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INDIVIDUALISING BOXING TRAINING: THE IMPACT OF MODERN TECHNOLOGY

PhD thesis summary

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Contents of Phd thesis

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Introduction

Glove sports can be considered as old as mankind. Starting from the earliest evidence in 2500 BC, moving on to the Greeks, who created a form of mixed martial arts called pankratius, later to the first rules of the Marquis of Quenssbury and up to the present day, boxing has always been closely watched (AIBA, 2011; Hickey, 1980). The aim of the sport is to hit your opponent without them touching you in the areas of contact allowed by the rules (Hickey, 1980).

Boxing first appeared as an Olympic event in 688 BC at the 23rd Ancient Olympic Games, however, evidence of the practice of this discipline was as early as the third millennium BC in Mesopotamia (Collins, 2020). Other evidence was discovered, at the same time, in Ancient Egypt, with the bas-reliefs of ancient buildings depicting two naked athletes fighting a battle in honour of the king ("AIBA boxing history", 2016).

The first rules of the sport appeared in ancient Greece. They were rudimentary and provided only for the way in which the match could be ended: by abandoning the fight or the opponent's inability to continue the fight.

The Romans took over fist-fighting from the Greeks and used it both as training for their armies and as entertainment for the masses of people gathered in gladiatorial arenas. But with the rise and development of Christianity, boxing was seen as an evil to be eliminated. Thus, in the following centuries this discipline was no longer practiced in competitive form (Collins, 2020).

The first edition in which boxing was part of the Games programme was in Saint Louis, America (1904), and since then this discipline has not been absent, except for the edition in Stockholm, Sweden (1912), as boxing was banned in that country at that time ("AIBA boxing history", 2016). On 24 August 1920, at the Olympic Games in Antwerp, Belgium, the International Amateur Boxing Federation officially came into being, thus giving many athletes the chance to participate in pestigious tournaments.

Importance and topicality of the theme

An important link in sports training is the individualisation of training. This concept aims to shape training according to the physiological and psychological abilities of the individual, directing training towards the achievement of the individual's maximum potential (Bompa, 2001a, p. 33).

Bompa and Haff (2014) propose detailed analysis of several parameters to give the coach a better insight into the athlete's work capacity, such as: biological and chronological age, training age (which represents the number of years spent practicing regular exercise), training history, health status, stress and the speed at which the athlete recovers.

In the book "Let's talk about boxing", the late emeritus coach Eustațiu Mărgărit mentioned that, by using the principle of individualisation, the coach aims to adapt any exercise, means of improvement, technical element to the characteristics of the individual. Based on this principle "the most appropriate ways or means of action will always be found according to the specific characteristics of the individual" (Eustațiu & Vîrtopeanu, 2009, p. 120). However, through individualization, one should not avoid learning the technique under ideal conditions, but one should take care to string the exercises in an adapted form (Eustațiu & Vîrtopeanu, 2009, p. 122).

More recent studies have also shown the importance of individualizing physical training in modern sports training in order to maximize the performance of athletes regardless of age or performance level (Boichuk et al., 2018; Kopchikova, 2014; Latyshev, 2013; Sukhwinder, 2016). Lately, individualization of sport training has been performed and directed using electronic devices with which effort parameters, heart rate, breathing capacity, etc. can be recorded. Nowadays, technology and sport are both aimed at ensuring athlete safety, measuring performance and also contributing to performance improvement (Müller & Glad, 2012).

Devices that monitor exercise parameters are increasingly used by both competitive athletes and leisure-time exercisers. They are used to monitor health status, physical activity, assess performance and monitor other activities (Kamišalic, et al., 2018).

Elements of novelty and originality

The novel element of this thesis is the integration of devices for monitoring exercise parameters and performance indicators in sports training, thus achieving an individualisation of training plans.

The originality of the work is given by the realization, finally, of a monitoring system for boxing training composed of accelerometers and heart rate monitoring belts, all integrated into a unitary system that does not require wearing several devices at the same time. This system can be used simultaneously by several athletes, with their performances recorded in real time and stored for analysis. I should mention that, at the moment, such equipment can provide coaches with precise information about the state of training of athletes, thus avoiding possible injuries or even overtraining. The technological substrate of this equipment is the installation of a Raspberry pi3 microcomputer which is connected to a three-axis accelerometer with gyroscope, type ADXL345. The latter is inserted into the punching bag, allowing various parameters during the hitting to be recorded. To the same microcomputer we were able to connect - via bluetooth interface - a heart rate monitor, model HD H603B. The data received by the accelerometer is processed in two phases: (1) with the help of the microcomputer by means of a rudimentary algorithm that actually measures the peaks of the acceleration graph composed of the acceleration of the 3 axes (the radical of the sum of their squares) and isolates them, (2) in an on-line storage space running a "machine learning" algorithm that by training the neural network could learn to recognize the hits as it is used.

The review of selected scientific articles addressing our topic provided us with a strong theoretical foundation representing the point of origin of the studies conducted in this paper. At the same time, by synthesizing them, an update of the information on some somatic, physiological and motor parameters of boxers was achieved, concentrating the results of the research in the literature in a single work.

The present work is composed of an introduction with a brief history of the discipline, the importance and topicality of the subject and the elements of novelty and originality followed by the three parts.

Part I of this paper is composed of five chapters: peculiarities of the adolescent age, sports training, the model of the performance boxer, technological means in sport and conclusions regarding the literature review.

Part II presents the pilot study in which the verification of the equipment used in the research and the intervention programme was carried out.

Part III includes two studies on the individualization of training in junior boxers and the development of a boxing-specific training monitoring system.

Summary of Chapter 1. The particularities of adolescence

Understanding the process of growing up is necessary in order to appreciate any changes that occur during physical activity. The determinants of sporting performance are closely linked to somatic growth. The period of growth, which begins at birth and ends somewhere around the age of 17-18, is the length of time during which the body goes through all the biological processes of maturation (Rowland, 2005a).

Growth, development and maturation have evolved, sometimes as discrete processes, but more often as an integrated series of biological events. Anthropologists and human biologists have long been interested in how human growth, development, and aging differ from corresponding processes in other primates (Bogin, 2015).

The timing and speed of growth in puberty varies widely, even among healthy children. In order to be able to determine the characteristics corresponding to a given growth rate, it is very important to consider the biological maturity of the child (Rogol, Clark, & Roemmich, 2000).

As they advance in age women reach on average 38% body fat and 60% muscle mass, and men on average 22% body fat and 71% muscle mass (Borrund et al., 2010).

Physical growth is the most important factor in observing changes in exercise during childhood. Between the ages of 6 and 16 years boys' lungs increase from a capacity of 1937 millilitres to 5685 millilitres and the weight of hearts from 95 grams to 258 grams. These increases are manifestations of the development of the maximum ventilatory rate in one minute and the volume of blood pumped by the heart.

Physical activity is necessary for all young people to improve aerobic endurance, muscle strength, bone mineral density and well-being. Almeida-Neto et al. (2020) observed that male athletes at pubertal age have higher testosterone levels that are associated with greater muscle strength compared to female athletes.

Summary of Chapter 2. Sports training

Sports training is a bilateral educational instructional process, carried out systematically and continuously, graduated, to adapt the body to intense physical and mental efforts, in order to achieve high results in one of the forms of competitive exercise (Alexe, 1974).

The main purpose of training is to maximize the performance capacity of athletes and at the same time to create strong psychological traits. It is necessary for training to be directed according to well-established scientific criteria, and for the instructional-educational objectives to be achieved through careful planning of short, medium and long-term training plans (Muraru, 2004).

In boxing, effort is determined by a series of factors that create a complex of specific physical and neurofunctional demands. An important characteristic of the specific effort in boxing is the complexity of the movements, determined by the great variety of situations and technical-tactical elements. This complexity is manifested both by the participation in the execution of movements of all segments and many muscle groups, and by the asymmetry of these movements.

The importance of discovering young talent, developing it and guiding it to high performance has attracted the attention of many specialist authors in order to avoid early burn-out syndrome, or to avoid injuries that can occur as a result of training that is too hard and inappropriate for the age of the athletes.

Gagné (1999) speaks of talent and giftedness, or the endowment of individuals with a range of skills, and has developed a model to differentiate between the two concepts. In this model, an individual's aptitude is one element of talent; thus, for an individual to be considered gifted, he or she must first possess a skill set above the average level of the population.

Platonov (2015) describes five stages of selection that take place during the individual's training:

1. Primary selection: determination of the possibilities to practice a particular branch of sport;
2. Preliminary selection: assessment of aptitude to perform in a sport;
3. Intermediate selection: assessing the possibility of achieving a sporting mastery;
4. Basic selection: assessment of the athlete's ability to achieve notable results;
5. Final selection: assessment of the athlete's ability to continue in the sport and perform in major competitions.

Periodisation of sports training is not a new term or a development of recent decades. The emergence of the notion of periodization of training appeared with the release of Matveev's 1964 book (Platonov, 2015). However, this issue related to adaptation of athletes to intended efforts and rational planning of training was also discussed by other specialists before Matveev, such as Ozolin in the book "Training of light category athletes" in 1949 or A. N. Krestovnikov in "Physiology of Sport" in 1939, who proposed the division of annual training into three parts: the preparatory period, the basic period and the transitional period.

The results of the research presented above cannot demonstrate that there is a single model of periodisation valid for all athletes. The effects of the implementation of these plans may be influenced by a number of factors such as the particularities of the individuals included in the research, the previous duration of training of the subjects, the sequence of training days and their number or the exercises used during training. As far as the opinion of specialists in the field is concerned, linear periodization is a model that can bring beneficial effects in the preparation of athletes, but the duration required to reach athletic form, maintain it, the period of exit from form and re-entry into it is far too long, this reducing the possibilities of achieving it to a single major competition per macrocycle (Bartolomei et al. 2016, Rhea and Alvar, 2002, Apel, Lacy and Kell, 2011).

In many sports (gymnastics, athletics, boxing, judo), individualised training planning is the only way to prepare athletes. The aim of individualised training is to increase the athlete's capabilities, to improve specific and general physical training, technical-tactical training, psychological training and, last but not least, to prepare the athlete according to his/her abilities.

It is well known that the first step to having well-prepared athletes is planning. Putting planning into practice is based on a number of principles including the principle of individualisation.

The realisation of the principle of individualisation in boxing involves processes of correcting sports training, taking into account the technical-tactical specificity and special qualities of boxers. Misinterpretation of this principle has led to its use only as a declarative notion, with existing information referring to professional boxers and less to amateurs (Saulea, 2015).

In the study by Băițel and Deliu (2014), the kinematics of the execution of a direct punch with the dominant arm was analysed and an activation of the anterior deltoid could be observed from the moment of the initiation of the movement until the moment of the contact of the fist with the target, when the posterior deltoid starts to activate. Analysing several blows delivered by the subjects, they conclude that the maximum value of the striking force is given by inter- and intra-muscular coordination and less by the mass and velocity of the fist. The difference between the strongest and the fastest punch was made by the involvement of the vastus medialis muscle (higher for the strongest punches) and a faster activation of the biceps brachii, from the beginning of the contact with the target, for the fast punch (Băițel & Deliu, 2014).

Lenetsky (2018) analysed the activity of the muscles that are involved during the execution of direct and lateral strikes for both arms using electrodes placed bilaterally on certain muscle groups (triceps brachii, latissimus dorsi, rectus abdominis, rectus femoris). In the case of the direct strike with the non-dominant arm, an activation of the entire musculature could be observed during the initiation phase of the movement. The rectus femoris muscle of the lower limb opposite the executing arm reaches the peak of activation at the beginning of the phase, and towards the end of the phase the rectus abdominis muscle is activated. In the execution phase, the activation of the rectus abdominis is high, followed by a decrease before impact.

Summary of Chapter 3. The performance boxer model

Boxing is a contact sport, and athletes in this discipline are divided into several weight categories so that matches are played with opponents with similar characteristics, both somatic and age. Thus, the training of boxers must be shaped according to the individual's capabilities and the specifics of each weight category. In the literature, there are numerous studies that determine the body, physiological or physical characteristics of boxers, but the number of publications that address the full spectrum required for a boxer to achieve peak performance is small.

Biomotor capacities are an important link in the whole chain of an athlete's development. Achieving top performance in boxing, as in any other sport, is an important issue in the selection of young athletes. The coach must have knowledge of both the specific sports sector, such as the periodisation of training, the periodisation of recovery phases, and areas such as physiology, anatomy, biomechanics, etc.

The comparative study conducted by Anilkumar (2013) shows that among wrestlers, judokas and boxers, the latter have higher levels of speed, strength and agility than the latter. In terms of flexibility, boxers are very rigid. This can also be explained by the lack of flexibility training.

Body build can be an advantage during a fight. The most common methods to determine the constitution of an individual from a morphological point of view are related to weight, amount of adipose tissue or dimensions of the bone system (Platonov, 2018).

Boxing is associated with acyclic movements and a variety of technical elements, these being said to accomplish tasks during matches actions executed with maximal and supramaximal intensity are required (Hubner-Wozniak, Kosmol, & Blachnio, 2011). This is further reinforced by the concentration of lactic acid in the muscles after a boxing match.

Arseneau (2010), was able to review numerous studies on the level of maximal oxygen consumption in boxers. In contrast to the limited data previously collected by other specialists, the results of his research showed that VO2max in boxers averaged 57.6 ml*kg-1*min-1 for treadmill tests and 54.9 ml*kg-1*min-1 for bicycle tests.

Another comparative study between senior and junior boxers conducted in England by Smith (2006) found that oxygen consumption values were significantly lower in juniors than in seniors 63.9, AS = 4.8 respectively 49.8, AS = 3.3 ml*kg-1*min-1. The author mentions that this difference may be influenced by the age of the subjects, the length of the bouts or the level of training. It is known that the value of maximal oxygen consumption decreases with advancing age and weight gain, regardless of whether athletes continue the training programme or not. From this we can deduce that the significant difference in the above mentioned results can be explained by the gap in the training level of the athletes, as all participants of the experiment had the same weight.

Strength is one of the dominant motor skills in boxing. In order to achieve maximum sports performance and to execute technical procedures during the fight efficiently, its development is necessary (Guidetti et al., 2002; Loturco et al., 2015; Rimkus, Satkunskiene, Kamandulis, & Bruzas, 2019). The ability to punch with power and finish the bout before the limit is a characteristic of boxing performance. Several categories of devices used in measuring indices during the execution of a punch are presented in the literature; these are motion sensors and video cameras, gyroscope accelerometers, pressure or odd sensors, or piezoelectrodes.

The values recorded during strokes depend on the measurement method, the athlete's skills or the type of stroke executed (Pilewska, Busko, & Pantelis, 2017). Authors in the field have determined values of dominant arm force equal to 4800 ± 227 N for elite porters, 3722 ± 133 N for intermediate athletes, and 2381 ± 116 N for novice athletes, respectively. At the same time, the values of non-dominant arm strength, vary from one class of athletes to another as follows: 2847 ± 225 N for elite athletes, 2283 ± 126 for intermediate athletes, 1604 ± 97 for novice athletes (M. S. Smith, Dyson, & Janaway, 2000).

Analysing the data collected from the studies, we can see that the number of punches varies from round to round and from one category of boxers to another. We can observe that winning athletes in a boxing match deliver a higher number of punches than losers regardless of the round they are in (Davis, Wittekind, & Beneke, 2013). At the 2012 London Olympics, the authors of a study could observe by analysing 29 matches that at this level an average of between 61 (20.5) and 70.8 punches (23.5) are delivered in a three-minute round. Winners in the games analyzed averaged 13.0 ± 7.2 shots hitting their target in the first half, 15.9 ± 7.7 in the second half, and 14.8 ± 7.2 in the last half, respectively, compared to losers 9.6 ± 6.0 in the first half, 12.3 ± 8.7 in the second half, and 11.3 ± 5.4 in the last half, respectively (Davis, Benson, Pitty, Connorton, & Waldock, 2015). Although an increasing trend in total hits can be observed in the second half (Davis et al., 2015; Rimkus et al., 2019) these results are not found in the other studies mentioned above. The inconsistency of the results may be due to different situations encountered during the match such as passive or aggressive opponents, similar levels of athletes' training, etc.

Summary of Chapter 4. Technological means in sport

Technology plays an important role in sport. Nowadays there are numerous systems that provide us with information about various parameters in sports training or competitions. These technological means can provide us with a range of information from quantitative to qualitative components (Fulton et al., 2020; Kimm & Thiel, 2015; Lintmeijer, Robbers, Hofmijster, & Beek, 2019; Pilewska et al., 2017). The development of technological means has led to the emergence of small-sized products that do not obstruct the athlete while wearing them, thus measuring athletes' movements in both laboratory and field conditions (Worsey, Espinosa, Shepherd, & Thiel, 2019). Technology at the moment is becoming increasingly accurate in terms of collecting data about the outcomes achieved by athletes (Worsey, Espinosa, Shepherd, & Thiel, 2020).

Performance in contact sports is underpinned by (or skill acquisition) achieving high levels of technical and psychological fitness. Continuous monitoring of training can reduce the risk of injury, avoid overtraining can determine the effectiveness of the training program, aspects that lead to increased sport performance.

Jovanovski and Stappenbelt (2020) were able to develop a force measurement system using two devices: one static device programmed to record the maximum force of a punch from the moment of impact, and a second device inserted into the glove that can record the acceleration of the punch from the moment of impact. According to them, systems incorporating piezoelectrodes have a limitation in terms of placement possibilities. Although they are small in size, they cannot be properly attached so as to provide information about the values recorded during the delivery of different types of blows.

Summary of Chapter 5. Conclusions on the literature review

The review of the literature that is related to the topic under discussion provides us with diverse and detailed information about the ideal boxer model. The possibility of collecting data during training with the help of technological means gives us the chance to find out real-time information about the motor demands of athletes. On the basis of this information, real-time analyses can be made and conclusions drawn about the athlete's physical capacity and motor capabilities. The information provided during training can then be correlated with the ideal model of the boxer and methodical adjustments can be made to optimise training. For example, with the help of these tools, training can be directed with greater precision so that losses of muscle mass and therefore strength are minimised when the athlete needs to reach the optimum competition weight.

The boxers motor possibilities during a competition are closely related to the level of his aerobic capacity. Aerobic capacity, as described in the literature, is determined by the level of maximal oxygen consumption (VO2max). A high value of maximal oxygen consumption can be associated with accelerated recovery and helps to maintain the metobolic requirements of the match. By improving the ventilometric parameters the athlete can inhale more air, this directly influences blood oxygenation and thus the muscles involved in the physical activity. By increasing the respiratory flow rate an efficient gas exchange can be ensured, thus helping the athlete to adapt the intensity of the effort to the demands of the competition.

Some authors have found that boxers reach maximum strength in the first round. With the onset of fatigue or other subjective causes, in the following rounds force values and energy consumption decrease (Čepulėnas, Bružas, Mockus, & Subačius, 2011; Hristovski, Davids, Araújo, & Button, 2006). High punching force is given by the synergy of whole body action starting from the lower limbs, to the torso and then to the arms.

Considering the multitude of factors that condition sport performance in boxing, we consider that all the variables described above are interdependent, therefore their importance in the training of athletes have roughly equal values. According to the theory and methods of sports training, these variables must be addressed in training according to certain factors (age, sports experience, competitive period), so as to avoid drift in the preparation of athletes.

Summary of Chapter 6. Effects of combined training on junior boxers

The development of physical qualities is correlated with the individualization of training plans, depending on the goals pursued (Kačar, Ljubisavljević, Crnjaa, & Gavrilović, 2012). Individualization should be viewed from both physiological, morphological and psychological perspectives.

The ability to achieve sport performance is conditioned by many factors, physical training being one of them. The difference in the boxing ring is made both by the qualities acquired by each individual athlete and by the determination they show during the fight. Training performed regularly and with optimal dosage can push the boxer towards reaching the maximum of his functional variables (Nasr, 2012). Glove sports are among the combat sports disciplines that require a high level of development of motor skills and psychological abilities. It is also well known that in order to achieve notable results on a world level, it is necessary that the variables of effort are appropriately dosed in order to optimize the training plan, both in terms of preparation and recovery phases (Muric & Kahrovic, 2008). In order to achieve maximum performance potential, an athlete must possess certain qualities, but an important weight is due to inherited biological possibilities (Martsiv, 2013).

The aim of the research was to investigate the effect of respiratory training on spirometry parameters, to verify the equipment to be used in the research, and to verify the proposed intervention program. This research had the following objectives:

- To measure the values of exercise parameters for each athlete;
- Identify specific indices that need to be improved;
- To verify the intervention programme;
- Verification of the equipment used in the research.

In this research the following assumptions were made: 1) the use of respiratory training in junior boxers will result in improved spirometric parameters; 2) motor skill development training will influence increases in speed, strength and power parameters.

To carry out this study, 22 male athletes from three boxing clubs in Timisoara voluntarily participated. The group was divided into two groups: experimental group (EG), N = 7, and control group (CG), N = 15. Only those athletes who had practiced boxing for at least one year and participated in national or international competitions were included in the study. The research was conducted for five months from 06.02.2017 to 09.06.2017. The initial testing was conducted from 06-09.02.2017 and the final testing from 07-09.06.2017. All subjects underwent the same testing using the same materials under similar conditions. All subjects and their parents or legal guardians gave their consent to participate in this study. The athletes' coaches and the management of the clubs to which the subjects belonged also gave their written consent.

A portable spirometer, SpiroTube Primary produced by Thor Laboratories, Hungary, was used to evaluate spirometric parameters. Assessment was performed using European Respiratory Society/American Thoracic Society criteria, with information on height, weight, age and whether the subject was a smoker or not being entered into the system. After entering personal data, each athlete performed the spirometry test three times, with the test that had the highest Forced Vital Capacity (FVC) parameter being recorded. Parameters measured in this test were forced vital capacity (FVC), expiratory volume in one second (FEV1), peak expiratory flow (PEF).

The breathing capacity assessment protocol was performed according to the procedures suggested by Miller et al., 2005; Tudorache & Oancea, 2008, subjects were asked to perform a minimum of three cycles of forced inspiration and expiration. Only those expirations whose automatic quality control was met according to the European Respiratory Society/American Thoracic Society (Chung et al., 2017) were considered. Thus, those breaths that did not meet quality control were not considered and the subject had to repeat the procedure. The prediction method used by the spirometer software was that proposed by the European Respiratory Society and Kudson (Temmeling, 1993). Respiratory capacity testing was performed using a portable spirometer, SpiroTube Primary produced by Thor Laboratories, Hungary.

For testing motor quality parameters (strength, speed, lower and upper limb power) the Myotest PRO, Power Analyzer, Switzerland was used. Two protocols were used for this test:

- Squat Jump (Sj);
- Direct kicks from supine with each arm.

The protocol used for Squat Jump was followed as adapted by Sheppard and Doyle (2008) and Păunescu, Pițigoi, Nicolae, Pricop and Păunescu (2012).

Parameters measured in this test were: power (P), maximum power (Pmax), force (F), velocity (V).

The protocol used for the Squat Jump test was followed as adapted by Păunescu et al., 2012. Before the start of the protocol the apparatus emits a first beep signal which is associated with triple flexion of the lower limb joints, the subject descending into a squat position with the knees bent at 90°, maintaining this position until the next signal when he must perform a rapid extension, followed by a release from the ground with the knees in extension. The device used shall emit a second beep only when the integrated sensor does not record any further movement in the longitudinal axis. The reliability of this apparatus was validated by Păunescu et al., (2012). Each subject performed a number of five repetitions being recorded the execution that had the highest value of maximum power.

The GE training program was modified by the introduction of training sessions for the respiratory muscles and for the development of specific motor skills. The weekly plan consisted of five training sessions of approximately 90 minutes. Each subject performed our proposed programmes three times during a weekly cycle (Appendix 3). Our proposals were incorporated into the athletes' plans so that their preparation and progress in competitions would not be affected. The workload for the development of motor skills (strength, power) was calculated according to each athlete's 1 RM value, known to them at the initial time.

In the training plans that were implemented it was also intended to increase the respiratory capacity. Thus, respiratory muscle training was introduced using the TrainAir machine, with a frequency of at least three training sessions per week. The device consists of a mouthpiece that takes the information from the moment of inhalation and feeds it through a serial port into the application installed on the computer.

Descriptive statistics show that the two groups are relatively close in terms of mean age, weight and height, with approximately the same standard deviation.

Performing the data distribution test shows that the values of the two groups are centrally oriented to the median axis.

Prior to data analysis, the Shapiro-Wilk test was performed to observe the distribution of data for spirometric parameters. Regarding this aspect, we could observe that the data are normally distributed.

Comparing the spirometric test results of the two groups, we could observe that there were no significant differences at the time of the initial test - T1

Regarding the FVC values, we can observe that the mean of the control group is higher than that of the experimental group. The mean values of FEV1 and PEF parameters, at the initial testing, were higher for the experimental group compared to the control group.

Analyzing the data collected from BP and SJ samples, we could observe that at the time of initial testing, significant differences were observed only for the parameter F_drp respectively F_stg. The GE mean for the F_drp parameter was 154 N (41.11), and the GC mean 225.60 N (83.42) ($t = -2.69$, $df = 19.83$, two-way p 0.14). The GE mean for the F_stg parameter was 145.42 N (± 35.07), and the GC mean was 221.86 N (84.92) ($t = -2.98$, $df = 19.90$, two-way p 0.007).

Using the Shapiro-Wilk test, it was found that the Pmax_stg parameter of the experimental group and the V_stg parameter of the control group did not have normal distribution, respectively. Thus, the Mann-Whitney U test was used to determine the differences between the two means. The Mann-Whitney U test for the Pmax_stg parameter shows that there are no significant differences between the two groups ($U = 38.5$ $N_{GE} = 7$, $N_{GC} = 12$, $p = 0.323$). Likewise, the results for the parameter V_stg showed us that there were no significant differences between the means of the two groups (U = 39.5 NGE = 7, NGC = 12= 12, p = 0.359).

The volume of forced vital capacity (FVC) recorded at the initial test M= 4.85 (0.54) L and that at the final test M= 5.57 (0.92) L differed significantly (t = -6.13 df = 6, two-way p = 0.001). The same phenomenon could be observed for the other two parameters: Forced expiratory volume in one second (FEV1) at initial test M = 4.16, AS = 0.54 L and final test M = 5.16 (0.90) L, t = -5.59, df = 6, two-way p 0.001, respectively peak expiratory flow rate (PEF) initial test M = 7.16 (0.84) L/min , and final test M = 8.50 (0.96) L/min , t = -6.32, df = 9, two-way p 0.001. The distribution of power, force and velocity data from the Myotest tests was also checked. The data analysis showed us that the data distribution is normal for most of the parameters, except for Pmax_stg and P_drp respectively. Thus, Wilcoxon test and paired samples t-test were used for their statistical interpretation.

By applying the paired samples t-test we could observe that the differences between the two test times were significantly improved for all the parameters of the upper train: Pmax_drp, F_drp, V_drp, P_stg, F_stg, V_stg.

Sports science researchers have examined the importance of breathing and its effects on athletic performance (McConnell, A., 2009). Respiratory muscle training produces improvements in exercise tolerance through two mechanisms: attenuation of perceived exertion by the individual (exercise is easier to perform after this type of training) and avoidance of reduced blood volume to the limbs when respiratory muscle fatigue occurs (McConnell, 2011). Respiratory training can provide a workout aid by reducing oxygen extraction by the muscles involved in the activity and altering oxygen transport to the limbs (Turner et al., 2016).

Comparing the values obtained in this study with results from other contact disciplines, we can see that wrestlers and kickboxers have higher levels of forced vital capacity (FVC = 5.17, AS = 0.7, FEV1 = 5.14, AS = 0.6 L, respectively FVC = 5.34, AS = 0.9 L, FEV1 = 5.21, AS =1 L).

By conducting this research we were able to verify the equipment used for both the measurements and the breathing training. Also, as a result of the proposed intervention the following aspects could be concluded.

In both groups we could observe an increase in the values of the parameters measured in the research. However the mean GE values were significantly improved at the time of the final testing for spirometric parameters and those within the BP sample, compared to the mean GC values. We could also observe significant differences between the two groups at final testing for eight parameters analysed (FVC, FEV1, PEF, Pmax_stg, Pmax_sj, F_sj, V_sj). Given that the differences in the means of the spirometric parameters were significantly improved gives us the premise to conclude that our hypothesis is accepted. Respiratory training significantly improved the spirometric parameters analyzed in the research.

As a result of our analysis we were able to identify a number of parameters that should be analysed in order to improve athletes' performance. It could be observed that training aimed at developing motor skills was not sufficiently well planned to influence the improvement of strength, power and speed indices. We could observe that using this training plan it was difficult to monitor the effort parameters, so we could not accurately track how they were achieved. We also observed that the athletes did not perform the personal assessment at full capacity, thus the breathing training was not performed at optimal parameters.

Therefore, we want to complement the training of athletes with specific training of respiratory muscles with the aim of improving static and dynamic spirometric parameters, but also to introduce modern means of monitoring effort parameters in training.

Summary of Chapter 7. The use of technological means in individualized training of boxers

This part of the paper includes two personal researches in order to observe the effects of individualizing training plans in boxers. At the same time, we aim to monitor effort parameters with the help of technological apparatus that can provide accurate information in real time.

In order to monitor health status, various wearable devices are regularly used in physical activities and performance evaluation (Kamišalic, Fister, Turkanovic, & Karakatic, 2018). Modular sensors can also be used which are easily connected to any device (phone, computer, etc.) in order to use the collected data (Kamišalic et al., 2018).

This study aimed to investigate the effect of respiratory training on spirometry parameters using modern technological means and visual feedback, to analyze the effects of introducing technological devices into the training program on sports training and to analyze the proposed intervention program. This research had the following objectives:

- The use of technological means in order to achieve the tasks of sports training;
- Development of motor skills specific to the sport of boxing;
- Individualization of training plans for the athletes of the expert group;
- Analysis of the effect of training on body composition with a view to weight classification.

In the present study the following hypotheses were assumed:

1. Introducing respiratory training into athletes' training plans will lead to improvement of spirometric parameters;

2. Our proposed individualized training program based on the VBT method will lead to an increase in upper and lower limb strength indices;

3. Sports training guidance with the help of technological means providing real-time feedback will lead to increased performance during boxing matches.

Thirty-two athletes who had been boxing for at least two years and who had been training for at least one year to participate in domestic and international competitions were selected for the research. These athletes were selected from six boxing sections of clubs in Timișoara, Lugoj, Sânnicolau Mare and Arad. All participating athletes belong to clubs affiliated to the Romanian Boxing Federation, are affiliated to their home clubs and had regular medical check-ups.

The sample was divided into two groups according to the choice of each subject: (a) experimental group (EG) N = 12, mean age M = 15.5 years, AS = 0.67 years; height M = 171.25 cm, AS = 7.18 cm; weight M = 71.04 kg , AS = 11.38); (b) control group (CG) composed of 20 athletes, age M = 15.4, AS = 0.68 years; height M = 172.45 cm, AS = 7.59 cm; weight M = 68.97 kg , AS = 11.22 kg.

For a better management of the training and therefore of our experiment, the athletes of the experimental group were assigned to body weight groups as follows:

- Athletes with body weight between 50 - 60 kg - semi-light category;
- athletes with body weight between 60 - 70 kg - light category;
- athletes with a body weight between 70 - 80 kg - middle category;
- athletes with body weight over 80 kg - heavy category.

This distribution facilitated the creation and organisation of individualised training plans and real monitoring of the athletes' development.

The research was structured in three stages: (1) initial testing, (2) implementation of the intervention programme and (3) final testing.

The initial testing (T1) took place from 08/01/2018 to 13/01/2018, as the athletes were at the beginning of their preparation for the new competitive season, having recently returned from a break of about two weeks. Final testing (T2) took place from 22/10/2018 - 27/10/2018 after the last major official competition of the competitive season.

The subjects were tested for somatic, spirometric parameters, maximum power, maximum number of strokes delivered in ten seconds, and analysis of a contested match:

1. Body composition using bioimpedance scales - body weight, adipose tissue, lean mass;
2. Respiratory capacity using spirometer - forced vital capacity (FVC), expiratory volume in one second (FEV1), peak expiratory flow (PEF);

3. Peak power during supine, unilateral arm extension - Peak left arm power (BP-stg), Peak right arm power (BP-drp);

4. Maximum strength during squat with jump (SJ);

5. Repetition speed during ten seconds - maximum number of strokes (L10sec) and average arm movement speed - average right arm speed (V-drp), average left arm speed (V-stg) ;

6. Match analysis - whereby the following parameters were recorded in each half (half 1 - R1, half 2 - R2, half 3 - R3): number of direct hits with the right arm (D-drp), direct hits with the left arm (D-stg), hook hits with the right arm (C-drp), hook hits with the left arm (C-stg), right-arm uppercut (U-drp), left-arm uppercut (U-stg), blocks (Block), dodges (Esc), total number of hits (L-total), number of hits that hit the target (L-target).

The training plans that were proposed by GE were implemented following analysis of the data collected from the initial testing. Thus, individualized training plans were developed for the GE and the technological means to direct and monitor the training were introduced into the training. All subjects followed the same annual training plan in terms of motor skills periodization. Differences, in terms of individualization of training plans, were implemented at the level of training lessons and microcycles (Appendix 4).

In order to monitor the volume and intensity of the specific part of the training (training conducted at the punching bag or with the coach) the athletes used devices to record the number of hits and the repetition speed during the executions. The seizers detect and record the blows by classifying them as direct blows or power blows (hooks and uppercuts), and the speed at which the blow was executed.

In terms of training to develop power motor quality and its manifestation forms, the Velocity Based training (VBT) method was used for GE. This alternative method of developing power motor quality and its manifestation forms originally proposed by Gonzalez-Badilo, J., J., and Sanchez-Medina, L., (2010) is based on monitoring the velocity of load displacement reported to the percentage of 1RM.

Regarding the values of breathing capacity, we can observe that there are no significant differences between the two groups included in this research at the time of the initial testing. For the FEV1 parameter, the Mann-Whitney U test also shows us that there are no significant differences between the two groups (U = 98.0 NGE = 12, NGC = 20, p = 0.392). These data indicate that at the beginning of the research the two groups were homogeneous in terms of the variables analysed. The Mann-Whitney U test for the SJ parameter shows that there are no significant differences between the two groups (U = 70.5 NGE = 12, NGC = 20, p = 0.053).

The total number of kicks delivered during the matches was analysed in order to observe differences between groups. Data distribution tests were carried out and it could be observed that the data were normally distributed for both groups, so the t-test for independent samples was applied. Statistically analysing the data, no significant differences were observed in the total number of shots delivered in the match between the two groups: GE, M = 128.67 (± 18.95) versus GC M = 123.15 (± 6.61) t = 0.97, 12.62, p = 0.24. Likewise, for the total number of hits that reached their target no significant differences could be observed GE: M = 32.00 (± 4.30) vs. GC 31.65 (± 5.11) t = 0.198, df = 30, p = 0.84. However the mean total number of shots delivered in the match for GE was about eight shots higher than for GC.

The number of shots that hit their target maintained the same pattern of increase from R1 to R2, respectively a decrease in the mean at R3. The means being GE: R1 = 10.25 (AS = 2.26), R2 = 10.91 (AS = 2.3), R3 = 10.83 (AS = 2.03). In the case of GC, an increase of the mean could be observed by about five hits in R2 (M = 12.00, AS = 4.19) compared to R1 (M = 7.25 AS = 2.35), and this increasing trend was maintained in R3 (M = 12.40±2.43). Comparing means within R1 it could be seen that the GE mean (M = 10.25, AS = 2.26) was significantly higher than the GC mean (M = 7.25, AS = 2.35) where U = 48.50, N GE = 12, N GC = 20, p < 0.004. Analysing the averages of the executed procedures, during the rounds, we can see that D-stg strokes are the most frequently used, followed by D-drp strokes. On the other hand the least used procedures are C-drp and U-drp.

Comparing the results of the final testing we could observe that the spirometric parameters of GE recorded higher values than GC. However, the values were not significantly different for all parameters followed. For FVC and FEV1 no significant differences were observed between the two groups.

For PEF, the GE mean (M = 9.63 L/min, AS = 1.05) was significantly higher than the GC mean (M = 8.23 L/min , AS = 0.74) t = 4.40, df = 30, p < 0.001.

The mean L-total in-match parameter for the experimental group at the final test was significantly higher than that of the control group [MGE = 154.58, AS = 14.54 compared to MGC = 135.80, AS = 8.81 (t = 4.569, df = 30, p < 0.001)].

Differences between the two samples at the time of the final test were significantly different for the number of shots delivered in R1, R3, and L-total delivered over the entire match, respectively. For R1 the mean of the experimental group was 50 hits (± 5.47) compared to the mean of the control group of 45 hits (AS = 3.64), t = 3.109, p = 0.004. The differences in R3 were as follows: the mean of the experimental group 52.83 strokes (AS = 6.96) versus the mean of the control group 43.5 strokes (± 4.48), t = 4.62, p < 0.001. In terms of the L-total transmitted in the match, the experimental group averaged 154.58 strokes (AS = 14.54) versus the control group 135.80 strokes (AS = 8.81), t = 4.56, p < 0.001.

The mean forced vital capacity at the final test (M = 5.21 liters, AS = 0.55) was significantly improved from the mean of the initial test (M = 4.56 liters, AS = 0.62) t = -8.08, df = 11, p < 0.001.

Forced expiratory volume in the first second at baseline testing was 4.09 (± 0.47) versus final testing 4.55 (± 0.52), $t = -2.67$, $df = 11$, $p = 0.02$, and peak expiratory flow rate the baseline test mean value was 6.58 litres/minute (± 1.18) and the group mean at final testing 9.63 litres/minute (± 1.05), $t = -13.12$, $df = 11$, $p < 0.001$. As for the maximum power results in the SJ and BP samples, significant differences were observed between the two testing times. The differences at T2 were higher by 16.6 W, 87.50 W and 86.00 W compared to T1.

The increase for the experimental group was about 15% for the right arm and 17% for the left arm, respectively. The difference in power between the two limbs of the athletes in the experimental group at baseline testing (9%) was decreased at the time of final testing (7%).

The present study aimed to observe the effect of using modern apparatus in sports training. At the same time, we wanted to achieve individualization of training plans and their direction using these means.

The results of the final testing showed that the differences between the two groups were not significantly different for all parameters analysed. However, comparing the results of the two tests we could observe that the subjects of the experimental group, following the breathing training, showed significant increases for the three parameters analyzed. Thus, our hypothesis that the introduction of respiratory training in the training plans of athletes is confirmed.

After going through the proposed individualized training program, we could observe in the final test that the GE athletes recorded significantly higher values for BP-drp, BP-stg and SJ compared to the initial test, while the GC averages showed a much decreased increase. Also, the differences between the two groups at the time of final testing were significantly different for all parameters analysed. Thus, our hypothesis that introducing an individualized training program based on the VBT method will lead to an increase in upper and lower limb strength indices is confirmed.

Analysing the final test matches we could observe an increase in the total number of strokes in both groups. GE delivered on average 18 more strokes than GC, the differences between the two groups being significantly different. Likewise, we could observe an increase in the number of hits from round to round for GE, while GC shows an increase in R2 and a decrease in R3. In terms of the number of shots hitting the target GE registered a significant increase in the final test for both groups. However, GE recorded an increase on average of 25.91 in the number of shots delivered in the match and 17.66 more shots hitting their target, while GC values increased on average by 12.65 and 6.45 shots respectively. The difference between the two tests in the success percentage (shots delivered/shots on target) was 7.29% for GE (T1 = 24.84%, T2 = 32.13%) compared to 2.35% for GC (T1 = 25.7%, T2 = 28.05%).

The limitations of this study in terms of power idice was that its assessment was performed using non-boxing specific methods such as push from supine and squat with jump. These assessments helped us in making a profile of power, but do not provide insight into the contribution of each segment in the kinetic chain of punches. In addition, the information obtained cannot be strictly generalized given the particularities of each athlete, the type of fight they adopt, the guard position or other variables.

Another limitation of the study is the limited number of devices designed to monitor athletes' performance. This aspect led to inconsistent monitoring of training and may have limited our desired effects. The lack of detailed information about the training methods used by the control group athletes prevents us from being able to state that the method used in this research produces greater differences in training compared to the classical method. However, from the literature review and the results obtained in our study, we can state that by implementing individualized training plans using the profile based on the relationship between load and speed, athletes can make significant progress in terms of power values.

Summary of Chapter 8. Developing a monitoring system for boxing training

The present study aims to observe the effects of visual feedback, provided in real time to participants, and the introduction of elements of gamification on the volume and intensity of boxing training.

Gamification is the introduction of game elements into other activities or programmes. The Marriam-Webster Dictionary describes the term "gamification" as the process of adding game or game-specific elements to certain actions/challenges with the goal of encouraging active participation by those involved (Christians, 2018).

Today's teenagers are part of the generation that is closely connected to mobile devices (phone, tablet), with a low attention span; thus, new ways to get them active and engaged in physical activities are needed (Elmore, 2010).

Consulting the literature, we can see that introducing gamification elements in physical activity leads to active involvement and a high degree of motivation of participants. However, it is very important when introducing gamification elements to pay attention to experience design and flow theory (Matallaoui, Koivisto, Hamari, & Zarnekov, 2017).

This study aimed to investigate the following aspects:

1. introduction of specific training monitoring devices in boxers (number of punches delivered to the punching bag, weight, percentage of adipose tissue, heart rate);

2. the provision of visual feedback to athletes (the possibility of being able to see at any time the number of punches delivered to the punching bag);

3. introduction of gamification elements in training (profiling of athletes and awarding of points).

In this study the following assumptions were made:

1. The introduction of visual feedback will lead to an increase in the volume of punches delivered into the punching bag.

2. The application of gamification elements (virtual participant profile, point accumulation, ranking) will lead to increased training intensity.

To carry out this research, 27 subjects from Timisoara were selected, boxers for at least one year, working at LPS Banatul Timisoara, CSM Timisoara and CS Viitorul Timisoara. Given the pandemic context at the time the study was initiated, the athletes were not in training at the clubs to which they are affiliated. The sample selected for the research was divided into two groups according to their ability to attend training classes: experimental group - GE (N = 13, age M = 15.61 years, AS = 0.31 years, height M = 176.01 cm, AS = 2.23 cm, weight M = 69.73 kg , AS = 2.53), control group GC (N = 14, age M = 15.28 years, AS = 0.35, height M = 172.22 cm, AS = 2.18 cm, weight M = 69.83 kg , AS = 2.68 kg).

The research was conducted from 19/04/2021 to 24/05/2021. During this period the athletes were not in training, as their access to the training rooms was limited, only those athletes who were going to participate in official competitions in the competition calendar were training in the sports clubs. The initial testing took place on 19/04/2021 and the final testing took place on 24/05/2021. Subjects participated in five training sessions per week, with the duration of a training session ranging from 90 to 120 minutes.

The assessments to which the subjects were subjected for the two tests were as follows:

- Body composition (measured using the Tanita DC 360 scale and Gmon for Tanita software);

- Resting heart rate;

- Repetition velocity: number of punches delivered to the punching bag during 30 sec (recorded using Hykso sensors).

Proposed intervention

- The same training programme was proposed for both groups in terms of duration of training hours, training intensity and complexity of the series of blows;

- The experimental group will always have the possibility to watch the number of kicks delivered to the bag in each round on a monitor in the gym, while the control group will not have this possibility, but the data were recorded by the system. Also, practices were held at different times.

- Subjects in the control group were asked to subjectively rate the number of hits delivered to the bag after each set to observe their self-assessment ability.

The training program proposed to the athletes was carried out during a five-week half-cycle. They had a frequency of five training sessions per week, totalling 169 punching bag rounds. For each training session, the total number of punches delivered to the bag and the average heart rate for each athlete were recorded. Both research groups performed their training in the Legend boxing and fitness gym in Timisoara. The manager of the boxing and fitness gym was the financial supporter of the design, development and implementation of the monitoring system.

The monitoring of these workouts was carried out using a system (Arnăutu et al., 2020) composed of:

- An accelerometer positioned inside the bag approximately 25 cm away from the base of the bag;

- a heart rate monitoring sensor worn by the subject; this transmits information to a microcomputer using Bluetooth connectivity.

- RaspberryPi microcomputer, which takes the data transmitted by the accelerometer and performs the primary processing, after which it transmits the information to the API. This system was created with the help of a team that performed the code writing and application part. This system was partly funded by a Smart StartUp programme: "Project Support and Motivation of Responsible and Talented Entrepreneurs - SMART Start Up" and by the Balvia SRL group of companies.

In order to determine the differences and their significance thresholds between the two research samples, the t-test for independent samples was used. Thus, we could observe that in the case of body weight there were no significant differences between the two samples regardless of the time of testing. The mean of the GE group in TI was 69.74 kg (AS=9.13) versus GC 69.83 kg (AS=10.04) where t = -0.02, df = 25, p = 0.98, and in the case of TF the GE mean was 69.61 kg (AS=9.15) versus GC 70.17 kg (AS=9.84) where t = -0.15, df = 25, p = 0.88.

The difference in means between the two groups in the sample maximum number of strokes delivered in 30 seconds at baseline was 14.74 strokes, thus the GC mean, M = 106.50 strokes (AS = 17.99) was significantly greater than the GE mean, M = 91.76 strokes (AS = 8.99), t = -2.65, df = 25, p = 0.01, effect size was 0.46.

The difference in means between the two samples at the final test was 19.25 hits in favour of the experimental group, resulting in significant differences between the two groups (MGE =

127.46 (AS = 8.26) while MGC = 108.21 (AS = 11.46), $t = 4.97$, $df = 25$, $p < 0.001$) effect size being 0.69.

The next step was to compare the actual results achieved by the control group and their estimates.

Comparing the number of strokes delivered by the control group athletes with their self-assessment we could see that the whole group overestimated their effort. An assessment closer to the real situation can be observed in the last week of training.

Although the subjects' estimates were close to the number of hits performed in the last week, the sum of the hits delivered in the punching bag during all rounds was significantly lower than the estimate made by the control group athletes (17826.28, AS = 221.82 vs. 19905.71, AS = 279.59) $t = -26.24$, $df = 13$, $p < 0.001$.

Following the completion of training we could see that subject 9 delivered the most hits in the five weeks of training 20399 hits, subject 3 20398 hits and subject 11 20357 hits. However, subject 11 ranked first in the score generated by the calculated score, obtaining 88 points. Subject 9 and Subject 3 ranked second with an equal score of 80 points.

Using the paired samples t-test we could observe significant differences between the two tests on one monitored parameter.

The mean body weight of the experimental group at the time of the initial test (TI) was 69.74 kg (AS=2.53) and a mean body fat of 13.04 kg (0.57). The final test (TF) of this parameter did not show major differences, with a mean body weight of 69.61 kg (AS=2.54) and a mean body fat of 12.95 kg (AS=0.55).

The mean resting heart rate for the experimental group at the time of initial testing was 63.38 (AS=2.50) beats per minute and at the time of final testing was 62.76 (AS=2.58) beats per minute. A decrease in resting heart rate can be observed between the two testing times is 0.62 beats per minute. The 95% confidence interval ranges from -0.74 to 1.97. Since the confidence interval passes through 0.00 the difference between the two test times is not significant at a significance level of 0.05 ($t = 0.98$, $df = 12$, $p = 0.34$). The mean value of the maximum number of hits transmitted in 30 seconds in the initial test was 91.76 (AS=8.99) hits and in the final test 127.46 (AS=8.26) hits. Comparing the results of the experimental group at the initial and final testing we could see that the differences that occurred after training were significantly different. The 95% confidence intervals ranged from -42.89 to -28.48 thus, the differences between the two testing times were significantly different ($t = -10.79$, $df = 12$, $p <0.001$). At the same time, it could be observed that all subjects of the experimental group recorded increases in the number of strokes delivered in 30 seconds. At the initial test the mean repetition rate in 30 seconds was 106.50 (AS=17.99) hits, and at the final test 108.21 (AS=11.46) hits. The sample mean at the final test was 1.71 strokes higher than that at the initial test, the differences between them were not significantly different. The 95% confidence intervals ranged from -13.25 to 9.8 thus, the differences between the two moments not being significant ($t = -0.32$, $df = 13$, $p = 0.75$). At the same time, increases in sample values at the final test could only be observed in 7 subjects.

The research carried out on a sample of 27 athletes allowed us to conclude the following:

1. The use of visual feedback aids can increase the workload of athletes. However, some clarifications are necessary so that they do not interfere with their training. One clarification would be that the screens on which information is displayed should not distract athletes. This data can either be displayed on small screens out of the athletes' sight during exercises or on certain devices that only the coach has access to in real time. Another important aspect is that the use of this type of feedback must be accompanied by heart rate monitoring, so there is control over the intensity of work keeping the athlete in the desired effort zone.

2. The insertion of game elements and the creation of leaderboards can add to the attractiveness of the training. This can develop training strategies that lead to the achievement of goals. The implementation of such a system can facilitate the individualisation of training plans by continuously monitoring effort parameters.

3. Comparing the results of the initial test with those of the final test, it was possible to observe an increase in the average number of strokes of 35.7 strokes in 30 seconds for the experimental group and only 1.71 strokes for the control group. The differences for the experimental group were significant at a threshold of $p < 0.05$. The difference between the two groups also changed. In the initial test, the mean value of the control group was significantly higher than that of the experiment group, whereas in the final test the experiment group made more progress making the differences significant in its favour ($p < 0.05$), with a mean effect size of 0.69.

4. No significant differences were observed in body weight, amount of adipose tissue or resting heart rate. This may be due to the very short period of training in which the subjects took part.

The results of this experiment could lead coaches to use technology more confidently to attract young people to physical activity. Although such systems are relatively expensive, there are enough affordable devices that can provide information about the athlete on the one hand, and create a competitive state with peers on the other.

Research limitations

The research presented above has a number of limitations:

1. The introduction of such a system in a specific boxing hall is difficult to achieve due to the required infrastructure;

2. Insufficient time to apply the method in order to observe whether these results can be achieved in other groups of athletes;

3. The pandemic period which did not give us the opportunity to deploy the technology in ideal conditions and over a long period of time.

Summary of Chapter 9. Final conclusions and future research directions

The performances of Romanian boxers in recent years have created the premises for this research. We believe that their poor performance is not sufficiently addressed in scientific research, and thus information on improving the training process is lacking in the Romanian literature. Following our research we wanted to identify some training structures or methods, so that we can develop methodical arguments that could contribute to the improvement of sports training and therefore performance.

The data monitored and recorded in real time have the effect of identifying, raising awareness and increasing the possibilities for improvement during training. The effects of introducing visual feedback have been observed in increasing the number of punches delivered into the punching bag, having a motivational effect among athletes.

We believe that a new vision of sports training is needed in boxers, starting from junior age, so that they can be directed towards performance. Specialists in the field should turn their attention to modern technological means that have the ability to transmit accurate information about the athletes' activity in real time to the coach.

We propose some reconsiderations in the approach to sports training:

a. Develop a profile of the athlete from the beginning of his/her activity so that the results of training and competitions can be analysed regularly;

b. Introducing technological means of monitoring effort parameters into the recurrent practice of sports training; this is difficult to achieve without them, being influenced by the subjectivity of the coach;

c. Introduction of respiratory training into training plans in order to improve spirometric parameters;

d. Implementation of means of visual feedback so that it constitutes a motivational element oriented towards maintaining the intensity and volume of effort necessary to optimise sporting possibilities;

e. Introducing gamification elements in training so as to increase the level of involvement of the athletes, encouraging them to compete in order to exceed their limits.

Research limitations

The limitations of the research conducted are as follows:

The literature, from abroad, dealing with this topic is extensive, giving us access to a lot of information necessary to carry out the studies included in the paper. However, the number of scientific publications in Romania that have analysed our topic is low. Thus, we cannot compare the results of our research with other studies conducted on Romanian subjects.

Human resources and the low number of participants were another limitation of the research. The low sample is due on the one hand to the small number of boxers affiliated to sports clubs, but also to the inclusion criteria used in the research.

The lack of complete information about the training of the control groups did not allow us to observe differences in detail from a methodological point of view.

Limited financial resources did not allow us to continue the research and develop the system from the last study so that it could be used in both punching bag training and motor skills training.

Future research directions could be directed towards:

- the development of an integrated system for monitoring boxing-specific training (number of punches delivered to the bag, heart rate, caloric consumption);

- the possibility of determining and recording the type of punch delivered (jab, hook, uppercut);

- determination of the intervals between blows and the type of action taking place during this time (moving around the bag or dodging);

- monitoring and analysing the boxers' ability to chain a series of complex blows.

The implementation of such a system could provide an accurate picture of the activity of the boxers during training by determining work intensity, volume and density.

The originality of this work lies primarily in conducting a review of the literature that approaches the sport of boxing from different perspectives. Thus, in the first part of this work, it has been possible to select those articles that provide current information in modern boxing, both from the perspective of training methodology and somatic, physiological and motor indices of boxers. As far as we know, at the time of writing this thesis, there is no other work in the Romanian specialized literature that offers an overview of the performance boxer model, touching both the somatic-functional and technical profiles.

Another point of originality is given by the monitoring system of boxing training, which was oriented towards directing the athletes in training and at the same time simplifying the coach's work. This system represents the first steps in the creation of a training ecosystem in which the profile of the athletes, their path in periodic tests and the whole calendar plan could be integrated.

We mention that during our research the athletes of the experimental groups managed to win 15 medals in major competitions in Romania (Romanian Cup and National Championship).

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