Impact of training experience and training total time on aerobic capacity and level of effective restitution of female Polish Judo National Team athletes during the preparation for the Olympic Games

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A Study Design
B Data Collection
C Statistical Analysis
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Abstract

Background and Study Aim: Judo sports competition at the highest levels requires a high level of aerobic capacity. The cognitive aim of the study was the knowledge about relationship between the level of aerobic capacity and post-exercise restitution, and the weekly training total time (which accumulates the components of the so-called training volume and exercise intensity), and athletes' body weight, during the preparation period before the planned Olympic Games in Tokyo. The authors posed two research hypotheses: H1 training experience improves the relative aerobic capacity of the athletes; H2 weekly training total time (volume and intensity) is significantly related to post-exercise heart rate and level of post-exercise restitution.

General remark: unfortunately, due to the coronavirus pandemic on a global scale, the Olympic Games scheduled for 2020 were postponed to 2021.

Material and Methods: The tests were carried out on the athletes of the Polish Judo National Senior Team of Women (n = 14; age 20.5 to 29.75 years), during the training camp in the preparatory period. The level of aerobic capacity was measured by the Maximal Multistage 20-m Shuttle Run Test (Beep-Test) was used. To determine restitution efficiency, the Klonowicz restitution efficiency index was used. For accurate analysis, the relative oxygen capacity, relative average running speed and relative distance covered in relation to the test body weight were determined. The training experience criterion was years of training (in this case over 17 years). Training total time was measured in hours.

Results: The heart rate (HR) value 5 minutes after the test increased. The most effective weekly training total time for the female senior group was between 15 and 20 hours. No significant relationship between training experience and relative capacity indices was shown.

Conclusions: Weekly training total time (included components of training volumes and exercise intensity) have a significant impact on aerobic capacity. It is necessary to regularly check the training load and the regeneration and adaptation levels of athletes. Otherwise, this may lead to a reduction of the capacity for post-exercise regeneration.

Keywords: intensity • load • physiological conditions • preparatory period • training volume

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Anaerobic metabolism – *noun* the breakdown of carbon and fats into energy without the presence of oxygen [25].

Cardiovascular – *adjective* relating to the heart and the blood circulation system [25].

Training volume – total amount of training as determined by number of sets and exercises for a muscle group, intensity, and frequency of training [6].

Training load – "A simple mathematical model of training load can be defined as the product of qualitative and quantitative factor. This reasoning may became unclear whenever the quantitative factor is called 'workload volume' or 'training volume' interchangeably with 'volume of physical activity'. Various units have been adopted as measures i.e. the number of repetitions, kilometres, tons, kilocalories, etc. as well as various units of time (seconds, minutes, hours) (...) As in the real world nothing happens beyond the time, the basic procedure of improvement of workload measurement should logically start with separation of the time factor from the set of phenomena so far classified together as '***workload volume***'. (...) Due to the fact that the heart rate (HR) is commonly accepted as the universal measure of workload intensity, the product of effort duration and HR seems to be the general indicator of ***training load*** defined as the amount of workload. It is useful in analyses with a high level of generality. (...) In current research and training practice the product of effort duration and HR was referred to as conventional units' or further calculations have been made to convert it into points." [7, p. 238].

Training intensity – the effort of training. A number of methods are used to establish training intensities which give maximum benefits. These include the lactic acid method, minute ventilation method, and target heart-rate [26].

INTRODUCTION

The highest levels of sporting struggle require athletes to improve their skills constantly and raise the level of their preparation as much as possible. Physiological conditions, such as oxygen capacity or the speed of restitution, are an inseparable element of sport, and they often determine the outcome of the sports struggle. A judo fight can end in just a few seconds if one of the fighters performs an action which, according to the Sport and Organization Rules (SOR) of the International Judo Federation (IJF), gives a victory ahead of time. However, in accordance with the SOR IJF, if there is no winner at the end of the regular 4-minute period, the competition continues under the *golden score* formula, which has no time limit [1]. Despite the fact that athletes, during the judo sports fight, obtain energy from anaerobic metabolism most often, it is also very important to achieve a high aerobic capacity. That capacity is supported by the use of lactic acid for better regeneration during judo sports fighting, which is characterized by high intensity and short rests during the fight [2, 3]. Moreover, aerobic capacity can be used to evaluate the efficiency of an athlete's cardiovascular system [4]. This, along with an effective restorative index, are two of the basic control tools in the training process [5]. These indices make it possible to assess the level of exercise adaptation and thus provide the basis for controlling, planning, modifying and determining subsequent loads in the training process.

The issue of this article concerns the impact of the training period (experience) and weekly training total time on the level of aerobic capacity, relative aerobic capacity in relation to body weight and the level of effective restitution for women of the Polish Judo National Team, during the preparation period for the Olympic Games Tokyo 2020.

In this work, we use the concept of training "volume" as defined by Heyvord [6] (see glossary). Many sports theorists include 'time' as one of the ingredients of "volume" training. We share the view of Kalina [7] and Szmuchrowski and Kalina [8] that time should be separated as an independent, very important component of the exercise (training) load – it is impossible to argue with the statement that "in the real world nothing happens beyond the time" (see glossary [7]).

In this study, the factors determining aerobic and anaerobic capacity in martial arts were analysed in a very general sense [9]. The aerobic capacity of judo athletes and students was compared [10], and the effect of maximum aerobic power and lactate concentration in the blood on the results in the special efficiency test of judo was studied [3, 11]. The aerobic capacity was analysed in the test consisting of entry to one of the techniques on a special machine with judo sleeves mounted [12], the variability of heart rate in elite female judo athletes was studied [13], the course of judo training conducted according to different intensity models was observed [14], and a program was developed to improve HR and VO_2max levels of elite judo athletes [15]. A long-term study was also carried out, comparing the weekly training and training time during the 6 months before the Olympic Games with the subsequent results at the main competitions [16]. So far, relative capacity indices have not been determined in relation to the body weight of the respondents, and they have not been compared with the weekly training volume, training time and training experience (measured by training years). Considering the competition in judo, divided into weight categories, the authors considered body weight to be an important element of process analysis and training programme, as a component that may affect the level of aerobic capacity.

The authors decided to analyse the course of the performance test and its results in relation to the body weight of the test subjects, additionally determining their own relative analytical indices, such as relative distance [m/kg], relative average speed of the last test level [km/h/kg] and relative VO_2max level [ml/kg/min/kg].

The cognitive aim of the study was the knowledge about relationship between the level of aerobic capacity and post-exercise restitution and the weekly training total time (which accumulates the components of the so-called training volume and exercise intensity), and athletes' body weight, during the preparation period before the planned Olympic Games in Tokyo

The authors posed two research hypotheses: H1 training experience improves the relative aerobic capacity of the athletes; H2 weekly training total time (volume and intensity) is significantly related to post-exercise heart rate and level of post-exercise restitution.

General remark: unfortunately, due to the coronavirus pandemic on a global scale, the Olympic Games scheduled for 2020 were postponed to 2021.

MATERIAL AND METHODS

Participants

The tests were carried out on female athletes of the Polish National Team in Judo in the senior age group, who, after being appointed, stayed at the first preparation camp for the Olympic Games. The tests were carried out on 14 women. The average age was 24.3 years, with the youngest participant being 20.5 years old and the oldest 29.75 years old.

Study design and tools

Aerobic capacity was tested using the Maximal Multistage 20-m Shuttle Run Test. During the test, the subject is to move between lines 20 meters apart, according to the sound signal, with increasing frequency. The person must cross the line before the sound, otherwise he or she receives a warning, the second warning means the end of the test [17]. For each test, the distance covered and the level of aerobic capacity at which the person completed the test were marked. The level of aerobic capacity was estimated using the formula:

$VO_2max = -32,678 + 6,592 \times P$, where:

P = maximum speed for the section where the run was completed (km/h) [18].

In addition, after each test, the Klonowicz effective restitution index was measured, at 3 minutes (WSR3') and 5 minutes (WSR5') after exercise, according to the formula:

$WSR_{3'} = \frac{Hr2-Hr3}{Hr2-Hr1}$ and $WSR_{5'} = \frac{Hr2-Hr5}{Hr2-Hr1}$, where:

Hr_1 – resting heart rate,
Hr_2 – heart rate measured after the test,
Hr_3 – heart rate measured in the 3rd minute of post-exercise restitution,
Hr_5 – heart rate measured in the 5th minute of post-exercise restitution [19].

Statistical analyses

In this paper, the arithmetic mean, standard deviation and Pearson's r correlation were calculated. Moreover, after examining the scatter plots, it was found that the relationships were curvilinear, so multiple curvilinear regression and analyses of variance were used. The results of the calculations were considered statistically significant when the *p*-value <0.05.

RESULTS

The athletes were characterized by large differences in the declared training period, weekly training total time, body weight, test results and post-exercise restitution time (Table 1).

Pearson's r correlation (Table 2) revealed no significant relationships between training experience and weekly training volume with any of the variables under study. Therefore, the scatter distribution and the curvilinear regression equation between the discussed variables were analysed. Scatter plots for the relationships for which the level of significance of the coefficient of linear to curvilinear dependence changed the most are shown in Figure 1. In all four cases, the linear and square components of the equations describing the relationships were statistically significant (p<0.05).

The relationship between the training experience of seniors, expressed in years, and their HR 5 min after Beep-Test r (curvilinear) = 0.624; p = 0.066 with a determination factor of 39% (partial significance levels of regression equations were 0.024 and 0.027 respectively) (Figure 1A), when the linear relationship (Table 2) r = −0.174; p = 0.552. Figures 1 B, C, and D show the relationships between the weekly training total time expressed in hours and HR 3 min after Beep-Test (Figure 1 B), HR 5 min after Beep-Test (Figure 1 C), and Klonowicz WSR 3' (Figure 1 D). For relation B, where the linear relationship was r = 0.038; p = 0.897, the curvilinear relationship is as follows: r = 0.741; p = 0.013 with a determination factor of 54.4% (partial significance levels of regression equations were 0.004 and

Training periodization – depending of the phase of periodization plan, the training emphasis will shift to develop specific characteristics and manage fatigue. A truly comprehensive plan includes dietary recommendation and psychological training. If the training plan is not completely integrated, the like hood that the athlete will achieve successful results is significantly decreased. The annual training should contain at least preparatory, competitive, and transition phases [23, p. 146].

Skill – *noun* an ability to do perform an action well, acquired by training [25].

Performance – *noun* the level at which a player or athlete is carrying out their activity, either in relation to others or in relation to personal goals or standards [25].

Periodisation – *noun* the act of planning a long-term training schedule for professional athletes, working around competitions [25].

Table 1. Training experience, weekly training total time, body weight, Beep-Test results and the indices for effective restitution of the female Polish Judo National Team.

Variable	Average	Minimum	Maximum	Standard deviation
Training experience [yrs]	15.357	9	20	3.319
Weekly training total time [h]	17.643	10	25	4.483
Body weight [kg]	64.729	54	82	9.898
Level in Beep-Test [in order of level]	9.214	6	11	1.424
Distance in Beep-Test [m]	1578.571	960	1920	281.148
Average running speed of the last level of Beep-Test [km/h]	12.607	11	13.5	0.712
VO_2max based on Beep-Test [ml/kg/min]	50.428	39.834	56.314	4.693
Resting HR [bpm]	65.929	52	73	6.342
Beep-Test – HR after the test [bpm]	165.357	100	192	26.930
Beep-Test – HR 1′ after the test [bpm]	124.786	80	156	22.368
Beep-Test – HR 3′ after the test [bpm]	102.143	72	124	14.769
Beep-Test – HR 5′ after the test [bpm]	93.857	68	116	11.909
WSR 3′ Klonowicz (restitution efficiency index 3′ after test)	63.21	47.059	77.311	10.485
WSR 5′ Klonowicz (restitution efficiency index 5′ after test)	71.652	57.143	88.235	8.273
Relative distance of Beep-Test [m/body weight]	24.814	25.244	10.667	34.909
Relative average running speed of the last level of Beep-Test [km/h/body weight]	0.195	0.196	0.122	0.255
Relative VO_2max based on Beep-Test [ml/kg/min/body weight]	0.784	0.797	0.443	1.04

Table 2. Training experience and weekly training total time vs. Beep-Test results and effective restitution indices (with Pearson's r Pearson correlation) for the female Polish Judo National Team (n = 14).

Variable	Training experience [yrs]	Weekly training total time [h]
Level in Beep-Test [in order of level]	−0.115; p = 0.695	−0.047; p = 0.872
Distance in Beep-Test [m]	−0.161; p = 0.582	−0.071; p = 0.809
Average running speed of the last level of Beep-Test [km/h]	−0.115; p = 0.695	−0.047; p = 0.872
VO_2max based on Beep-Test [ml/kg/min]	−0.115; p = 0.695	−0.047; p = 0.872
Resting HR [bpm]	−0.134; p = 0.648	−0.139; p = 0.636
Beep-Test – HR after the test [bpm]	0.110; p = 0.707	0.072; p = 0.807
Beep-Test – HR 1′ after the test [bpm]	0.033; p = 0.910	0.051; p = 0.864
Beep-Test – HR 3′ after the test [bpm]	−0.243; p =0 .403	0.038; p = 0.897
Beep-Test – HR 5′ after the test [bpm]	−0.174; p =0 .552	−0.064; p = 0.827
WSR 3′ Klonowicz (restitution efficiency index 3′ after test)	0.397; p = 0.160	−0.009; p = 0.975
WSR Klonowicz (restitution efficiency index 5′ after test)	0.304; p =0.292	0.099; p = 0.736
Relative distance of Beep-Test [m/body weight]	−0.193; p = 0.509	−0.128; p = 0.663
Relative average running speed of the last level of Beep-Test [km/h/body weight]	−0.178; p = 0.544	−0.150; p = 0.608
Relative VO_2max based on Beep-Test [ml/kg/min/body weight]	−0.175; p = 0.551	−0.137; p = 0.641

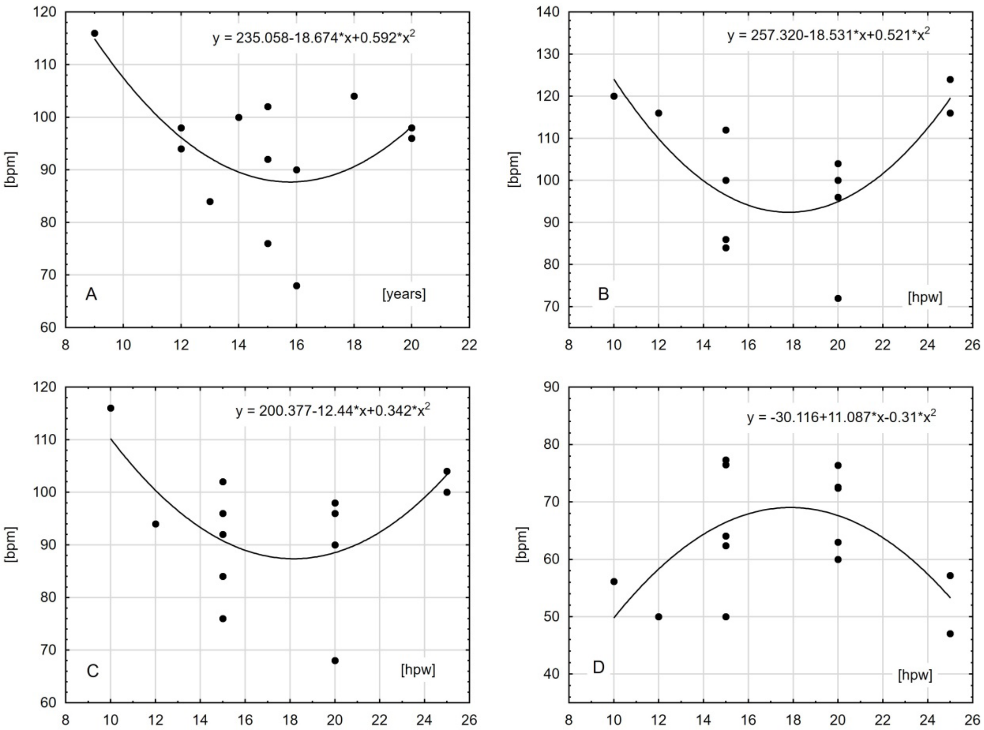

Figure 1. Relationships between the training period and HR value 5 min after the test (A) and weekly training total time and HR value 3 min after the test (B), HR value 5 min after the test (C) and Klonowicz WSR 3′ (D) of female Polish Judo National Team (n = 14).

0.004 respectively). For relation C, where the linear relationship was r = −0.064; p = 0.827, the curvilinear relationship was as follows r = 0.607, p = 0.080 with a determination factor of 36.9% (partial significance levels of regression equations were 0.028 and 0.029 respectively). For relation D, where the linear relationship was r = −0.009; p = 0.975, the curvilinear relationship is as follows R = 0.621; p = 0.069 with a determination factor of 38.6% (partial significance levels of regression equations are 0.025 and 0.024 respectively). The HR value 5 minutes after the Beep-Test increases again in female athletes with training experience of over 17 years. At the same time, the most effective weekly training total time was between 15 and 20 hours.

DISCUSSION

The results showed that training experience and weekly training total time (with accumulates training volume and exercise intensity) had significant influences on heart rate and level of effective restitution in the Polish Judo National Team.

In relation to the hypotheses set for this study, it should be noted that training experience did not show any significant link to the relative aerobic capacity indices. The only significant correlation was shown between those with training experience of over 17 years and HR 5 minutes after the test.

However, the second research hypothesis was confirmed. Significant relationships were shown between weekly training volume of the subjects and post-exercise heart rate of 3 min and 5 min after the test and with the Klonowicz effective restitution index 3 min after exercise.

After the distribution of scattering and the curvilinear regression equation, it was shown that the HR value 5 minutes after the test increased in the athletes with training experience over 17 years. Taking into account the average age (24.3 years) and the age distribution of the tested athletes (20.5 years to 29.75 years), it can be assumed that older athletes had more training experience and the HR values may result from biological aspects and a decrease in the level of cardiovascular performance.

This would be consistent with many earlier studies that showed that both regenerative capacity and aerobic capacity decrease with age in women [20]. It has also been demonstrated that changes in HR in adults progress with age [21]. Moreover, they have been demonstrated to be unavoidable, predictable and irrespective of gender, habits and physical fitness levels [22]. However, to fully verify the authors' assumptions, it would be necessary to compare the age of respondents with their heart rate values after the test. However, that was not done as it was not the main goal of the study.

The relationship between the weekly training total time and HR 3 min after the test and HR 5 min after the test and the rate of effective restitution 3 min after the exercise also was demonstrated. Athletes who had a weekly training total time of less than 15 hours and more than 20 hours showed a higher HR 3 min after the test and 5 min after the test. They also had a lower effective restitution index 3 min after the test. It should be noted that women declared a significantly lower weekly training total time (17.64 hours) than those in a study of Brazilian Olympic judo medallists (26.3 hours per week) at a similar point in their training (6 months before the Olympic Games) [16]. Considering that the optimal weekly training total time for the examined athletes was 15 to 20 hours and the fact that the tests were conducted at the beginning of the grouping, during a period when international competitions were not being held, it can be assumed that the athletes were in a state of undertraining or overtraining (such a conclusion is justified by the theory and methodology of training periodization [23]).

These observations have been confirmed by studies of heart rate variability depending on performance in elite judo Bae MJ, Kim HC and Park KJ athletes. Those studies showed that heart rate values were significantly higher in the athletes competing at higher, international levels, compared to athletes competing at lower levels. Moreover, the group of high-performance athletes, with higher resting HR scores and longer recovery time of HR to resting values, showed higher dominant activity of the sympathetic nervous system, which may indicate the state of overtraining [13]. However, in those studies, the authors did not take into account the training total time or intensity (disregarding the detailed indicators of training volume) of the participants, nor did they consider the level of competition and the potential levels of physical and mental strain on the athletes as determinants for dividing the respondents into groups.

However, as other research shows, regardless of the division into training groups and the periodization strategy of judo sports training, it was necessary to take care of properly planned regeneration periods [24]. On that basis, the results of this study can be used as determinants of the level of post-exercise adaptation in relation to the intensity of exercise, taking into account the training assumptions and the training period in which they are measured. This will allow for appropriate gradation of training loads, increasing the possibility of adaptation to physical effort, regardless of the period in which the athletes are.

CONCLUSIONS

This study indicated that it is necessary to plan carefully and regularly analyse the weekly training total time (as well volume and intensity) during a preparation period, as this significantly affected the level of post-exercise restitution of the judo national team athletes. The best results for post-exercise restitution were achieved by athletes whose weekly training total time was between 15 and 20 hours. Since the judo athletes in this study were at the beginning of the training camp during the preparation period, it can be assumed that some athletes were in a state of overtraining (which may result from excessive training load) or undertraining (which may result from insufficient weekly training load). With this in mind, it is necessary to determine the level of weekly training (total time, volume and intensity of exercises) for each athlete and to monitor whether that athlete is carrying out the program with the planned loads and regeneration form, so as to gradually increase exercise adaptability and the possibility of increasing weekly training load in preparation for the main event. This would enable the whole female team to train and implement similar loads (time, volumes and intensity), while correctly implementing the assumed training and competition plans (including control and main competition).

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