ORIGINAL ARTICLE
INNOVATIONS IN RESEARCH METHODOLOGY

Special Boxing Fitness Test: validation procedure

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Wiesław Chwała [1ABCDE], **Wojciech Wąsacz** [2ABCDE], **Łukasz Rydzik** [2BCDE], **Wacław Mirek** [2BE], **Piotr Snopkowski** [2DE], **Tomasz Pałka** [3AB], **Tadeusz Ambroży** [2BCDE]

[1] Department of Biomechanics, Faculty of Physical Education and Sport, University of Physical Education in Krakow, Krakow, Poland
[2] Institute of Sports Sciences, Faculty of Physical Education and Sport, University of Physical Education in Krakow, Krakow, Poland
[3] Department of Physiology and Biochemistry, Faculty of Physical Education and Sport, University of Physical Education in Krakow, Krakow, Poland

Received: 12 February 2023; **Accepted:** 14 March 2023; **Published online:** 27 March 2023

AoBID: 16225

Abstract

Background & Study Aim: In the scientific community specializing in combat sports, there is a consensus on the crucial role of diagnostic tests evaluating general and special fitness and performance. This is due to the unique structure of tasks characteristic for these disciplines, which require a holistic approach and integrated function, energy efficiency, and muscular fitness of the human structural-functional system. Therefore, diagnostic tools informing about the comprehensive and special components of combat sports athletes' physical fitness are particularly useful. The aim of the study was to validate a Special Boxing Fitness Test.

Material & Methods: The study involved 18 boxing athletes (three representatives from six regulatory weight categories) characterized by a high level of sport performance. The Special Boxing Fitness Test (SBFT) created by the authors was based on the following motor and exercise time assumptions: 90-second (3 rounds of 30s) fatigue test with the implementation of boxing techniques in the form of straight punches delivered with full force to the beat of a metronome, performed on a boxing bag. For the validation of the author's SBFT were used (as a reference system) Pawluk's Boxing Test based on the quantitative aspect of delivered blows. To assess the reliability of SBFT, it was carried out on two occasions, with a seven-day interval. Indicators were recorded for each special attempt and subsequently, an Index SBFT illustrating comprehensive special performance was calculated for all attempts using a specialized formula. Statistical procedures were used to comparatively analyse results and examine associations in specified combinations between tests and measurement dates, ultimately validating the SBFT.

Results: The analyses showed statistically significant associations of very high and high strength for cross-sectional Special Endurance Indices, between the arrangement of both tests and the two measurement dates. Regarding both SBFT dates, similar levels of indices were observed, without signs of significant differentiation and with a profile of a weak effect. For both SBFT measurement dates, very low internal variability of indices was recorded.

Conclusions: The comparative arrangement and the applied test-retest procedure revealed high applicability value of SBFT. The proposed SBFT provides a reliable, cross-sectional assessment of the fitness and special performance of boxing athletes and is conducive to its use in field conditions.

Keywords: boxing technique • combat sports • endurance • Pawluk's Boxing Test

Conflict of interest: Authors have declared that no competing interest exists

Ethical approval: Not required

Provenance & peer review: Not commissioned; externally peer reviewed

Source of support: The project is funded under the program of the Ministry of Science and Higher Education (Poland) 'Regional Excellence Initiative' for the years 2019-2022, project number 022/RID/2018/19, with a budget of 11,919,908 PLN; grant number 40/PB/RID/2022 with funding amount 56,500 PLN

Author's address: Łukasz Rydzik, University of Physical Education, Aleja Jana Pawła II 78, 31-571 Krakow, Poland; e-mail: lukasz.rydzik@awf.krakow.pl

INTRODUCTION

Boxing is classified as 'hits (strokes)' in the combat sport category [1] – see glossary. The confrontation takes place in the ring between two rivals, in a standing position (distance, half-distance, clinch), employing a broad spectrum of specialized offensive (single or series of attacks: straight punches, hooks, and uppercuts) and defensive techniques (evasive manoeuvres, dodges, blocks, and covers) to gain an advantage over the opponent [2]. The sport is practiced both amateurishly and professionally, and the classification of matchups and fight time depends on the variant of boxing, weight category, age, and gender [3]. A bout can be decided prematurely (e.g., knockout, technical knockout), on points, or through disqualification or injury [4]. A good athlete should possess a comprehensive range of motor skills, a rich spectrum of technical-tactical skills, combined with excellent physical condition to meet the demands of training and competitive rivalry [5, 6].

Physical fitness in combat sports can be assessed through population tests and specialized laboratory measurements [7]. However, the results of these inquiries do not always reflect the outcome achieved in sports competition [8]. Alongside general fitness measurements, discipline-specific special fitness tests are also successfully used [9-12]. Under such conditions, the subject experiences a reaction to the specific effort that occurs in sports combat [13, 14]. This also allows for monitoring training adaptation in the area of special endurance (typical for the discipline), the level of technical-tactical advancement, and the speed and quality of its application in combat [15]. Special tests should be based on technical elements of the discipline and segments of combat [16, 11] – should inform about the level of 'special physical fitness' – see glossary).

In boxing, a specialized tool exists for identifying the level of special fitness called the Pawluk's Boxing Test [9], based on measuring the number of strikes on a boxing bag within 20 seconds. The diagnosis describes the level of speed capabilities and muscle resistance to acidification (number of techniques performed in a unit of time) [17]. The test's effectiveness has also been used in the assessment of men practicing combat sports specialized preparation [18]. In the quest for a comprehensive diagnosis and evaluation of the 'pillars of the boxing craft', as well as the implementation of special fitness tests, it is worth considering the possibility of constructing one based on combining specific to this discipline ('special physical fitness') offensive techniques (straight punches) not only with a quantitative aspect (number of delivered punches) but also a qualitative one (punches delivered with maximum force). Such an action will allow for the identification of the level of special endurance, as well as the athlete's potential for conducting intense combat or their predisposition for ending fights prematurely. Ending a boxing confrontation prematurely constitutes an unquestioned victory and is the essence of the discipline. This is mainly conditioned by the potential of the anaerobic system, strength-speed fitness, and masterful technical level [5, 6]. Therefore, a boxer's special fitness test should be developed and standardized based on these identified areas. This fact has become the author's inspiration and direction for scientific exploration aimed at optimizing the training process. The research team specialized in combat sports undertook the attempt to develop and validate a boxer's special fitness test.

The Special Boxing Fitness Test (SBFT) created by the authors was based on the following motor and exercise time assumptions: 90-second (3 rounds of 30s) fatigue test with the implementation of boxing techniques in the form of straight punches delivered with full force to the beat of a metronome, performed on a boxing bag. The aim of the study was to validate a Special Boxing Fitness Test.

PZB – Polish Boxing Association [19].

Combat sports – the group of sports disciplines, in which the gist of the competition is the direct clash of two competing athletes. They are affiliated to the national and international sports organizations in order to carry out official competition, classification, etc. [1].

Division of the combat sports under forms of the direct confrontation – workings of weapons; hits (strokes); throws and grips of immobilisation of opponent's body [1].

Technique – ***noun*** a way of performing an action [40].

Boxing technique – are smooth, effective movements used in attack and defence, taking into account the fighting conditions and the boxer's skills [9].

Tactics – ***plural noun*** the art of finding and implementing means to achieve immediate or short-term aims [40].

Special physical fitness – motor efficiency related to the technical skills of a given sports specialization, thus it is the ability of a sports adept to function effectively in a given sports discipline [11].

Performance – ***noun*** the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [40].

Load – ***noun*** **1.** a weight or mass which is supported **2.** the force that a body part or structure is subjected to when it resists externally applied forces **3.** the amount of something, usually weight, that a body part can deal with at one time [40].

MATERIAL AND METHODS

Participants

The material consisted of the test results of 18 male competitive boxers. The group included three representatives from each of the six senior weight categories (60kg, 63.5kg, 67kg, 75kg, 80kg, 92kg) according to the regulations of the Polish Boxing Association – PZB [19]. The average body weight of the subjects was 73.56 kg ±11.29, while the average body height was 174.51 cm ±8.5. An A213 anthropometer was used to measure body height and a certified TANITA TBF-538 electronic scale was used to evaluate body weight in accordance with anthropometric recommendations [20]. The age of the subjects ranged from 19 to 27 years (average age: 22.72 ±2.85). Training experience ranged from 6 to 15 years of systematic training, with 4 to 6 training sessions per week, depending on the training mesocycle (average training experience: 9.89 years ±2.97). The study was conducted during the preparatory period. The athletes were not on a restrictive diet. All subjects participated in master-level competitions – international, national, and local – achieving significant sporting results. Information on chronological age, activity, and competition experience was obtained using a diagnostic survey method, carried out through direct interviews with the athletes and the coaching staff.

Research Design

The research was conducted according to the following scheme shown in Figure 1.

Research tools

For the validation of the author's special fitness boxing test (SBFT) were used (as a reference system) Pawluk's Boxing Test based on the quantitative aspect of delivered blows [9].

Pawluk's Boxing Test

According to the protocol procedure, the test involves performing the maximum number of strikes on a punching bag within 20 seconds [9, 18, 21]. The assessment included: the number of correctly delivered punches and measurement of heart rate (HR) immediately after the test (HR

Training session – *noun* a period of time during which an athlete trains, either alone, with a trainer or with their team [40].

Mesocycle – training cycle of medium length, a part of the annual cycle (macrocycle) characterized by dynamic loads and the nature of work in the period of approx. 4 weeks.

Condition – *noun* **1**. the particular state of someone or something **2**. a particular illness, injury, or disorder; ***verb*** to undertake a fitness plan to improve general health, appearance, or physical performance [40].

Endurance – *noun* the ability or power to bear prolonged exertion, pain, or hardship endurance athlete [40].

Knockout – *noun* **1.** (*in boxing*) a punch that knocks an opponent down for a count of ten and so wins a contest **2.** a sports competition in which a person or team beaten in one game or match is eliminated from the entire competition [40].

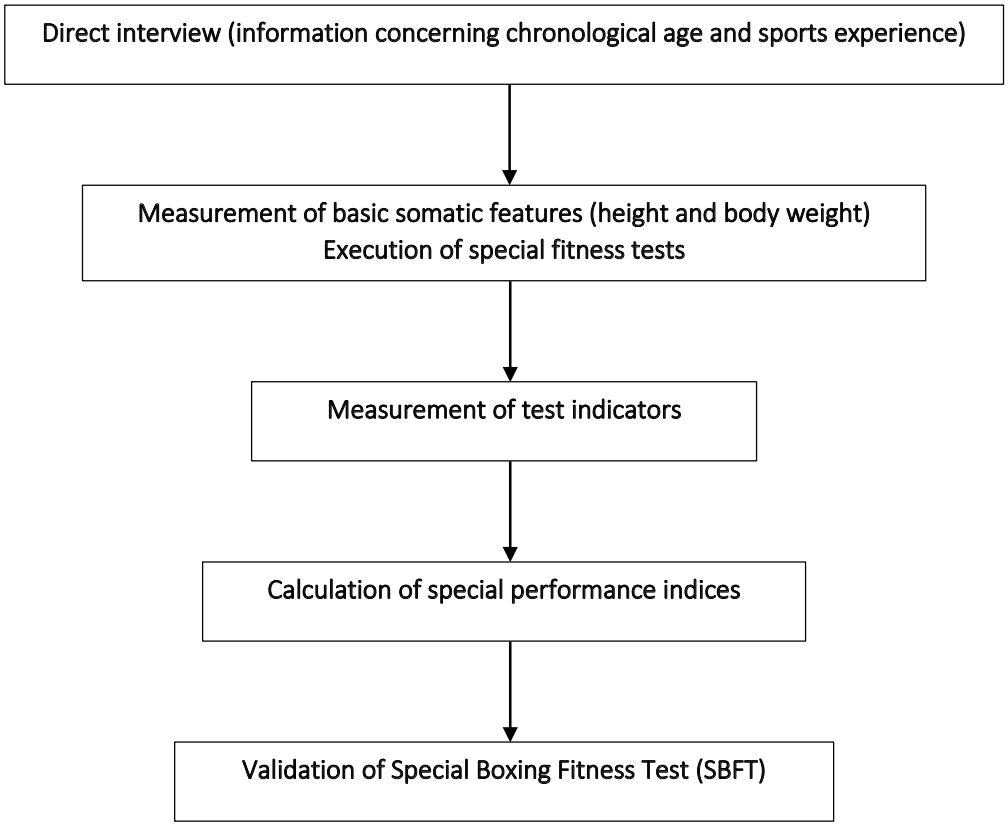

Figure 1. Research design of the Special Boxing Fitness Test (SBFT).

max) and one minute after completion (HR 1min.). Subsequently, special performance indices were calculated based on the formula: quotient of the sum of HR post-exercise and after 1 minute of rest / divided by the sum of punches delivered in 20 seconds [11].

Author's Special Boxing Fitness Test (SBFT)

Material and didactic base

The following devices and equipment are required for the test: a suspended punching bag with a mounted accelerometer, boxing gloves, metronome, stopwatch for time measurement, a protocol for recording results, and a sports tester (for heart rate measurement).

Preparing the subjects for physical exertion

Before the test, participants should perform a warm-up consisting of 5 minutes of jogging and 10 minutes of general warm-up exercises (formative) and stretching (flexibility). Then, they should execute the test techniques several times at a slow pace to become familiar with the tasks and testing equipment.

Execution of SBFT

The fatigue-type test consists of three 30-second work periods (three rounds, each 30 seconds) separated by 60-second breaks. The subject stands at fighting distance, directly and frontally before the punching bag, adopting a boxing stance of their dominant side. On the command 'BOX' the right-handed subject begins 'Round I' by executing a technical combination of a left and then a right straight punch (left-handed participants start the combination with a right straight punch). This sequence is repeated for the entire 30-second work period in each round, while punches are delivered in sync with the metronome rhythm, i.e., 2 punches per second. The procedure requires 60 punches in a given round and 180 punches in the entire test (sum of punches from 3 rounds). The command 'STOP' indicates the end of 'Round I' and a 60-second break. The break is passive in nature. After the break, the subsequent 'Round II' begins from the same starting position, followed by the last 'Round III' in the same sequence. The total time of specialized effective work in the performed test is 90 seconds (3x30 s), while the passive time is 120 seconds (2x60s breaks). Each punch should be executed with maximum force by the subject. The aim is intensive exertion.

Description of the boxing combination technique used in SBFT

The starting position is the boxing stance, followed by a rotation of the hips to the right while lifting the left heel off the ground. In relation to the upper body, the left shoulder is extended, along with a straightening of the left arm, with the elbow leading downwards. Next, there is

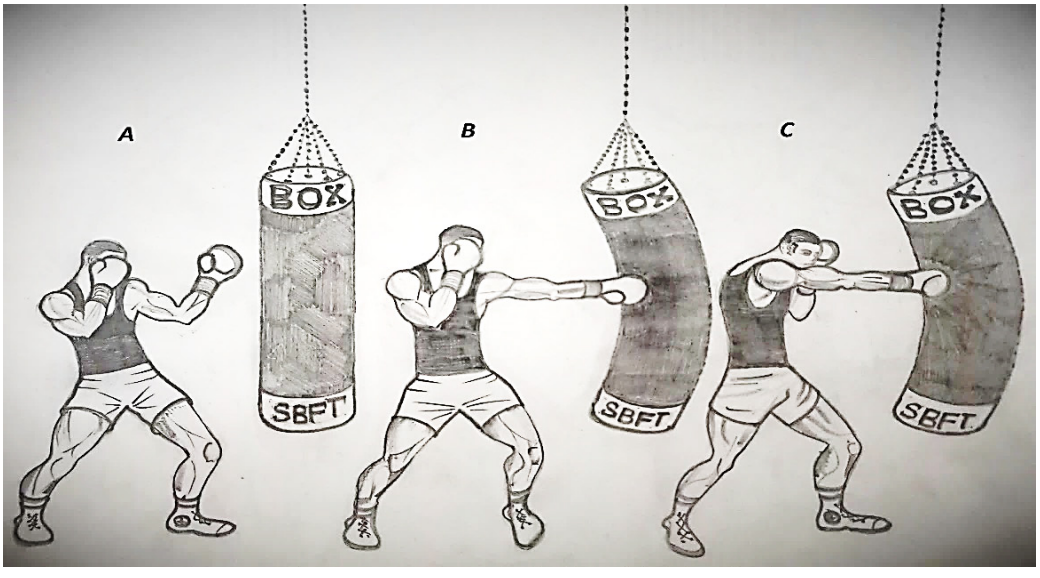

Figure 2. Graphic diagram of boxing combinations in SBFT.
A starting position (boxing stance); **B** left straight punch; **C** right straight punch
Source: Own elaboration

a return to the starting position (retraction of the left hand, fist near the chin, elbow close to the torso), from which there is a rotation of the hips to the left, lifting the right heel off the ground, extending the right shoulder, straightening the right arm, and leading with the elbow downwards, then returning to the starting position [3] – visualization Figure 2.

Measurement of SBFT indicators

An accelerometer mounted on the punching bag recorded the cumulative force of punches based on the acceleration measured in each punch. This cumulative force is the sum of the force of individual punches on the punching bag. Subsequently, the cumulative force was standardized relative to the body mass of the subjects. The final load result was expressed in Nkg-1. Next, the heart rate (HR) frequency was measured in beats per minute (bpm) directly after the completion of the test (HR max) and one minute after the work was completed (HR 1min).

Drawing on the Sterkowicz formula developed for judo [11], the SBFT Special Endurance Index (Index SBFT) was calculated using the following equation. This was based on the ratio of the sum of HR measurements after exertion and after 1 minute of rest, divided by the total relative load (in Nkg^{-1}).

$$\text{Index SBFT} = \frac{HR\max\ (bpm) + HR1\min\ (bpm)}{total\ relative\ load\ Nkg^{-1}}$$

where: **HR max** final heart rate, recorded immediately after the completion of the test; **HR 1min** heart rate recorded 1 minute after the completion of the test; **total relative load Nkg^{-1}** cumulative relative load.

The Index SBFT reflects the level of a boxer's special endurance, which signifies the effective collaboration of the body's exertional capabilities, overall fitness, and technical skills. The interpretation of the test result is inversely proportional – the higher the level of special endurance, the lower the value of the Index SBFT.

Test procedures (experimental approach to the problem)

The research process was conducted in January 2023, at the Central Scientific Research Laboratory – Biokinetics Workshop, at the Bronislaw Czech University of Physical Education in Krakow (Poland). Before the measurement activities, participants were thoroughly acquainted with the instructions for performing all stages of the research process.

The verification of the original test was carried out as follows:

1. In the first measurement unit, subjects performed the Pawluk's Boxing Test [9] in a randomized order. After completing the measurement trials, each subject's number of correctly executed punches was recorded, along with the measurement of heart rate frequency (HR).

2. Two days later, in the second measurement unit, subjects also performed the SBFT (SBFT I) test according to the procedure of the original research tool, again in a randomized order. After completing the test, the force of the punches was recorded, along with the standardization and measurement of heart rate frequency indicators.

3. Seven days later, the subjects repeated the SBFT test in accordance with the original procedure (SBFT II).

After completing the multi-stage measurement process, the Special Endurance Index based on Sterkowicz formula [11] was calculated for both tests based on the results obtained. The conducted measurement process aimed to examine the validity and verify whether: the proposed SBFT test using standard boxing punches and with a focus on strength capabilities positively correlates with the verified Pawluk's Boxing Test in both SBFT measurement terms. The aim of establishing its reliability was to check how the variability of the metrics used to calculate the SBFT value compares between the first and second measurements.

Statistical analysis

In the study's results, basic statistical methods were applied, determining the arithmetic mean, standard deviation, minimum value, maximum value, lower and upper quartile, and the coefficient of variation. The normality of the distribution was checked and confirmed for the variables using the Shapiro-Wilk test. To assess the relationship between the variables under study, Pearson's linear correlation was employed. Authors calculated

the correlation coefficients of the studied population between the verified Pawluk's Boxing Test and the proposed SBFT (conducted at two separate times), with respect to the Special Endurance Index indicators.

The degree of differentiation between SBFT I and SBFT II was evaluated using the paired t-test. Additionally, the effect size was calculated using Cohen's d. The analysis of the collected data was carried out in the Statistica software version 13.3 (Statsoft, Krakow, Poland) [22].

RESULTS

Statistically significant correlations of very high and high strength were observed between the sets of test trials SBFT (I and II) vs Pawluk's Boxing Test. Very high positive, statistically significant correlations (r = 0.83) was noted between the SBFT I test performed at the beginning of the measurement period and the SBFT II test carried out at the end of the research period (Table 1).

For both SBFT test periods, similar Index SBFT values were shown, without any significant differences, and with a profile of weak effect. The results obtained in the first test period generated slightly more favourable Index SBFT values (Table 2, Figure 3).

The results indicate that the internal variation of the analysed indices (CV%) was very low in both measurement periods (Figure 4). A slightly lower variation of the results was observed for the first measurement period (Index SBFT I = 4.69%) relative to SBFT II = 5.12%.

DISCUSSION

SBFT Validity

Care was taken to ensure that the test would not require complex equipment and could be conducted in a training room setting. For athletic tests to be effectively employed, they must be both valid and reliable [23]. In verifying the accuracy of the SBFT, its results were analysed and compared with the verified Pawluk's Boxing Test [9]. By analysing the results of the multidimensional Special Endurance Index obtained in both tests, statistically significant relationships of high strength were detected. Very high correlation with the verified test was confirmed both in the first and second term of the SBFT study (Table 1). This suggests similar requirements of both tests in terms of general specialized performance. Furthermore, these results confirm the thesis about the validity of this research tool [24, 25]. According to sports theory, validity reflects whether the test measures the desired attribute (e.g., motor ability, maximum aerobic and anaerobic capacity) for the specific discipline [23].

Table 1. Pearson's correlation coefficients (r) for indicators of Special Endurance Index between SBFT trials (the first and second measurements) and the Pawluk's Boxing Test.

Pairs of indexes	r	p
SBFT I vs Pawluk's Boxing Test	0.89	<0.001
SBFT II vs Pawluk's Boxing Test	0.67	0.002
SBFT I vs SBFT II	0.83	<0.001

Table 2. Statistical characteristics of the Special Endurance Index from two measurement periods of SBFT.

Period	Index	SD	Min	Max	Q1	Q3	p_1	p_2	d
SBFT I	178.66	8.38	155.10	191.07	175.37	183.58	0.11	0.86	0.03
SBFT II	178.89	9.17	154.10	190.14	174.09	187.61	0.08		

Note: $\tilde{\mathbf{X}}$ arithmetic mean, **SD** standard deviation, **Min** minimum value, **Max** maximum value, **Q1** lower quartile, **Q3** upper quartile, **V** coefficient of variation, **Shapiro-Wilk** p_1 level of significance for normality of distribution, **t-Student** p_2 level of significance for differentiation, **d Cohen** effect size for differentiation

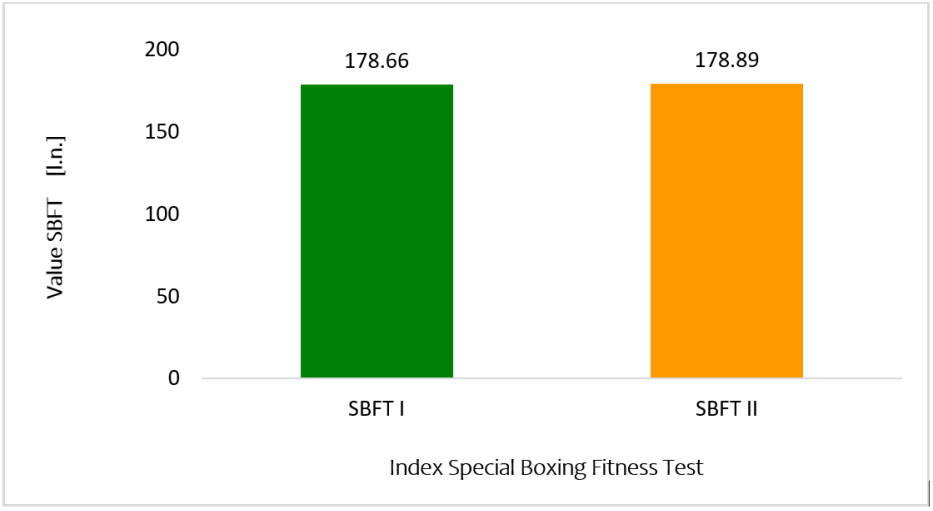

Figure 3. Comparative overview Indexes SBFT.
Note: **l.n.** denominator

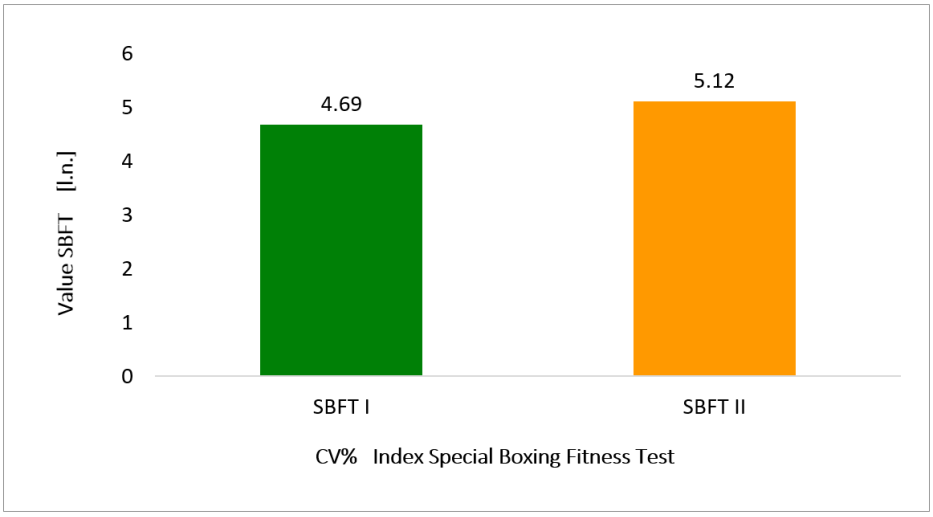

Figure 4. Comparative overview of variability indicators in Indexes SBFT.
Note: **l.n.** denominator

Regarding the time structure (number of series, time of work in series), the tests are differentiated. However, a similar trend could be seen in the area of decreased performance (number of repetitions – Pawluk's Boxing Test, force of successive strikes – SBFT) in subsequent work series. Our test enabled the assessment of anaerobic capacity, which is also indicated by the increased heart rate measured at the end of the test at all measurement times. In this respect, an analogy was noted compared to other published and successfully functioning special performance tests for combat sports [11, 12, 14, 26, 27].

Indicators of vascular-heart stress (HR) indicate that the SBFT was a test of very high effort intensity comparable to sports fighting, as the heart rate immediately after exercise ranged from 162 to 187 beats per minute. The obtained results are similar to literature data indicating that intense effort based on hand-to-hand combat techniques in trained athletes causes an increase in the minute frequency of heart contractions ranging from 165 to 185 beats per minute [28].

Regarding the quality of the punches (full-force strikes), the SBFT is closely related to muscular

performance and its power-speed and strength-endurance potential, which determines the degree of engagement of FG (fast glycolytic) and FOG (fast oxidative-glycolytic) muscle fibres [23]. Moreover, the HR values from SBFT are similar to those obtained by a group of senior amateur boxing athletes after completed tournament fights ($\bar{x}$ = 178 beats/min) [29].

In light of current findings on the discipline of boxing, it turns out that the structure of fights in competitions consists of high, moderate, and low-intensity movements, often varying during sports matches [5, 30, 31]. Therefore, boxing confrontation requires high physical abilities, comprehensive technical-tactical, and motor preparation [32-34]. Anaerobic energy efficiency, power, and muscle strength determine the effectiveness of decisive moments such as knockout, technical knockout, or corner surrender [35, 36].

There is a high demand for energy that cannot be satisfied solely by oxidative metabolism [37]. In conclusion, the specifically applied combination of stimuli in the original SBFT allowed for measuring factors determining achieving the highest form of advantage over an opponent in a boxing clash. The multi-aspect Special Endurance Index allows a cross-sectional inference about the quality of anaerobic work, strength performance along with an indicator of the proportion of activated muscle fibres, as well as aerobic possibilities and post-exertion recovery capabilities (HR analysis after 1 minute) [11, 38].

In coaching practice, this information can be helpful in selection, control, and planning of individualized training goals. From a tactical-technical perspective, athletes with high anaerobic potential will impose an explosive-offensive fighting style, aiming to end the confrontation early. In contrast, an athlete relying on high endurance will be forced to use different solutions for optimizing the chance of final success (e.g., winning on points). The proposed tool also allows for assessing the technical level of athletes, especially in the range of staple straight punches used in professional boxing, which are one of the pillars of the offensive capabilities of this discipline [4, 6]. The technical skills used in it also ensure the test's selectivity, making it unavailable for those who do not have the appropriate level of technical advancement.

Reliability of SBFT

The test is reliable if its results are similar and thus repeatable after multiple testing of the athlete within a short period [23]. To assess the reliability of SBFT, its results were analysed in terms of the degree of differentiation in two measurement periods, separated by a 7-day break (Table 2, Figure 3). It was shown that there are no significant differences between the recorded effects of special indexes. Very high, significant correlations between measurements were also noted. These results confirm the reliability of the test in terms of its repeatability [39]. The applied test-retest reliability procedure also showed very low internal variability for both measurements, which also attests to the reliability of this research tool (Figure 4).

Adoption of SBFT into Other Combat Sports

It is recommended to use SBFT in other striking combat sports such as kickboxing, muay thai, or ju-jitsu fighting formula with a cross-sectional fighting plane (standing, ground) due to the presence of boxing techniques in these professions. In particular, regular diagnostics are recommended for athletes who, due to their individual fighting model and technical-tactical profile, focus on increased activity in the stand-up striking plane of confrontation ju-jitsu. Due to the movement patterns occurring in a particular discipline, modification of the starting position in SBFT (boxing stance) is necessary. It is recommended to use a starting position consistent with the original discipline. These recommendations were largely formulated through deduction and are based on athlete-coach experience; therefore, they require confirmation based on scientific premises, thereby opening up new horizons for research exploration.

Limitations

Our studies were burdened with certain limitations, including the small number of studied boxing athletes. In future actions, it is recommended to expand the study population. To capture the multi-dimensional clinical context, it is also recommended to extend the diagnostics to measure the concentration of lactic acid in the blood of the subjects before and after the application of the test stimulus, to determine the level and make a comparative set with the sports fight.

CONCLUSIONS

The specificity of movements typical for boxing justifies the introduction of tests based on offensive techniques for special fitness testing. The use of an appropriate combination of stimuli in the form of selective striking techniques and the aspect of their quality, that is, delivering them with full force, increases the diagnostic value of the SBFT test. Classification and course of physiological mechanisms of the body during the execution of the original Special Boxing Fitness Test reflect key moments of gaining an advantage over the opponent (ending the fight early) and are consistent with the nature of the fight in this discipline. The proposed SBFT test is a selective, standardized, accurate, and reliable diagnostic tool that favours cross-sectional assessment of fitness and special endurance of boxing athletes in various weight categories.

Practical Implication

The SBFT proposed in this study can be a tool for the selection and interpretation of boxing athletes' results, as it offers a reliable, accurate, and user-friendly research tool. The recommended test can be safely used in gym conditions for a comprehensive assessment of the level of preparation in terms of fitness and special endurance among boxing athletes. Due to the similar technical-tactical specificity of the stand-up plane of combat, it is recommended to use SBFT in other combat sports disciplines (kickboxing, muay thai, ju-jitsu fighting formula).

REFERENCES

1. Kalina RM. Teoria sportów walki. Warszawa: Centralny Ośrodek Sportu; 2000 [in Polish]
2. Ambroży T, Snopkowski P, Mucha D et al. Obserwacja i analiza walki sportowej w boksie. Secur Econ Law 2015; 9(4): 58-71 [in Polish]
3. Karpiński D. Elementarz boksu. Głogów: Wydawnictwo My Wojownicy; 2020 [in Polish]
4. Durjasz M. Technika boksu. Warszawa: Mariusz Durjasz; 2012 [in Polish]
5. Chaabène H, Tabben M, Mkaouer B et al. Amateur boxing: physical and physiological attributes. Sports Med 2015; 45(3): 337-352
6. Ambroży T, Zalas M, Mucha D et al. Analiza skuteczności ciosów zawodników boksu zawodowego w wadze ciężkiej. Secur Econ Law 2016; 12(3): 18-32 [in Polish]
7. Löllgen H, Leyk D. Exercise Testing in Sports Medicine. Dtsch Arztebl Int 2018; 115(24): 409-416
8. Borkowski L, Faff J, Starczewska-Czapowska J. Evaluation of the aerobic and anaerobic fitness in judoists from the Polish National Team. Biol Sport 2001; 18(2): 107-117
9. Fidziński J. Materiały informacyjno-szkoleniowe: boks. Wrocław: Wydawnictwo Akademii Wychowania Fizycznego, Polski Związek Bokserski; 1982 [in Polish]
10. Story G. Fitness testing for karate. Sports Coach 1989; 35-38
11. Sterkowicz S. Test specjalnej sprawności ruchowej w judo. Antropomotoryka 1995; 12-13: 29-44 [in Polish]
12. Ambroży T, Omorczyk J, Stanula A et al. A Proposal for Special Kickboxing Fitness Test. Secur Dimens 2016; 20: 96-110
13. Sterkowicz S. Czynności zawodowe trenera. In: Sterkowicz S, Ambroży T, editors. Ju-jitsu sportowe: proces szkolenia: (podręcznik trenera). Kraków: European Association for Security; 2003 [in Polish]
14. Ambroży T, Kędra A, Wrześniewski K et al. Propozycja wykorzystania autorskiego testu specjalnej sprawności fizycznej w różnych sportach walki. Secur Econ Law 2017; 16(3): 139-154 [in Polish]
15. Błach W, Ambroży T, Obmiński Z et al. Proposal for the revision of the special fitness test in Judo. J Kinesiol Exerc Sci 2021; 93(31): 43-49
16. Januszewki J, Żarek J. Teoria Sportu: (tezy wykładów i ćwiczeń). Kraków: Akademia Wychowania Fizycznego; 1995: 28-29 [in Polish]
17. Szopa J. Struktura zdolności motorycznych – identyfikacja i pomiar. Antropomotoryka 1998; 17-18: 79-86 [in Polish]
18. Adamczyk JG, Leszczyński W, Boguszewski D. Poziom sprawności specjalnej mężczyzn uprawiających sporty walki. Rocz Nauk Wyż Szk Wych Fiz Tur Białymst 2013; 12-15 [in Polish]
19. Polski Związek Bokserski. Regulamin sportowy [accessed 2023 Jan 12]. Available from: URL:http://pzb.com.pl/attachments/article/1376/Regulamin%20Sportowy%2001.12.2022.pdf [in Polish]
20. Marfell-Jones MJ, Stewart AD, de Ridder JH. International standards for anthropometric assessment. Wellington: International Society for the Advancement of Kinanthropometry; 2012
21. Szot T, Bonisławska I, Ellwart M. Przegląd testów sprawności fizycznej w wybranych sportach i sztukach walki. Rocz Nauk AWF Gdańs 2017; 27: 10-20 [in Polish]
22. Arska-Kotlińska M, Bartz J, Wieliński D. Wybrane zagadnienia statystyki dla studiujących wychowanie fizyczne. Poznań: Akademia Wychowania Fizycznego imienia Eugeniusza Piaseckiego; 2002 [in Polish]
23. Sharkey BJ, Gaskill S. Fizjologia sportu dla trenerów. Warszawa: Centralny Ośrodek Sportu; 2013 [in Polish]
24. Peeler J, Leiter J, MacDonald P. Accuracy and Reliability of Anterior Cruciate Ligament Clinical Examination in a Multidisciplinary Sports Medicine Setting. Clin J Sport Med 2010; 20(2): 80-85
25. Spieszny M, Starowicz M, Klocek T. Propozycja testów zdolności szybkościowo-siłowych dla potrzeb kontroli treningu w piłce ręcznej i w koszykówce. Acta Sci Acad Ostrov Sec B 2012; 1: 112-121 [in Polish]
26. Villar R, Gillis J, Santana G et al. Association Between Anaerobic Metabolic Demands During Simulated Brazilian Jiu-Jitsu Combat and Specific Jiu-Jitsu Anaerobic Performance Test. J Strength Cond Res 2018; 32(2): 432-440
27. Marković M, Kukić F, Dopsaj M et al. Validity of a Novel Specific Wrestling Fitness Test. J Strength Cond Res 2021; 35: S51-S57
28. Matsushigue KA, Hartmann K, Franchini E. Taekwondo: Physiological Responses and Match Analysis. J Strength Cond Res 2009; 23(4): 1112-1117
29. Ghosh AK, Goswami A, Ahuja A. Heart rate & blood lactate response in amateur competitive boxing. Indian J Med Res 1995; 102: 179-183
30. Arseneau E, Mekary S, Léger LA. VO_2 Requirements of Boxing Exercises. J Strength Cond Res 2011; 25(2): 348-359

31. Safronov DV, Kozin VY, Kozina ZL et al. Determining the style of conducting a fight of qualified boxers based on neurodynamic indicators using multivariate analysis methods. Health Sport Rehabil 2019; 5(2): 78-87
32. Smith MS. Physiological profile of senior and junior England international amateur boxers. J Sports Sci Med 2006; 5(CSSI): 74-89
33. Blaževic S, Širić V, Matas A. Factor structure of boxer's motor abilities. Acta Kinesiol 2008; 2: 30-36
34. Kalač R, Gontarev S. Relations of basic and specific motor abilities in boxers. Res Kinesiol 2014; 42(2): 122-127
35. Warnick JE, Warnick K. Specification of Variables Predictive of Victories in the Sport of Boxing. Percept Mot Skills 2007; 105(1): 153-158
36. Ambroży T, Maciejczyk M, Klimek AT et al. The Effects of Intermittent Hypoxic Training on Anaerobic and Aerobic Power in Boxers. Int J Env Res Pub He 2020; 17(24): 9361
37. Krakauer JW, Hadjiosif AM, Xu J et al. Motor learning. Compr Physiol 2019; 9(2): 613-663
38. Zatoń M, Jastrzębska A, editors. Testy fizjologiczne w ocenie wydolności fizycznej. Warszawa: Wydawnictwo Naukowe PWN; 2010 [in Polish]
39. Niedomagała W. The result of "testing fights in a vertical posture" as a selection criterion for professional training of judo sport – prognostic value TFVP. Arch Budo Sci Martial Art Extreme Sport 2016; 12: 181-190
40. Dictionary of Sport and Exercise Science. Over 5,000 Terms Clearly Defined. London: A & B Black; 2006

Cite this article as: Chwała W, Wąsacz W, Rydzik et al. Special Boxing Fitness Test: validation procedure. Arch Budo Sci Martial Art Extreme Sport 2023; 19: 41-50