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Training experience and weekly training total time vs. aerobic capacity and level of effective restitution of male Polish Judo National Senior Team athletes during the preparation period for the Olympic Games

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

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Abstract

Background & Study Aim: The sport judo at the championship level contains many interconnected components, which ultimately determine the results achieved. One of these components is physiological condition, including the level of aerobic capacity and the index of effective restitution. The cognitive aim of this study was the knowledge about relationship between aerobic capacity and post-exercise restitution and the training experience, weekly training total time (which accumulates the components of the so-called training volume and exercise intensity), and body weight of the examined men, within 7 months before the planned Olympic Games in Tokyo. There were verify two hypotheses: H1) training experience improves the relative aerobic capacity of the competitors; H2) weekly training total time positive affects the 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 & Methods: The subjects were 9 men (age 20.5 to 26.5 years) on the Polish Judo National Senior Team at a training camp early in the preparatory period. The Maximal Multistage 20-m Shuttle Run Test (Beep-Test) was used to measure aerobic capacity, and the Klonowicz index was used to determine restitution efficiency. In addition, the relative aerobic capacity, relative average running speed and relative distance covered in relation to the subjects' body weight were determined. The training experience criterion was years of training (in this case over 15 years). Training total time was measured in hours.

Results: The both research hypotheses of this study were fully confirmed. The training experience significantly improved all relative aerobic capacity indices. There were also significant relationships between the weekly training total time of Polish National Judo Senior Team athletes and the level of effective Klonowicz restitution at 3 minutes and 5 minutes after exercise. The study showed that the higher the weekly training total time the athletes declared, the poorer the effective restitution index they had, both after 3 minutes and 5 minutes after the exercise.

Conclusions: Training experience and weekly training total time have a significant impact on aerobic capacity and post-exercise restitution. It is necessary to control and adapt training loads and to rest properly after exercise. Otherwise, overtraining could lead to a decrease in the load capacity of the athlete. In addition, relative indicators of an relating to the athlete's body weight may help to assess adaptation to aerobic effort during the preparation period.

Keywords: intensity • Klonowicz index • load • preparatory period • training program

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INTRODUCTION

The judo sports process at the championship level contains many interconnected components, which ultimately determine the results achieved. One of these components is physiological condition, including the level of aerobic capacity and the index of effective restitution. These often play an important role in the most important phases of a tournament. In judo sports fighting, according to the International Judo Federation Sport and Organization Rules, when there is no winner at the end of the regular time of the fight, an overtime in the *golden score* formula takes place. This overtime has no time limit; it continues until the winner is determined [1]. Thus, although judo, in its most important activities during the fight, is characterized by the use of anaerobic metabolism, a high level of aerobic capacity is equally important. This helps to use lactic acid for better regeneration during short rests between the intensive efforts characteristic of judo [2, 3]. In planning the training process, maximum oxygen uptake is used to determine the efficiency of the cardiovascular system [4]. Along with the assessment of effective restitution, it should serve as one of the basic control tools to assess the level of exercise adaptation. Consequently, these indicators provide the basis for planning, modifying and setting subsequent exercise loads and goals during preparation for the main competition [5].

The issues of this article concern the differences and selected conditions in the level of aerobic capacity and restitution level among the competitors of the Polish Judo National Seniors' Team, in the period of preparation for the Olympic Games in Tokyo in relation to their training experience and weekly training total time (which accumulates the components of the so-called training volume and exercise intensity).

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 influencing the aerobic and anaerobic capacity in martial arts were analysed in a very general sense [9] as well as the aerobic capacity of judo athletes and students of the faculty of sport and physical education [10]. The influence of aerobic capacity on the results obtained in the special judo efficiency test measured by the Sterkowicz Test (SJFT) [11-13] – see more about author this test [14] – and the level of aerobic capacity using the judo test consisting in the performance of the *uchi-komi* in *ippon-seoi-nage* technique on a machine with *judogi* sleeves mounted [15] were analysed. The analysis involved 4-week judo training plans in various intensity models [16] and the possibility of using the heart rate to monitor stress and regenerative abilities of judo athletes, depending on the training load level [17]. Moreover, tests were carried out to analyse the weekly training total time of athletes during the 6 months before the Olympic Games together with the subsequent results [18]. The importance of the issues discussed can be emphasized by the aerobic training program prepared for elite judo athletes, aimed at improving HR and VO_2max levels [19], which are the main variables analysed in this study.

What is important is that the authors found no studies of the relationship of aerobic capacity to the body weight of the subjects. Since sports

Anaerobic metabolism – *noun* the breakdown of carbon and fats into energy without the presence of oxygen [34].

Cardiovascular – *adjective* relating to the heart and the blood circulation system [34].

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].

competition in judo is divided into weight categories, the authors considered body weight to be a key reference point in the training process.

The cognitive aim of this study was the knowledge about relationship between aerobic capacity and post-exercise restitution and the training experience, weekly training total time, and body weight of the examined men, within 7 months before the planned Olympic Games in Tokyo. Therefore, in this paper, the authors verify two research hypotheses: H1) training experience improves the relative aerobic capacity of the competitors; H2) the weekly training total time positive affects the level of post-exercise restitution.

MATERIAL AND METHODS

The tests were carried out on the 9 male athletes (average age 22.82 years; the youngest 20.5- and the oldest 26.5 years) of the Polish National Judo Senior Team, who, after being appointed, stayed at the first preparation camp for the Olympic Games in Tokyo.

Study design and tools

Aerobic capacity was tested using the Maximal Multistage 20-m Shuttle Run Test. During the test, the subject was to move between lines 20 meters apart, according to the sound signal, with increasing frequency. The tested person must cross the line before the sound, otherwise he receives a warning, the second warning means the end of the test [20]. 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) [21].

In addition, after each test, the Klonowicz effective restitution index was measured at 3 minutes ($WSR_{3'}$) and 5 minutes ($WSR_{5'}$) after exercise, according to the formulas:

$WSR_{3'}$ = and $WSR_{5'}$ = 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 [22].

Ethical issues

The authors have obtained the consent of the Bioethics Committee at the Medical University of Poznań, issued on 12 September 2019 with the number 880/19.

Statistical analyses

In this paper, the arithmetic mean, standard deviation and Pearson's **r** correlation were calculated.

RESULTS

The average values of independent variables were 15 years for training experience, where 11 years was the shortest and 19 years the longest training experience and 14 hours for weekly training total time, where 10 hours was the smallest and 20 the largest weekly training total time. In addition, special attention should be paid to the level of effective post-exercise restitution, where the mean for the indicator calculated after 3 minutes was 60.514 and after 5 minutes 72.887, but the difference between the lowest and highest score in both calculations was almost 3 times (Table 1).

Pearson's r correlation 6 important links between training experience and weekly training total time and dependent variables were shown. The training experience increased the distance covered in the test (0.682; $p = 0.043$), the relative distance in relation to body weight (0.736; $p = 0.024$), the relative average speed of the last Beep-Test level in relation to body weight (0.667; $p = 0.050$) and the relative VO_2max level in relation to body weight (0.700; $p = 0.036$). Weekly training total time showed a negative relationship to the effective restitution index, both 3 minutes after exercise (−0.716; $p = 0.030$) and 5 minutes after exercise (−0.791; $p = 0.011$) (Table 2).

DISCUSSION

The both research hypotheses of this study were fully confirmed. The training experience significantly improved all relative aerobic capacity indices. There were also significant relationships

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 [35].

Judogi – is the formal Japanese name for the traditional uniform used for judo practice and competition [***Wikipedia*** see also [37].

Technique– *noun* a way of performing an action [34].

Uchi-komi (uchikomi) – repetition of basic technique in kendo and judo training [36].

Ippon seoinage – single back throw (one of fifteen hand throwing techniques – ***te-waza*** – in judo).

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 [31, p. 146].

Skill – *noun* an ability to do perform an action well, acquired by training [34].

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 [34].

Table 1. Training experience, weekly training total time, body weight, Beep-Test results and effective restitution indices for the male (n = 9) Polish National Judo Senior Team athletes.

Variable	Average	Minimum	Maximum	Standard deviation
Training experience [years]	15	11	19	2.693
Weekly training total time [h]	14	10	20	2.916
Body weight [kg]	85.667	77	101	7.921
Level in Beep-Test [in order of level]	11.333	9	13	1.414
Distance in Beep-Test [m]	2053.333	1560	2420	310.484
Average running speed of the last level of Beep-Test [km/h]	13.667	12.5	14.5	0.707
VO_2max based on Beep-Test [ml/kg/min]	57.413	49.722	62.906	4.661
Resting HR [bpm]	61.222	50	78	8.497
Beep-Test – HR after the test [bpm]	161.444	145	176	12.156
Beep-Test – HR 1′ after the test [bpm]	127.111	94	152	17.324
Beep-Test – HR 3′ after the test [bpm]	100	64	122	18.276
Beep-Test – HR 5′ after the test [bpm]	87.333	52	120	23.622
WSR 3′ Klonowicz (restitution efficiency index 3′ after test)	60.514	30.12	88.889	18.320
WSR 5′ Klonowicz (restitution efficiency index 5′ after test)	72.887	34.94	98.413	21.034
Relative distance of Beep-Test [m/body weight]	24.238	22.526	17.931	31.429
Relative average running speed of the last level of Beep-Test [km/h/body weight]	0.161	0.157	0.134	0.188
Relative VO_2max based on Beep-Test [ml/kg/min/body weight]	0.676	0.639	0.558	0.817

Table 2. Training experience and weekly training total time vs. Beep-Test results and effective restitution indices (with Pearson's r correlation) for the male (n = 9) Polish National Judo Senior Team athletes.

Variable	Training experience	Weekly training total time
Level in Beep-Test [in order of level]	0.657; p =0.055	0.1213; p = 0.756
Distance in Beep-Test [m]	0.682; p = 0.043	0.0967; p = 0.805
Average running speed of the last level of Beep-Test [km/h]	0.657; p = 0.055	0.1213; p = 0.756
VO_2max based on Beep-Test [ml/kg/min]	0.657; p = 0.055	0.1213; p = 0.756
Resting HR [bpm]	−0.377; p = 0.317	0.0908; p = 0.816
Beep-Test – HR after the test [bpm]	0.008; p = 0.984	−0.4444; p = 0.231
Beep-Test – HR 1′ after the test [bpm]	0.059; p = 0.880	0.2574; p = 0.504
Beep-Test – HR 3′ after the test [bpm]	0.279; p = 0.467	0.5771; p = 0.104
Beep-Test – HR 5′ after the test [bpm]	−0.094; p = 0.809	0.6280; p = 0.070
WSR 3′ Klonowicz (restitution efficiency index 3′ after test)	−0.375; p = 0.320	−0.7164; p = 0.030
WSR Klonowicz (restitution efficiency index 5′ after test)	0.027; p = 0.945	−0.7913; p = 0.011
Relative distance of Beep-Test [m/body weight]	0.736; p = 0.024	−0.2383; p = 0.537
Relative average running speed of the last level of Beep-Test [km/h/body weight]	0.667; p = 0.050	−0.4620; p = 0.211
Relative VO_2max based on Beep-Test [ml/kg/min/body weight]	0.700; p = 0.036	−0.3677; p = 0.330

between the weekly training total time of Polish National Judo Senior Team athletes and the level of effective Klonowicz restitution at 3 minutes and 5 minutes after exercise. The study showed that the higher the weekly training total time the athletes declared, the poorer the effective restitution index they had, both after 3 minutes and 5 minutes after the exercise.

The results showed that the training experience and weekly training volume had a significant influence on the level of aerobic capacity, the level of aerobic capacity taking into account the body weight and the level of effective restitution in the Polish National Judo Senior Team.

The training experience showed a significant correlation with the most detailed component of the test, which is the distance covered by the test subjects. According to the analysis of judo fights at senior tournaments, the competitors start fighting more and more often and impose a fast pace. To increase their chances of success they must be able to maintain such a pace until the end of each fight for the entire tournament [23]. This means that competitors must have a high aerobic capacity, which can be a decisive element in the final stages of the fight, as well as during the post-exercise regeneration of the body for the next fight [24, 25]. To achieve this, they must be properly prepared, but also managed, so that the effort they make is as effective as possible.

When the study was conducted, the athletes were aware that this would be an effort that would last as long as possible and the result of the effort could be influenced by the ability to maximise work during the effort. This ability should be the result of various components of the training process, such as exercise tests, fitness tests and training with various instructors who teach them how to optimize their physical effort, as well as from sports fights (in this case mainly from *golden score* fights). These experiences should result in an action strategy that the competitor uses during the test, which is characterized by gradually increasing fatigue. Likewise, the athlete should apply an appropriate work strategy during the competition, where his fatigue will increase in proportion to the phase of the tournament.

The study also showed significant links between training experience and all relative measurements of aerobic capacity – distance, speed and capacity in relation to the test body weight. In many prior studies, it has been noted that the aerobic capacity decreased as the body weight of an athlete increased [26, 27]. It has been repeatedly indicated that competitors in combat sports reduce their body weight before a competition. Many times this is done in an inappropriate manner [28], without taking into account the effects of fat and lean body mass on the level of exercise tolerance [29], which may reduce their ability to maintain effort at the maximum level. Moreover, it has been demonstrated that the highest levels of aerobic capacity are achieved by competitors with lower levels of fat tissue, particularly those below 12.5% [30]. This confirms earlier findings that it is important to regularly control body weight and its components as they have an effect on aerobic capacity. Therefore, the authors believe that determining and analysing the relative aerobic capacity will provide the possibility of improved monitoring of the effectiveness of training activities, in terms of aerobic capacity. This will give the possibility to determine the optimal body mass for a given athlete, by means of the results for aerobic capacity achieved by him, with a simultaneous observation of changes in the capacity level in relation to body mass during the test. This may help to determine the optimal weight category, based on the relative capacity results. For such a method to be justified and useful in the training process, it is necessary, in the opinion of the authors, to carry out subsequent analyses of changes in the relative aerobic capacity in relation to particular elements of body mass composition. This could verify the hypothesis that relative aerobic capacity could serve as an indicator of the optimal weight category for an athlete.

Weekly training total time in the male group showed a significant negative correlation with the level of effective restitution at 3 minutes and 5 minutes after the test. The results of the weekly training volume in men can be compared with the average results of judo athletes from Brazil (women and men) at the Olympic Games, who were analysed by Franchini and Takito [18] for 44 years (6 months before each Olympic Games). In those studies, the authors divided the respondents into two groups – medallists and non-medallists. Medallists trained more per week (26.3 hours) than non- medallists (22.9 hours). In both cases, it should be noted that the weekly training total time was much higher than that declared by

the examined Polish National Judo Senior Team athletes (14 hours). It should be noted that for the subjects of this study a correlation was observed that showed that the greater the weekly training volume of an athlete the lower the level of post-exercise restitution, after both 3 minutes and 5 minutes from the end of the effort.

The research on the regeneration time of judo (male) athletes was conducted by Morales et al. [17] with regard to exercise loads. They divided the athletes into 2 training groups, where one implemented the high level of load and the other a moderate level. The training program for both groups was 4 weeks. The study showed that the training group with the high load achieved a general recovery, as well as sport-specific recoveries, enabling a return to full capacity at full load, at much lower levels than the athletes with moderate loads.

This may indicate that the training loads of the athletes are too high or that the athletes are overtraining. It was confirmed by testing elite judo athletes in a 12-week aerobic-capacity-oriented training program. The results showed that such a program, properly planned and conducted, could improve both aerobic capacity and post-exercise restitution over the 12-week period to a significant extent [19]. It can be concluded that in the early period of preparation, the athletes are subjected to excessive loads, the loads to which they are subjected are not graded, they do not meet the indicated training assumptions (contrary to the principles of periodization, theory and methodology of training [22, 31]). This results in a low level of adaptation to training loads, or the regeneration periods are inadequately selected.

The authors also see a deficit in research into optimal training volume and weekly training total time in the preparation period. These studies would help to determine the optimal volumes, weekly training total time and loads for athletes at the highest sports levels in the process of preparation for the most important sports competitions.

CONCLUSIONS

Training experience and weekly training total time affect the capacity and level of exercise restitution of senior national team athletes. Larger training experience affects the distance covered by the examined men and the distance, speed and fitness level in relation to their body weight. Based on this, it can be concluded that athletes with more training experience can better control their own body during maximum effort (also control internal proportions of body composition [32], effects of caloric restriction [33] and many factors that can subject to self-observation). This may indicate the validity of greater and earlier education of athletes in managing their own maximum effort. In addition, it has been shown that it is reasonable to relate the capacity results to the body weight of athletes, and this can be used to determine the optimal body weight and weight category.

In addition, increasing the level of weekly training total time of the examined athletes led to a decrease in the effectiveness of their post-exercise restitution. Taking into account the fact that the examined athletes were at the beginning of the training camp during the preparation period it can be concluded that they were in a state of overtraining. Therefore, it is advisable to regularly analyse the level of fatigue of athletes, who are carrying out training programs with assumed loads, and to analyse weekly training total time and recovery periods outside the national team groupings.

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