DETERMINATION OF THE REAL TRAINING LOAD BASED ON MONITORING OF K1 KICKBOXING BOUTS

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Keywords: Kickboxing, K1, heart rate, fight analysis, training load

Abstract:

**Background:** Kickboxing is a combat sport in which scientific observations are regularly made to improve the quality of the training process. Heart rate monitoring is the basic form of the evaluation of training load and diagnosing the athlete’s capabilities. The purpose of this study was to determine training load based on heart rate measurements in K1 kickboxers.

**Methods:** The study was conducted on 18 kickboxers, with HR recorded over a 3-round kickboxing fight. HRmax level was calculated for each athlete according to the most recent formula. Based on these data, the percentage training load was determined according to the needs arising from the training periodization.

**Results:** The results of the study showed that training of K1 kickboxers is based primarily on submaximal heart rates, which increase with each round of the bout (p<0.001).

**Conclusions:** The training load for a K1 kickboxing bout based on maximum heart rate should be 95.44% HRmax in the first round, 96.23% HRmax in the second, and 97.01% HRmax in the round.

Introduction

Sports fight analysis is an important part of coaching supervision [1]. Observation of athletes allows for the evaluation of their activeness, efficiency, and effectiveness. In striking combat sports, coaches make regular observations and calculations of the number of techniques and their hits [2]. This helps coaches diagnose the athlete’s technical and tactical capabilities and modify the training process [3]. Another element is to monitor heart activity by means of the measurement of the athlete’s heart rate. This allows for the evaluation of the recovery rate and (indirectly) the athletes’ physical capacity, which underlies general and special endurance [4]. This method of assessing the athlete’s performance has been used primarily in running sports [5–8] and now there are attempts to adapt it to other sports, including combat sports [9]. According to numerous studies in the field of sports theory, the training load (especially the level of intensity) is often determined as %VO2max [10, 11]. In training practice, it is easier and more efficient to determine these levels by measuring the athlete’s heart rate (HR), for example, using heart rate monitors.

Furthermore, more effective measurement of maximum heart rate can be performed using proven laboratory methods [12]. However, there are methods of estimating this level indirectly. They are used to determine HRmax under training or competitive conditions and are being constantly improved [13]. The most popular formula for determining maximum heart rate is 220-age [14], whereas Tanaka made a modification using the formula 208-(0.7*age) [13]. Recently, however, the formulas have undergone modifications and Lach et al. have recently developed the most accurate formula: 202.5–0.53*age [15].
Physiological analysis of the course of a kickboxing bout has been carried out many times [16–19], especially in K1 kickboxing, which is the most demanding and energetic variation of kickboxing fights [20]. There was also an analysis of changes in acid-base balance and total blood gas saturation during the fight [21]. The HR and lactate levels achieved by the athletes during a real kickboxing bout were determined [22, 23]. Slimani has repeatedly performed heart rate monitoring in combat sports [9, 24] to determine the physiological responses to this type of exercise. Heart rate measurements are also regularly performed in boxing [25, 26]. The exercise intensity was evaluated during simulated boxing fights [27]. Imamura conducted heart rate verification during a 20-round karate fight [28]. Also in this sport, physiological loads have been repeatedly measured in athletes during and after fights [29–31]. Similar analyses have been often made in taekwondo [32–34]. Furthermore, such examinations are regularly performed in soccer [35–38] and swimming [39, 40]. However, the literature is lacking in defining training loads based on HR levels in K1 kickboxing.

Therefore, the aim of this study was to deepen the knowledge of determining the training load based on heart rate measurements, for kickboxing athletes fighting in K1 rules formula.

**Material and Methods**

*Study design*

In the present study, the intensity of the training load during a K1 kickboxing fight was determined by monitoring the body’s responses using heart rate measurements. Maximum heart rate was then calculated for each participant according to formulas pro-posed in the literature. The experiment was conducted according to the following design (Figure 1).

![Study design](image-url)
Participants
The study was conducted on a group of 18 kickboxers who regularly competed under K1 rules. The mean age of the participants was 22.94±2.33 years, with their mean training experience of 6.61±1.28 years. The selection of athletes was purposive based on the inclusion and exclusion criteria described in Table 1.

Table 1. Inclusion and exclusion criteria for the study

<table>
<thead>
<tr>
<th>Inclusion criteria</th>
<th>Exclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Training experience of at least 5 years</td>
<td>Training experience &lt; 5 years</td>
</tr>
<tr>
<td>Regular participation in competitions</td>
<td>No participation in competitions</td>
</tr>
<tr>
<td>Good health status</td>
<td>Injuries</td>
</tr>
<tr>
<td>Consent to participate in the study</td>
<td>No consent to participate in the study</td>
</tr>
<tr>
<td>Male</td>
<td>Female</td>
</tr>
<tr>
<td>Minimum age: 18 years</td>
<td>Age &lt; 18 years</td>
</tr>
</tbody>
</table>

Measurement methods
Heart rate analysis was performed using a Garmin Fenix 6x pro heart rate monitor (Garmin, USA, Olathe) along with a Garmin HRM Pro chest strap (Garmin, USA, Olathe). All athletes fought a three-round kickboxing bout refereed under K1 rules. Each round lasted 2min, while the break between rounds was 1min. Prior to the fight, the athletes performed an individual warm-up according to the procedures they usually followed before the competitions. The fights were held in a neutral training room which was unfamiliar to the athletes. This was aimed to most closely simulate the competitive environment. Each fighter wore a chest belt throughout the fight. However, due to the dynamics of the fight, to avoid erroneous readings due to the belt slip, peak HR was recorded for the present study. The research was approved by the Bioethics Committee at the Regional Medical Chamber (No. 287/KBL/OIL/2020).

Determination of maximum heart rate
The maximal heart rate for each kickboxer was calculated using the latest maximal heart rate formula developed by Lach et al. [15]

\[ HR_{max} = 202.5 - (0.53 \times age) \]

The spreadsheet was then used to calculate the percentage values recorded during the bout relative to HRmax.

Statistical analysis methods
Statistical analysis of the collected material was conducted in Statistica v13.3 software (Statsoft, Kraków, Poland). Basic descriptive statistics were calculated: arithmetic means, standard deviations, minimum, maximum, and value of the first and third quartile. Consistency of the variables with normal distribution was confirmed by the Shapiro-Wilk test. The significance of differences between the three measurements was calculated using a one-way analysis of variance (ANOVA) with repeated measures. The significance of differences between rounds (I vs II, II vs III, I vs III) was calculated using Tukey post-hoc test. The level of statistically significant differences was set at p<0.005. The effect size between the three measurements was calculated using eta-squared, whereas between rounds - using Cohen d. The results of the analysis are presented in tables and figures, including 95% confidence intervals.

Results
With each round, the athletes showed higher peak heart rates, which proved to be statistically significant (p=0.00) with the large effect size. Between the first and second rounds, and between the second and third rounds, the effect size was medium and the values were statistically significant p<0.005 (Table 2) (Figure 2).
Table 2. Peak heart rate values during a kickboxing fight under K1 rules

<table>
<thead>
<tr>
<th>HR</th>
<th>Descriptive statistics</th>
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<tbody>
<tr>
<td></td>
<td>n</td>
</tr>
<tr>
<td>HR Peak 1st round</td>
<td>18</td>
</tr>
<tr>
<td>HR Peak 2nd round</td>
<td>18</td>
</tr>
<tr>
<td>HR Peak 3rd round</td>
<td>18</td>
</tr>
</tbody>
</table>

ANOVA

\(p=0.00\)  
ES = 0.99

n—number of participants, \(\bar{x}\)—arithmetic mean, min—minimum, max—maximum, Q1—first quartile, Q3—third quartile, SD—standard deviations, \(p\)—significance of differences, ES—effect size, \(p_1\)—statistical significance for the first measurement, \(p_2\)—statistical significance for the subsequent measurement, ES1—effect size for the first measurement, ES2—effect size for the subsequent measurement.

Figure 2. Peak heart rate in individual rounds of the fight

Vertical bars indicate 95% confidence intervals

Results of individual calculations of maximum heart rate for each athlete are shown in Table 3.

Table 3. Detailed description of the study group with calculations of maximum heart rate according to the formula

| Athlete No. | Age (years) | HR max according to the formula by Lach et al.  
(\(HR_{max}=202.5-(0.53*\text{age})\)) |
<table>
<thead>
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<tbody>
<tr>
<td>1</td>
<td>23</td>
<td>190.31</td>
</tr>
<tr>
<td>2</td>
<td>26</td>
<td>188.72</td>
</tr>
<tr>
<td>3</td>
<td>21</td>
<td>191.37</td>
</tr>
<tr>
<td>4</td>
<td>20</td>
<td>191.9</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>189.25</td>
</tr>
<tr>
<td>6</td>
<td>24</td>
<td>189.78</td>
</tr>
<tr>
<td>7</td>
<td>23</td>
<td>191.37</td>
</tr>
<tr>
<td>8</td>
<td>22</td>
<td>190.84</td>
</tr>
<tr>
<td>9</td>
<td>18</td>
<td>192.96</td>
</tr>
<tr>
<td>10</td>
<td>20</td>
<td>191.9</td>
</tr>
<tr>
<td>11</td>
<td>21</td>
<td>191.37</td>
</tr>
<tr>
<td>12</td>
<td>24</td>
<td>189.78</td>
</tr>
<tr>
<td>13</td>
<td>23</td>
<td>190.31</td>
</tr>
</tbody>
</table>
In the first round, the athletes’ percentage heart rate was 95.44% HRmax, with the level increasing to 96.23% HRmax in the second round and 97.01% HRmax in the third. These values were statistically significant (p=0.00) and characterized by large effect size (Table 4, Figure 3). The mean heart rate relative to the maximal heart rate in the entire bout was 96.22% HRmax.

**Table 4. Percentage of heart rate relative to maximum heart rate**

<table>
<thead>
<tr>
<th>% HR</th>
<th>Description statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>x</td>
</tr>
<tr>
<td>After 1st round</td>
<td>18</td>
</tr>
<tr>
<td>After 2nd round</td>
<td>18</td>
</tr>
<tr>
<td>After 3rd round</td>
<td>18</td>
</tr>
</tbody>
</table>

**ANOVA**

p=0.00

ES=0.99

**Figure 3. Percentage of heart rate during the fight relative to maximum heart rate**

**Discussion**

An analysis of peak heart rate during a K1 kickboxing bout showed that the fighters reached a mean HR level of 181.66 bpm in the first round. Therefore, it can be concluded that they quickly reached submaximal HR, as it corresponded to 95.44% HRmax. Similar results were obtained in a physiological analysis of kickboxing fights, with the results indicating that the athletes relied heavily on anaerobic metabolism [22]. Interpretation of the results recorded in successive rounds lead to the conclusion of growing fatigue as illustrated by higher HR values. The high heart rate values recorded in the bout may be due to the specific K1 rules, in which techniques performed...
at full speed and strength are al-low-d [41, 42], consequently encouraging the athlete to maintain maximum con-
centration and commitment during the entire fight. Analysis of our results showed that athletes fight with a mean
heart rate of 96.22% HRmax. The load they experience is higher than analyses that have been conducted using
similar methods on judo [43, 44], taekwondo, karate, and Muay Thai [9] fighters. Repeated observations have
proven that fighters in a kick-boxing bout often attempt to end the fight by knockout [20]. Consequently, each
attack is performed with maximum effort. Exercise intensity manifested itself in high HR values maintained until
the end of the bout. An official K1 fight lasts 3 times for 2 minutes, and therefore, due to the relatively short time
of the bout, fighters are able to maintain a high disposition based on anaerobic metabolism throughout the fight.
This has been confirmed in studies analyzing the indicators of technical and tactical performance in kickboxers.
The results of these studies indicated that the athletes had high levels of activeness of the attack throughout
the fight [3, 45, 46]. The present study was designed to present physio-logical responses to the load induced
in fighters during a K1 kickboxing bout so that coaches can simulate competitive conditions during specialized
endurance training.

Endurance is defined as the ability to use the biological potential of physical capacity while taking into account
personality and mental capabilities such as motivation, willpower, and tolerance to fatigue [47]. Cardiorespiratory
endurance is a type of endurance related to the ability to continue exercise conditioned by the efficiency of the car-
diovascular and respiratory systems. Applying the loads at an intensity level of 96.22% HRmax during training offers
an effective method of maintaining cardiorespiratory en-durance. It is also an important indicator of the correct
implementation of peak loads during direct pre-competition preparation [11].

Limitation of the study
The present study was conducted using a chest strap to measure the heart rates of athletes. As a result of the
dynamic fight and the appearance of sweat, the belt tended to slip. Therefore, the peak heart rate was used in the
present study instead of its mean values for the entire round. Presenting mean values for a round would underestimate
HR values, affecting the conversion of the load to values relative to maximum heart rate. Furthermore, maximum heart
rate was evaluated using a formula used in the literature, which is an indirect method of determining HRmax and may
be inaccurate.

Conclusions
Fighters in a kickboxing bout perform exercise at submaximal heart rates, which increase with each round. Our study
showed that the exercise intensity of the training load in a K1 kickboxing bout relative to maximum heart rate should
be 95.44% HRmax in the first round, 96.23% HRmax in the second, and 97.01% HRmax in the third. An overall mean
level of 96.22% HRmax can be adopted as a training load during simulation practice that corresponds to the volume
and intensity of an entire kickboxing bout.

Practical implication
The method of diagnosis and determination of training load intensity presented in this paper can be useful for coaches
to quickly assess and individually adjust training loads in each athlete.

Funding: This research received no external funding

Institutional Review Board Statement: The research was approved by The Bioethics Committee at The Regional
Medical Chamber (No. 287/KBL/OIL/2020).

Informed consent statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: All data are presented in the study.

Conflicts of Interest: The authors declare no conflict of interest
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