when they did not respond with the correct action or did not perform it) or by the evaluator (when they requested an action different from the sequence of the cycle). The videos were analyzed using a checklist of the sequences of the specific test.

2.9 Statistical analysis

Data were collected and organized into an Excel spreadsheet for further analysis. For test-retest reliability on the variables of heart rate, RPE, ROF, and lactate concentration, Student's t-test was used for related samples. For the variables in which the assumptions of the Student's t-test were not parametric, the Wilcoxon test was used (RPE and ROF). The level of significance adopted was 5%, with $p \leq 0.05$.

For the variables, total cycles, estimated actions, total actions, athlete error and evaluator error, relative reliability was assessed using the intraclass correlation coefficient (ICC). ICC values less than 0.50 are indicative of poor reliability, values between 0.50 and 0.75 indicate moderate reliability, values between 0.75 and 0.90 indicate good reliability and values greater than 0.90 indicate excellent reliability [Ribeiro *et al.* 2020]. To assess absolute reliability, we used typical error of measurement (TE). The usefulness of the test was assessed by comparing the smallest worthwhile change (SWC) and the TE. The SWC was assumed by multiplying the between-subject standard deviation in section 1 by 0.2 (SWC 0.2), 0.6 (SWC 0.6) and 1.2 (SWC 1.2). Thus, if the TE was higher than SWC, the evaluation of the variable being used was "marginal;" if the TE was similar to the SWC, it was "medium;" and if TE was less than the SWC, and evaluation of "good" was given to the test to detect small (0.2), medium (0.6), and large (1.2) differences. In addition, the minimal detectable change (MDC95%) was also calculated ($TE \times 1.96 \times \sqrt{2}$) [Franchini *et al.* 2018]. These analyses were performed using the software *R*, version 3.6.0.

3. Results

The results of physiological variables (Table 2) during the test showed no differences between Test and Retest for RPE, ROF and lactate concentration, showing that the perceived and measured intensities during the test were similar between evaluations. Heart rate presented different values in each round when reliability was assessed, but there was no difference in heart rate when compared between rest and the five- and ten-minute recovery periods after the third round.

The relative reliability of the performance analyses by video indicates moderate reliability for the variables, except to the Mean Eva. Error, which was poor. The absolute reliability indicated that the evaluation for all variables being used (performance analyses by

Table 1. Characterization of the volunteers.

	Mean ± SD
Age (years)	25.83 ± 6.1
Body weight (kg)	71.23 ± 9.66
Height (cm)	173 ± 5
Body Mass Index (kg/m²)	23.9 ± 2.69
Wingspan (cm)	180.42 ± 8.49
Body fat (%)	13.48 ± 6.08
Lean mass (kg)	58.41 ± 7.77
Body Water (%)	63.33 ± 4.21
Basal Metabolic Rate (calories)	1806.75 ± 233.49
Bone mineral density (kg)	3.05 ± 0.37
Fights	45.33 ± 89.84
Titles	2.33 ± 4.33
Competition Time (years)	4.67 ± 5.28

Table 2. Heart rate, RPE, ROF and lactate concentration.

	Test	Retest	*p*
Rest HR (bpm)	64.33 ± 8.91	62.67 ± 12.19	0.410
Round 1 Highest HR (bpm)	181.5 ± 13.49	178.25 ± 13.3	0.006*
Round 2 Highest HR (bpm)	187.33 ± 11.30	183.83 ± 12.43	0.016*
Round 3 Highest HR (bpm)	190.25 ± 10.18	186.25 ± 12.96	0.022*
After 5' HR (bpm)	115.83 ± 14.33	115.42 ± 17.98	0.905
After 10' HR (bpm)	107,58 ± 11.75	107.5 ± 14.45	0.969
Rest RPE	6 ± 0	6 ± 0	0
Round 1 RPE	13.33 ± 2.35	13.42 ± 1.78	0.642
Round 2 RPE	15.83 ± 2.04	15.08 ± 1.73	0.147
Round 3 RPE	17.92 ± 1.93	17.25 ± 1.82	0.082
After 5' RPE	11.67 ± 3.11	10.42 ± 3.42	0.211
After 10' RPE	8 ± 2.56	7.17 ± 1.8	0.090
Rest ROF	0.25 ± 0.62	0.5 ± 0.67	0.345
Round 1 ROF	4.33 ± 1.44	4.25 ± 1.71	0.597
Round 2 ROF	6.25 ± 1.66	5.83 ± 1.53	0.343
Round 3 ROF	7.67 ± 1.61	7 ± 2.25	0.056
After 5' ROF	4.17 ± 2.25	3.33 ± 1.83	0.222
After 10' ROF	2.25 ± 1.6	1.67 ± 2.02	0.170
Rest Lactate (mmol/L^{-1})	2.03 ± 0.41	2.16 ± 0.38	0.398
Round 1 Lactate (mmol/L^{-1})	6 ± 1.82	6.25 ± 1.7	0.316
Round 2 Lactate (mmol/L^{-1})	7.88 ± 2	7.63 ± 2.27	0.333
Round 3 Lactate (mmol/L^{-1})	8.27 ± 2.31	8.42 ± 1.8	0.179
After 5' Lactate (mmol/L^{-1})	6.55 ± 2.28	6.08 ± 1.88	0.460
After 10' Lactate (mmol/L^{-1})	5.67 ± 1.58	5.33 ± 2.07	0.174

Values are mean and standard deviation, unless marked otherwise; p – value; *p<0.05; HR: heart rate; RPE: rating of perceived exertion; ROF: rate of fatigue.

Table 3. Performance analyze in Test and Retest and reliability measures

	Test	Retest	I.C.C. (95% CI).	TE (95% CI)	SWC (0.2, 0.6, 1.2)	MDC 95%
Total Cycles	26.16 ± 3.71	30.02 ± 5.93	0.66 (-0.09 – 0.91)	1.86 (1.32; 3.16)	0.74, 2.23,4.46	5.15
Mean Action/s	1.69 ± 0.2	1.87 ± 0.32	0.66 (-0.03 – 0.90)	0.12 (0.08; 0.20)	0.04, 0.12, 0.24	0.33
Mean Ath. Error	4.04 ± 2.99	3.18 ± 2.03	0.50 (-0.08 – 0.80)	1.83 (1.26; 3.11)	0.60,1.80, 3.59	5.07
Mean Eva. Error	1.81 ± 1.31	1.22 ± 0.96	-0.18 (-0.66 – 0.41)	1.25 (0.89; 2.13)	0.26, 0.79, 1.58	3.46

Values are mean and standard deviation, unless marked otherwise; I.C.C: intraclass correlation coefficient; 95% CI = 95% confidence interval;
TE = typical error; SWC = smallest worthwhile change; MDC = minimal detectable change. Action/s: action per second; Ath.; athlete; Eva.: evaluator.

video) was good for the test to detect large (1.2) differences, and medium differences (0.6) to the Total Cycles variable. Still, Mean Action/s and Mean Ath. Error evaluations were medium to the test to detect medium (0.6) differences, and the MDC values were higher than the values differences found between the moments (Table 3).

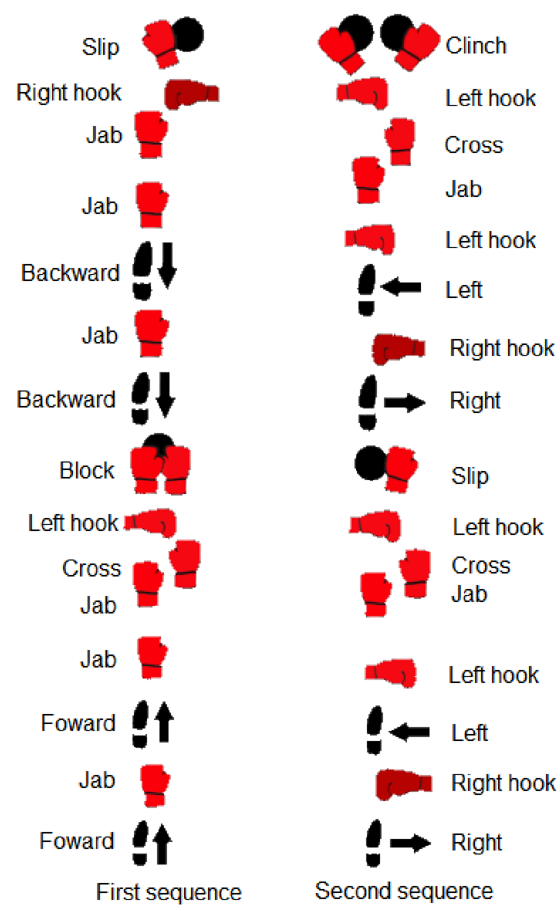
4. Discussion

The present study indicates that the specific test proposed for amateur boxing presented moderate to good test-retest reliability for both physiological and performance measurements, except for HR and Mean Ava. Error. It also reproduces the intensity of an official fight when compared to results already shown in other studies [Khanna, Manna, 2006; Siegler, Hirscher, 2010; Arseneau *et al.* 2011], besides being similar to tests with simulations of fights [Davis *et al.* 2014; Thomson, Lamb 2017].

Regarding the characterization of the athletes, it was observed that the volunteers had body conditions corresponding to the modality; by comparison, we found a of body fat percentage of 13.48% while another study recorded values of 9.1 to 26.8% [Chaabene *et al.* 2015]. This variation occurs mainly when super-heavy athletes, who do not have a weight limit and are occasionally overweight are included. There is also a variation in the number of ages, fights, and titles according to the time of competition of each athlete, showing that the volunteers did not have the same experience in the modality, a fact that can alter the results of evaluations on athletes of any level, as shown by Khanna *et al.* [2006].

The lactate concentrations observed in our study after the third round were similar to those measured by Khanna *et al.* [2006] (7.4 mmol/L) and Arseneau *et al.* [2011] (9.4 mmol/L), which used sparring exercise, as well as the tests performed by Davis *et al.* [2014] with 9.5 mmol/L. It is important to emphasize these values since the higher the athlete's lactate concentration before a round, the lower the effectiveness (number of blows landed) of their punch [Bruzas *et al.* 2014].

Figure 1. Specific boxing test sequences.



Sequences begins from bottom to top.

Some studies have presented lower lactate concentration values such as Finlay *et al.* [2018] and Thomson *et al.* [2017], with respectively 4 and 4.6 mmol/L. Our study, similarly to those published by Davis *et al.* [2014] and Thomson *et al.* [2017], had proposed tests using focus mitts exercises, with the sequences based on movements and actions carried out in an official fight. Finlay *et al.* [2018] also based the actions of their test on official fights, but the execution occurred against a punching bag, whose intensity, as an exercise, is lower than the focus mitts training [Arseneau *et al.* 2011].

A difference between the test suggested by Thomsom *et al.* [2017] compared to ours and with that proposed by Davis *et al.* [2014], is the limitation on the number of actions performed during the test; as their test was carried out using a recording tape, and because of that, the number of actions will always be the same, which might explain the difference in lactate concentration and RPE between these studies.

We observed that the subjective perception of exertion after the third round was greater than 17 points in both the test and retest, being similar to the test with sparring exercises published by Siegler *et al.* [2010] (17 points), higher than that reported in the tests of Thomson *et al.* [2017](8 points), as well as in the tests with sparring conducted by Arseneau *et al.* [2011] (12 points, but in three rounds of two minutes), showing that the high intensity of the exertion achieved in the test proposed here is, in fact, similar to a fight. On the other hand, the perception of fatigue after the end of the specific tests was seven points or higher, approximately one point below the "very tired" classification, which shows that the specific test time was not enough to fatigue the volunteers, despite the high intensity of the exercise performed [Tianlong, Sim, 2019].

Although heart rate did not show test-retest reliability their values determined the specific test as high intensity exercise, reaching percentages above 90% of the maximum heart rate during the third round, which is similar to studies with sparring exercises that show a maximum heart rate above 90% [Siegler, Hirscher 2010; El-Ashker *et al.* 2018], as well as studies that used tests [Arseneau *et al.* 2011; Thomson, Lamb 2017], but higher than those presented in the tests by Davis *et al.* [2014] and Finlay *et al.* [2018].

Differences between tests with sparring are related to the absence of blows against the volunteer [Davis *et al.* 2014; Finlay *et al.* 2018], being carried out under a controlled environment and with the guarantee that despite the physical exertion performed there would not be the imminence of assault, which can decrease the intensity of the test in relation to a fight. Such a condition was determinant to lead us to use a model in which there is no limit on the number of actions, allowing the substitution of the stress of being able to be struck by the stress of a greater load of actions performed.

In fact, actions per second in both test and retest produced higher results (1.69 and 1.87) than those seen in studies of official fights, such as Davis *et al.* [2018] that verified 1.55 actions per second, and Slimani *et al.* [2017] that verified 1.4 shares per second. Producing a higher activity in the test than that observed in a fight can be an important factor to approximate the intensity of the test to the competition situation, in an attempt to compensate the lack of stress observed in competitions, or the absence of blows during a test. It is also worth emphasizing the importance of executing a high number of actions, mainly blows, since winning boxers land more punches than their opponents [Chaabene *et al.* 2015; Davis *et al.* 2018; Dunn *et al.* 2019].

In this study, during the tests, an increase from round 2 to round 1, and also from round 3 to round 2, occurred in all variables evaluated round by round, which has already been observed in the evaluations of official fights [Slimani *et al.* 2017; Davis *et al.* 2018; El-Ashker *et al.* 2018], showing a possible motion economy in the first rounds, and also in the retest, which may have been the determining factor for the non-reproducibility of heart rate.

The test proposed by us presents moderate relative reliability to the performance analyses (except for the Men Ava. Error). Relative reliability refers to the degree to which repeated measurements vary for individuals (consistency of scores of individuals), while absolute reliability refers to the degree to which individuals maintain their position in a sample with repeated measurements in which typical error of measurement is used for evaluative tests to monitor changes over time [Atkinson, Nevill 1998]. In this context, values of absolute reliability indicated that the evaluation was medium to the test to detect medium (0.6) differences to Mean Action/s and Mean Ath. Error evaluations. However, it was good for the test to detect large (1.2) differences for all variables and medium (0.6) differences in the Total Cycles.

The error count showed that, despite being a test conducted by a human instructor and dependent on the correct response of the volunteer, the number of errors was considered to be statistically low. In both counts, the value was minimal compared to the actions that occurred during each round in the test and retest, respectively. Furthermore, the fact that all variables have been shown to be "marginal" to the test to detect small (0.2) differences, may be occurred due to the little familiarization during warm-up, and to a learning effect shown by the increase in cycles and actions per second between test and retest, as well as the decrease in heart rate between these two moments. The cycles, however, showed a high deviation between the values obtained, raising possible technical/tactical and physical differences between the athletes, which athletes with more experience would perform more cycles than novice athletes. These facts should be considered for the conduction and improvement of the proposed test, which can probably improve its reliability even more.

Besides, the values of the MDC for the performance variables did not show to be higher than the differences between the moments, which indicates that the test can be reproducible since MDC is interpreted as the minimal change required in a given variable to the coach or sport scientist to be confident that a real change has occurred [Franchini *et al.* 2018].

It is worth noting that specificity and feasibility are important aspects in performance testing for combat sports [Chaabene *et al.* 2018]. Thus, the proposed test becomes a good alternative as a low cost possibility to test physiological and performance characteristics of amateur boxers as it does not need a complex system or very specific equipment and software, which might not be available to many coaches and physical and conditioning professionals. However, even being similar to other studies in the modality [Arseneau *et al.* 2011; Cepulenas *et al.* 2011; Bruzas *et al.* 2014], we must include the low sample size as one of the limitations of this study, requiring caution to extrapolate the results presented. Moreover, despite the attempt to homogenize the sample, another limitation to be considered is the variation observed in relation to the experience in competitions and time of practice in the modality by the volunteers [Khanna, Manna 2006].

Conclusion

The specific test for amateur boxing, in the model of attack and defense sequences based on official fights, showed to be accessible and low-cost, being reproducible and physiologically like an official fight (heart rate, RPE, ROF, and lactate concentration), providing a performance estimate based on the athletes' actions count and number of error made by them. In this context, it can be used both for the evaluation of the athlete's physical condition and for the prescription of specific training, providing boxing professionals with a wider range of tools.

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Propozycja i reprodukowalność testu sprawności specjalnej w boksie amatorskim

Słowa kluczowe: test wysiłkowy, sport, ćwiczenia, sprawność fizyczna, wyniki sportowe

Streszczenie

Tło i cel. Na podstawie założenia, że test sprawności specjalnej w boksie amatorskim może pomóc w ocenie zawodników i selekcji treningu opartego na działaniach w ringu, niniejsze badanie miało na celu zaproponowanie takiego testu i ocenę jego reprodukowalności, mając na celu fizjologiczne odwzorowanie walki oraz oszacowanie wyników sportowych.

Metody. Dwunastu bokserów zostało ocenionych w dwóch dniach, z odstępem 48 godzin między testem a powtórnym testem. Ocena polegała na teście sprawności specjalnej, w którym oceniający prowadził zawodników przez trzy rundy, powtarzając ataki, obronę i ruch. W trakcie testu oceniano zmienne maksymalnego tętna (HR), stężenie mleczanu (LA), ocenę percepcji wysiłku (RPE) i zmęczenie (ROF) w stanie spoczynku na koniec rund oraz pięć i dziesięć minut po teście. Dodatkowo test był filmowany w celu analizy wyników sportowych (liczba akcji). Reprodukowalność testu została zweryfikowana za pomocą naukowo rygorystycznych metod.

Wyniki. Test sprawności specjalnej okazał się podobny do oficjalnej walki ze średnią ilością akcji na sekundę wynoszącą od 1,69±0,2 do 1,87±0,2 oraz średnimi wartościami HR wynoszącymi 190 uderzeń na minutę, RPE wynoszącymi 17,92 punktów i LA wynoszącymi 8,42 mmol/L (w trzeciej rundzie). Stwierdzono reprodukowalność zmiennych fizjologicznych i wyników sportowych, z wyjątkiem HR i średniego błędu oceniającego (MEE).

Wnioski. Test sprawności specjalnej w boksie amatorskim posiada cechy i reakcje fizjologiczne zbliżone do walki oficjalnej oraz wykazuje reprodukowalność w analizowanych zmiennych, dostarczając oszacowania wyników sportowych; jednak HR i średni błąd oceniającego nie okazały się reprodukowalne.