# Maximal oxygen uptake changes during judoist's periodization training

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## Abstract

**Background and Study Aim:** To evaluate the maximal oxygen uptake ($\dot{V}O_2$max) of judoists in consecutive training periods: a) GPP, b) SPP, c) CP and to exanimate the efficiency of special training of judoists group and assessing their fitness level

**Material/Methods:** Fifteen male judoists aged of 22±7 years took part in this study. Their competition levels varied from departmental (group D, $n$=7) to inter-regional (group IR, $n$=8) experience. The standing height was measured with a wall-mounted wooden stadiometer. An electronic weighing scale was used to assess the body mass (W) in each period of preparation. The $\dot{V}O_2$max was measured indirectly using the multistage 20-meters shuttle run test.

**Results:** The performance level had a statistically significant bearing ($p<0.001$) of judo competitors weight, but not with the time factor. The pattern of changes in weight in both groups IR and D was different during the training period. We also noticed that the weight of group D members decreased in SP period and increased in CP. We didn't observed a significant difference of $\dot{V}O_2$max between group D and IR (95% Tukey HSD intervals are overlapping). The competition level affects significantly the HRmax ($p<0.001$). Group D presented higher HRmax values in three testing periods (GPP, SP and CP) than IR group. The time factor was close to reach significance level.

**Conclusions:** The $\dot{V}O_2$max is different in terms of individual training periods, but cannot be considered as physiological indices to determine the competition level of each judoka. HRmax has an impact on their sporting level, but cannot be used as a physiological parameter for aerobic fitness checks. $\dot{V}O_2$ maximum is very sensitive to changes in training loads, more than HRmax during training periods and is suitable for use as an indicator of adaptation changes in workload. Use of the test can greatly help trainers in the diagnosis, monitoring and appropriate classification of its competitors what directly lead to improving achieved results.

**Key words:** $\dot{V}O_2$max • heart rate • training period • Judo • weight reduction

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## Background

Periodisation training is a systematic planning of a short- and long-term training, and consists on modulating workload, including optimal rest and recovery. The plan serves as a template for the athlete and fitness coach, and provides a structure to manage the stress and the recovery needed to induce the training adaptation [1].

In competitive sports, the assessment of aerobic fitness is necessary to determine the workload for the athletes and check the developments of these finesses. The judo fight solicits considerably the cardiorespiratory system and the aerobics processes in the production of energy [2].

Maximal oxygen uptake ($\dot{V}O_2$max) is commonly used to express the cardiovascular fitness, the measurements

**$\dot{V}O_2$max** – is the maximum capacity of individual body's to transport and use the oxygen during maximal exercise, which reflects the physical fitness of the individual. $\dot{V}O_2$max is expressed either as an absolute rate in liters of oxygen per minute (l/min) or as a relative rate in milliliters of oxygen per kilogram of bodyweight per minute (ml/kg/min) [27].

**Training periodization** – the organization of the training year into different periods to attain different objectives. One commonly schema of periodization divides the year into three periods: preparation period, competition period and transition period. Each period is subdivided into three phases [24]. Yearly judo training cycling generally divided in double perdiodization.

appear limited by different mechanisms in which $\dot{V}O_2$max is controlled by maximal cardiac output, while skeletal muscle metabolism plays a big role in determining submaximal exercise performance fitness status and workload of the athletes [3,4].

Laboratory tests showed that judo athletes have a moderate aerobic fitness [5]. The $\dot{V}O_2$max of elite judo players has been reported to be range 50 to 60 $ml \cdot kg^{-1} \cdot min^{-1}$ [6–9].The importance of the aerobic capacity in judo has been revealed among others by Mickiewicz [10] who showed that during exercises tests simulating judo fight, the judo player needs more than 90% of their $\dot{V}O_2$max. It is, therefore, likely that despite their no sport specific design, the $\dot{V}O_2$max is an important physiological measurement for judo player.

Authors [11,12] have suggested that judo players with a higher $\dot{V}O_2$max would have an advantage in a period of fight with maximal duration (5-min), because the same absolute supra-maximum effort would represent a lower relative intensity compared to an athlete with a lower $\dot{V}O_2$max. Together with the faster CP resynthesis, a faster lactate removal and pH recovery in athlete with higher aerobic power could benefit the recovery process. An increase in aerobic contribution is said to be another factor to improve athletic performance in athlete with higher aerobic fitness [13].

Analysis of lactate concentration in specific situations of judo has been reported in order to obtain information on the metabolic demand and implications for training intensities [14]. It should be noted that from the Osaka World championship [15], the fight time was again disrupted and contemporary rules of IJF obliging fighters to prolong combat of 3 minutes maximum in case of equality (golden score*).

The literature manifested a lack of physiological studies on combat sports [16]. In addition, a physiognomy of judo fight results of several various factors: a) irregularity and uncertainly of combat and usually intermittent exertion time; b) variation of opposition strength of each opponent, c) variation technical skills of each opponent d) uncertainly number of combat in the same day. Therefore, it is very difficult to quantify exactly the effort produces in order to establish a typical model of physiological responses of judo athlete. That's how it is delicate to determinate exactly the energetic metabolism predominant in judo fight.

Authors have rarely reported about training periods, in which they tested $\dot{V}O_2$max of judo athletes. Several studies [8,17] have evaluated $VO_2$max of judo competitors in preparation period. Another recent study [18] assessed the $\dot{V}O_2$max in the competitive period However; no studies examined the $\dot{V}O_2$max in special and competitive training period

The main purpose of this study is to evaluate $\dot{V}O_2$max responses in consecutive training period; general preparatory period GPP, special period SP, competitive period CP and to check the specific effectiveness of training in judoists group and diagnosing their sporting level

**Research questions**

1. Do the three training periods (general preparatory period, special preparatory period, competitive period), when consecutive, induce significant changes in the physiological fitness of judo athlete?
2. Is the physiological performance related to the sport level of judo athletes?

**Hypothesis**

1. There is a significant difference in $\dot{V}O_2$max while comparing in one side the general preparatory and the specific training period, and in another side, the general preparatory and the competitive period.
2. The maximal heart rate (HRmax) can be affected by the sport level;

## Material and Methods

### Subjects

Fifteen (n=15) male judo athletes (Algerian judo players) of 22±7 years old participated in our study. Their rank ranged from 1st kyu to *Shodan* (first degree black belt) and trained regularly four to five times per week. All subjects completed amedical screening questionnaire and signed a form of informed consent. The study was approved by the Ethics and Research Committee of the Faculty of Health Sciences of the University of Algiers and all subjects agreed and signed agreement before entering the study. Their competition levels vary from departmental (group D, *n*=7) to inter-regional (group IR, *n*=8) experience (Table 1).

**Table 1.** General characteristics of judo athletes (mean and SD).

| Groups level | Departmental (n=7) | Inter-regional (n=8) |
|---|---|---|
| Age(years) | 21±5 | 22±5 |
| Judo experience (years) | 6±3 | 9±3 |
| Height (cm) | 179.29±8,85 | 174.36±9,43 |
| Weight (kg) | 73.80±11.60 | 70.81±8.61 |

* Golden Score is a sudden death situation where the clock is reset to match-time, and the first contestant to achieve any score wins.

**Table 2.** Physiological responses in consecutive training periods of both groups D and IR (mean and SD).

| | General preparatory period (GPP) | | | Special period (SP) | | | Competitive period (CP) | | |
|---|---|---|---|---|---|---|---|---|---|
| | W (kg) | HRmax (bpm) | $\dot{V}O_2$max (ml·kg$^{-1}$·min$^{-1}$) | W (kg) | HRmax (bpm) | $\dot{V}O_2$max (ml·kg$^{-1}$·min$^{-1}$) | W (kg) | HR max (bpm) | $\dot{V}O_2$max (ml·kg$^{-1}$·min$^{-1}$) |
| D | 73.78 (0.5) | 200 (21) | 51.64 (0.31) | 72.78 (0.5) | 200 (21) | 52.38 (0.31) | 73.64 (0.5) | 198 (21) | 51.90 (0.31) |
| IR | 70.81 (0.45) | 187 (6) | 51.83 (0.29) | 71.35 0.47 | 186 (6) | 52.39 (0.29) | 70.94 (0.47) | 187 (6) | 51.85 (0.30) |

Sport level: D – Departmental, IR – Inter-regional; W – weight.

### Procedures

#### Body weight and height

The standing height was measured with a wall-mounted wooden stadiometer to the nearest 0.1 cm, and an electronic weighing scale (Tanita) was used to assess the body mass to the nearest 0.01 kg in each training period.

#### Aerobic fitness assessment

Aerobic fitness was measured by the multistage 20-meters shuttle run test proposed and validated by Leger and Lambert [19] for estimating the maximal oxygen consumption on the field. The test requires subjects to run back and for the between distance set at 20 meters apart. Running pace was determined by signal snores (beepers), emitted from a pre-recorded cassette tape, the initial speed being 8.5 km/h and increased by 0.5 km/h stage (shuttle). The cassette tape was calibrated over one minute of prior to each test. Subjects were instructed to run in straight line, pivot upon reaching the other end of the line and to pace themselves in accordance with time interval. The test was concluded when the subject failed to reach the end line concurrent with the beepers on twice consecutive. The final score was recorded as the number of shuttle and level completed and converted to an$\dot{V}O_2$max equivalent. The heart rate was recorded continuously during the test using heart rate monitor Polar RS800 (Electro, Kempele, Finland).

All subjects performed this test in the general preparatory period, after 6 weeks of special training period and after 6 weeks of the beginning competitive period.

#### Statistical analysis

Analysis of variance (ANOVA) with repeated measures was used to test difference in physiological responses in consecutive training periods. The limit for the significant value was set at $p<0.05$ and values are expressed by mean ±SD. In case significant ANOVA a multiple comparison procedure to determine which means are significantly different from which others was used.

## Results

The results are presented in Table 2.

It was found that the sport level had a statistically significant bearing ($F=36.20$, $p<0.001$) with the judo competitors weight, but not with the time factor. The patterns of changes in weight in both groups IR and D were different during the training periods. This is showed in the different shapes presented in Figure 1.

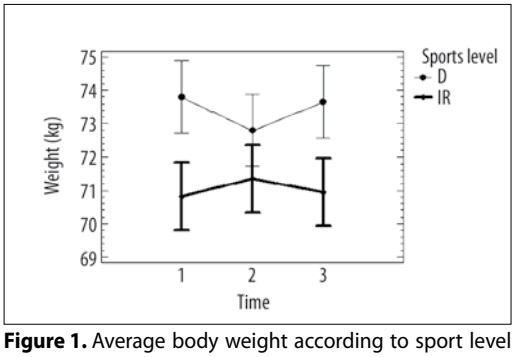


**Figure 1.** Average body weight according to sport level and 95% Tukey HSD intervals. Remark: 1 – GPP, 2 – SP, 3 – CP, D – Departmental, IR – Inter-regional.

However, the differences observed between the specified periods within each group were not statistically significant. We also observed that weights of group D members decreased in SP period and increased in the CP one. The differences in weights between group D and IR are not statistically significant (95% Tukey HSD intervals are overlapping)

The sport level affects significantly the values of HRmax reached at $\dot{V}O_2$max ($F=1305.18$, $p<0.001$). Group D manifested higher values of HRmax in all testing phases (GPP, SP and CP) than group IR. Time factor is very close to statistical significance level ($F=3.33$, $p=0.051$) as well as its interaction with the Sport level factor ($F=2.57$, $p=0.096$). Figure 2. shows the shape of lines (unparallel) characterising the changes in HRmax observed during the training cycle.

**Heart rate** – is the number of heart beats per unit time, usually expressed as beats per minute (bpm). The heart rate is based on the number of contractions of the ventricles [27].

**Judo** – Literally meaning "the way of softness and flexibility", a martial art (budo) created by Jigoro Kano, based on his development and adaptation of several styles of juju-tsu as well as his own philosophical ideals [28].

**Weight reduction (weight control)** – The ability to control body weight using the appropriate balance of weight-losses associated with the energy expended in training and weight-gains related with the intake of food [27].

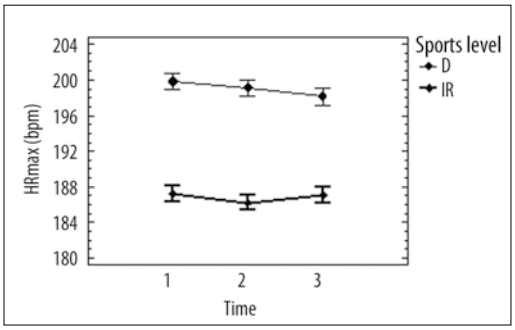


**Figure 2.** Average heart rate according to sport level and 95% Tukey HSD intervals. Remark: 1 – GPP, 2 – SP, 3 – CP, D – Departmental, IR – Inter-regional.

We have observed similar shape of lines characterising the $\dot{V}O_2$max changes during the training cycle in both groups D and IR (Figure 3). $\dot{V}O_2$max values increase from GP to SP and decrease between SP and CP (F=2.50, p=0.101).

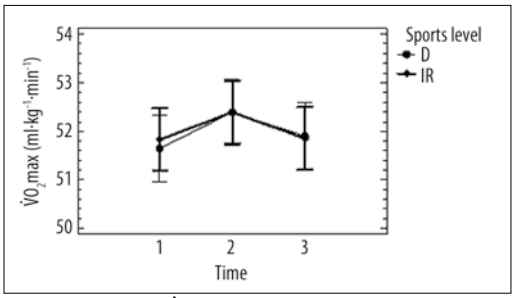


**Figure 3.** Average $\dot{V}O_2$max of judo athletes according to sport level and 95% Tukey HSD intervals.1 – GPP, 2 – SP, 3 – CP, D – Departmental, IR – Inter-regional.

## Discussion

### Time factor

This doesn't show a significant change of body weight between different training periods. Although, it well-recognized that a large number of judo athletes have periodically to reduce their body weight as required by judo competitions rules [20]. Indeed, judo combats are organized by weight category, i.e., it is more advantageous for a judo athlete to move toward the limits of his or her weight class when competition approaches. Nevertheless, we observed individual changes during the training periods. One study showed that the lightweight judo athletes (<73 kg) presented a higher fat free mass percentage [21] than heavyweight judo athletes (>73 kg). So, the later have constraints to train more times and to make use of different weight reduction methods in order to maintain the optimum weight and to match to the competition rules related to the body weight.

### Maximal heart rate (HRmax)

The Heart rates reached at $\dot{V}O_2$max did not change in different training periods (p>0.05).

The HRmax seems less sensitive at workload change than $\dot{V}O_2$max in different training periods. According to Valentini et al. [22], the available evidence clearly indicates that factors affecting heart rate are multifold, a major role being played by neural influences, either central or reflex in nature. The autonomic neural control of heart rate has a complex interpretation, and thus does not permit considering the heart rate itself as a precise marker of sympathetic activity. Nevertheless, because of its easy quantification and to its sensitivity to changes in neural cardiovascular control, heart rate measurement remains a valuable, although not always specific tool to measure neural cardiovascular modulation, with obvious diagnostic, prognostic, and therapeutic implications also for daily practice. In the same perspective, Borresen et al. [23] observed regular physical activity training elicits a decreasing of heart rate rest (RHR) and at submaximal exercise but HRmax slightly decreases or remains unchanged with endurance regular training.

### Maximal oxygen consumption ($\dot{V}O_2$max)

Training load is a combination of training volume and training intensity. In GPP, both volume and intensity increase simultaneously, but volume increases initially much faster. At some spot, usually slightly after the midpoint of this period, it is impossible to go on increasing both volume and intensity. As a result, the aerobic power ($\dot{V}O_2$max) is higher in this period than in CP.

During the SP, the volume increase until reaching a maximum, but we privilege the intensity at the end of this period to transit at the beginning of the competitive period, so we can expect this slightly increase of $\dot{V}O_2$max. Our result is also comforted by, the study of Nurkić et al. [17] who concluded to a significant difference of $\dot{V}O_2$max between the preparation period and the competitive training period (initial: 55.23±3.78 vs final; 57.18±2.53 ml·kg$^{-1}$·min$^{-1}$)

During the competitive period, the goal is to attain the maximum intensity at the end of the preparation period – the beginning of the competition period. During the competition period, both volume and intensity will fluctuate close to their maximum values: as intensity rises, volume decreases (100% of intensity and 70% off phenomenon of tapper off). As each of the competitions which are the justification for this period's name approaches, volume decreases and intensity rises – and after the competition this trend reverses. This is most

pronounced just before the most important competition, and is often termed the "taper", implying that, while intensity rises to its highest values, volume decreases so much that the total training load. So we can explain the slightly decreasing of $\dot{V}O_2$max in this period.

**Times factor and sport level**

***Body weight***

The body weight changes significantly statistically ($p<0.001$) in consecutive training periods (GPP, SP and CP) considering the sport level factor. Probably, this difference between two groups D and IR linked at the different commitment in competition. Because the IR group partake more competition (local competition tournament and official competition). The body weight must be controlled in several occasions. Opposing to group D who takes part rarely in competition and isn't constrained to reduce the body weight.

***HRmax***

The training experience and the sport level affect significantly the values of heart rate responses in different training periods (GPP, SP and CP). According to McArdle et al. [24] the well-trained subjects had lower heart rate responses than less trained athletes. In the same view, the author of one recent study [16] recorded in special judo test higher values of heart rates in sub-elite than elite judo players and concluded that the later have a best effort cardiovascular adaptation. A high negative correlation for number attacks per combat (during their first three minutes) with HRmax percentages and HR at the threshold of decompensate metabolic acidosis (TDMA) can explain the cardio-respiratory efficiency of body judoist in combat [18].

**Maximal oxygen consumption ($\dot{V}O_2$max)**

The $\dot{V}O_2$max values obtained in this study are statistically equal for both D and IR groups (51.90±0.31 vs 51.85±0.30 $ml \cdot kg^{-1} \cdot min^{-1}$). The values found in the present study are near or/and similar than those described in the literature for high-level judo players. For example, one current study [9] reported the $\dot{V}O_2$max values of 50.6±9.3 $ml \cdot kg^{-1} \cdot min^{-1}$ for Algerian elite judokas. Consequently, the greatest involvement of aerobic fitness in high judo performance is doubtful and need more deepen investigation. In previous researches investigated by some authors [25,26] a significant difference of $\dot{V}O_2$max between elite and sub-elite judo players have not been demonstrated. Interestingly, one recent study [16] reported a wide scatter of peak $\dot{V}O_2$max who ranged from 34.6 to 58.3 $ml \cdot kg^{-1} \cdot min^{-1}$ in judo players of the same competition level, confirming that $\dot{V}O_2$max alone cannot be an accurate predictor of high judo performance. We can also consider that $\dot{V}O_2$max is affected by the decreasing of the attacks number during the 4–5 minutes and golden score in combat [18]. The factors; (i) relatively large error (SD) (ii) the small change in $\dot{V}O_2$max during the different phases of the preparation, and (iii) the limited value in discriminating performance differences in judoist emphasize that $\dot{V}O_2$max results need to be interpreted with caution in high and low judo player's level.

## Conclusions

The $\dot{V}O_2$max varies in consecutive training periods but is must not considered as physiological indices for determining the performance level of judo players. In the research of judo talent identification, a moderate aerobic fitness should not signify a low judo performance. Nevertheless, tests more specifically related to judo could be expected to provide more information.

The HRmax is influenced by the Sport level but it must not be used as physiological parameter for the aerobic fitness monitoring. As a remark concluding, the $\dot{V}O_2$max is very sensitive to the workload changes than HRmax in the training periods and it is useful to use it as an adaptation marker of workload variations.

**Recommendations**

Although the $\dot{V}O_2$max can provides practical information of aerobic conditioning of judo players, but it is insufficient to arbiter efficiency her development in training periodization. In other hand, our finding suggests that it not necessary to repeat $\dot{V}O_2$max measurement in each training periods. Also, we strongly recommend for future research to investigate more physiological parameters for determining reliable indices for monitoring the aerobic fitness progress.

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