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The impact of fatigue on agility and responsiveness in boxing

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Summary

Study aim: To assess the effects of fatigue on agility and responsiveness in boxing.
Material and methods: A group of 20 amateur boxers aged 14–45 years participated in the study. Ditrich's test and a computer test, both measuring the speed of reaction to a visual stimulus, as well as agility run and 4 × 10 m shuttle run with carrying blocks, both measuring agility, were performed. Running agility and reaction speed were measured at 3 levels of fatigue expressed by the heart rates. The capacity to maintain the highest possible level of measured variables was assessed by applying the performance index (PI) (mean value of three or four (in the case of Ditrich's test) repetitions to the maximum one). Student's t-test for dependent data and Pearson's correlation coefficients were used in data analysis, the level $p \leq 0.05$ being considered significant.
Results: Both running agility and responsiveness markedly decreased with mounting fatigue, e.g. running speed from 1.73 ± 0.12 m/s to 1.55 ± 0.11 m/s.
Conclusion: Developing anaerobic endurance would markedly improve agility skills and speed of reaction to external stimuli. Measuring the performance index (PI) from short, maximal, repeated exertions spaced with constant intermissions may be a valuable tool in directing training activities towards development of selected elements of boxers' physical fitness.

Keywords: Boxing – Fatigue – Reaction speed – Agility

Introduction

Boxing is a highly complex motor activity. It may be practiced by professional fighters, competitive athletes or by amateurs – in that case without fights or full-contact sparring. Due to the specific nature of boxing, long-lasting daily training, consisting of repeated actions of diverse complexity, together with continuous development of physical and psychoemotional fitness, is indispensable to achieve success.

Blows, body position, leg work, defense, feints, distance keeping and complex actions are the principal technical elements in boxing [11]. Good technical performance calls for developing and improving strength, endurance, speed and coordination, the coordinative motor skills being fundamental for the technical skills in most sports [6, 7, 13, 14]. Among the key technical skills are reaction speed and agility, which enable precise and fast feints, slipping, blow parrying, fast modification of body movements and its directions. In assessing agility, usually running tests are used that employ changing direction, skipping obstacles or translocating objects [9, 15].

A boxing match consists of several rounds lasting 3 min each with 1-min intermissions, the exertions being maximal but non-continuous and including the abovementioned elements [3]. The mounting fatigue brings about decreased fight speed and dynamics, the heart rate associated with training or a boxing encounter in the range 160–200 bpm [4, 5], which classifies boxing as an anaerobic sport. Thus, boxers are expected to tolerate high-intensity exertions, i.e. to perform efficiently at high heart rates, a high anaerobic threshold, anaerobic power output and muscle strength being indispensable [8]. These factors, in turn, would thus determine the so-called anaerobic endurance, i.e. the capacity to maintain the highest possible level of the measured variable (e.g. running speed) in repeated maximum exercises [20].

The aim of this study was thus to assess the selected coordinative skills (agility and reaction speed) in boxers under conditions of mounting fatigue.

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Material and methods

Subjects: A group of 20 amateur boxers aged 14–45 years, members of the X-Fight Piaseczno club, were studied. Their basic characteristics are shown in Table 1. All subjects trained every other day, 3 days a week under the supervision of boxing and kickboxing coaches. The training was meant to develop speed endurance, strength and boxing technique. The participants were informed about the aim and course of the study. The participants were to provide consent for their inclusion. The study was conducted in accordance with the guidelines provided for in the Declaration of Helsinki and accepted by the appropriate Ethics Committee.

The subjects varied considerably in their characteristics (Table 1).

Table 1. Basic characteristics (means ± SD and ranges) of amateur boxers (n = 20)

Variable	Mean ± SD	Range
Age [years]	23.9 ± 8.8	14–45
Body height [cm]	178.3 ± 8.5	159–194
Body mass [kg]	72.7 ± 13.9	47–103
Training experience [years]	2.0 ± 1.8	0.5–8

Methodology: Four tests were administered: the ruler-drop test (Ditrich's test) and a computer test (http://webfactory.hanzo.eu), both measuring the speed of reaction to a visual stimulus, as well as agility run and shuttle run 4×10 m with carrying blocks, both measuring agility.

The ruler-drop test (Ditrich's test) [1, 10] was performed 4 times without pauses; all results and their mean value were noted.

The reaction speed test was performed as follows: 4 circular fields, linearly arranged on the computer screen, were randomly lighted; the subject was to lay a finger on the laptop touchpad immediately. The reaction time was measured with 0.001 s accuracy. The test was performed 4 times without pauses; all results and their mean value were noted.

The agility run consisted of running continuously three times the course set by marking flags (Fig. 1) so as not to touch the flags. Time was measured using a stopwatch with an accuracy of 0.1 s. The shortest running distance was estimated at 53 m.

Shuttle run 4 × 10 m with carrying blocks was performed as follows: upon the signal, the subject was to run a 10-m distance, take one of the two wooden blocks (5 × 5 × 5 cm), run back and put (not drop!) the block on the ground, then run back to take the other block, run back again and put the block on the ground. Time was measured using a stopwatch with an accuracy of 0.1 s. The test was repeated, and the better result was recorded.

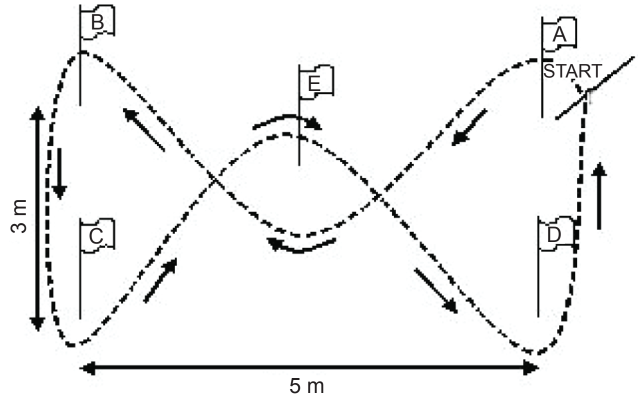

Fig. 1. Running course of the agility run test

All time measurements were converted to velocities. The results of Ditrich's test were converted to inverse measures ([50 – test results in cm]/50). In that way, all data were positively oriented (the higher the result the better).

The measurements were conducted three times at weekly intervals in a sport hall, on training-free days, in the afternoons. The conditions and procedures were in all cases identical. The measurements were preceded by a 20-min standard warm-up (jogtrot, arm swings, 5–10 m-sprints); then, a pulsometer (Polar RS400, Poland) was mounted and the subject hit the punchbag until reaching the required heart rate: 160, 180 or 200 bpm, on the first, second and third occasions, respectively. Immediately thereafter, the tests were performed in the same order: Ditrich's test, agility run, reaction speed test and shuttle run.

The capacity to maintain the highest possible level of measured variables was assessed by applying the performance index (PI) [16, 18, 19, 20], i.e. the ratio of the mean value of three or four (in the case of Ditrich's test) repetitions to the maximum one. Analysis of variance for repeated measures with the Bonferroni post-hoc test was used for comparison of means, the level $p \leq 0.05$ being considered significant. Effect size was estimated by partial eta squared (η^2). Normality of distributions was assessed by the Shapiro-Wilk test (criterion $p > 0.05$).

Results

The results of the tests performed for different fatigue levels (expressed by heart rate) are shown in Table 2. Distributions of all variables were considered normal.

Mean values of all studied variables significantly decreased with mounting heart rate as shown by the t-test and correlation coefficients (Table 2). On the other hand, in no case was a significant correlation with age or with training experience noted.

The results presented in Table 3 show a high resistance to fatigue in all tests except the reaction speed test,

Table 2. Mean values (±SD and ranges) recorded in amateur boxers (n = 20) subjected to 4 tests

Variable \ Heart rate	160 bpm	180 bpm	200 bpm	$F_{2,38}$	p	Partial η^2
Ditrich's test [-]	0.86 ± 0.06 (0.76–0.95)	0.80 ± 0.07 (0.67–0.92)	0.75 ± 0.04 (0.63–0.83)	85.26	<0.001	0.818
Agility run [m/s]	2.21 ± 0.15 (1.91–2.50)	2.16 ± 0.17 (1.78–2.38)	1.98 ± 0.15 (1.70–2.27)	103.35	<0.001	0.845
Reaction speed test [1/s]	2.36 ± 0.23 (2.03–3.04)	2.35 ± 0.24° (2.03–2.92)	2.16 ± 0.28 (1.81–2.83)	6.79	0.003	0.263
Shuttle run 4 × 10 m [m/s]	3.88 ± 0.44 (3.17–4.65)	3.57 ± 0.35 (3.03–4.40)	3.34 ± 0.38 (2.84–4.08)	36.38	<0.001	0.657

° Not significantly different from the value at 160 bpm; in all other cases, mean values differ significantly from one another (p < 0.01).

Table 3. Mean values (±SD and ranges) of the performance index (PI) computed for all 4 tests applied to amateur boxers (n = 20)

Variable \ Heart rate	160 bpm	180 bpm	200 bpm
Ditrich's test [-]	0.962 ± 0.017 (0.918–0.994)	0.950 ± 0.021 (0.910–0.985)	0.933 ± 0.012 (0.917–0.956)
Agility run [m/s]*		0.954 ± 0.014 (0.930–0.977)	
Reaction speed test [1/s]	0.904 ± 0.046 (0.822–0.967)	0.836 ± 0.107 (0.501–0.951)	0.853 ± 0.081 (0.620–0.966)
Shuttle run 4×10 m with carrying blocks [m/s]*		0.930 ± 0.044 (0.812–0.994)	

* Computed for all heart rate levels combined.

in which as low PI values as 0.501 or 0.620 were noted in one subject.

Axes of the ellipse in Fig. 2 corresponds to ±1 SD ranges of both variables, the axes cross at mean values of both variables. Thus, the upper right area above the ellipse reflects the best fit – high maximum values and high resistance to fatigue – while the lower left area reflects the opposite. Within the ellipse the average values are located.

Discussion

As expected, increased heart rates clearly affected the results of tests assessing the movement agility and the speed of response to external stimuli, as also reported for other sports [6, 7, 13]. In order to reduce the effects of fatigue on task performance, good preparation is indispensable. That includes the right selection of loads and their distribution (exercise economy), as well as good planning of intermissions. The speed and dynamics of a boxing encounter would, of course, decrease with mounting fatigue, so an accurate assessment of a boxer's resistance to fatigue is of prime importance. The hitting force and velocity depend on the boxer's experience and his technical skills and increase with weight category [2, 17, 22]. Hitting force is determined mainly by leg power output, body turns and hitting distance [17]. According to Obmiński and Borkowski [12], good boxing training improves the boxer's performance under fatigue conditions and the reaction time may be crucial for the fight outcome.

The anaerobic endurance of boxers studied, reflected by the performance index, may be rated as high under the study conditions, as the PI values mostly exceeded 0.9. However, those high values might also indicate insufficient induced fatigue, not actually corresponding to a boxing fight. Nevertheless, the example dot diagram presented in Fig. 2 enables objective classification of boxers according to their capacities and limitations reflected by Ditrich's or agility run tests. The subjects situated in the lower left area, below the ellipse, are those who had both insufficient speed and maximum performance. Those three subjects had unsatisfactory results in the other three tests as well.

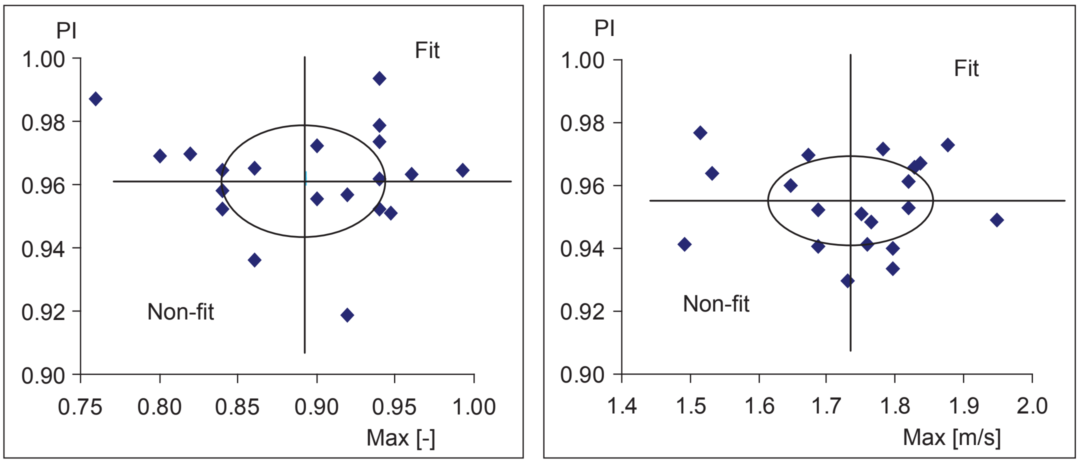

Fig. 2. Relationship between the performance index (PI) and maximum values attained in Ditrich's test (left) and in agility run (right) by amateur boxers (n = 20)

Thus, the position of a given subject on the diagram is informative as to the weaknesses of that subject that need improvement.

Boxing training ought to develop and improve endurance but strength and specific technical skills are fundamental. Furthermore, training ought to combine aerobic and anaerobic exertions in order to improve the general fitness and resistance to fatigue. That view was put forward by e.g. Sundar [21], who studied the effects of such exertions on boxers' fitness. He demonstrated that training sessions consisting of both types of exertions produced better effects compared with uniform sessions.

Conclusions

- The agility and speed of reaction to external stimuli were found to significantly decrease with mounting fatigue; thus, developing anaerobic endurance may improve the performance of boxers.
- Administering to boxers tests consisting of repeated anaerobic exertions and computing the performance index (PI) from test results may help coaches in undertaking appropriate training modes aimed at improving deficient skills, thus contributing to designing optimum training protocols.

Conflict of interest: Authors state no conflict of interest.

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