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# Seasonal variability of maximal power of upper and lower limbs in ju-jitsu athletes

**Artur Litwiniuk[1] ABCDE*, Juris Grants[2] ACDE, Behnam Boobani[2] ACDE, Oscar Romero Ramos[3] ACDE, Wieslaw Blach[4] ACDE, Zbigniew Obminski[5] ABCDE***

**Authors' Contribution:**

A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

[1] Jozef Pilsudski University of Physical Education in Warsaw, Faculty of Physical Education and Health, Biala Podlaska, Poland
[2] Riga Stradins University, Riga, Latvia
[3] Sport department, Faculty of Education Sciences, University of Malaga, Malaga, Spain
[4] University of Health and Sport Sciences, Wroclaw, Poland
[5] Institute of Sport-National Research Institute, Warsaw, Poland

*** Corresponding author:** Artur Litwiniuk; Jozef Pilsudski University of Physical Education in Warsaw, Faculty of Physical Education and Health, Biala Podlaska, Poland; email: artur.litwiniuk@awf.edu.pl, and Zbigniew Obminski; Institute of Sport-National Research Institute, Warsaw, Poland; email: zbigniew.obminski@insp.pl

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## Dictionary:

**Athlete** – *noun* 1. someone who has the abilities necessary for participating in physical exercise, especially in competitive games and races 2. a competitor in track or field events [76].

**Brazilian jiu jitsu (BJJ)** – is a type of fight in which a uniform or gi is used; its main purpose is to project or take your opponent down. Once on the ground, you must seek to control your adversary with different techniques (immobilizations, chokes, joints locks). In the absence of submission at the end of the fight, the winner is declared by the number of points won [77].

**Combat sports** – noun a sport in which one person fights another, e.g. ju-jitsu, wrestling, boxing, taekwondo and the combat sports [76].

**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 [76].

**Abstract:**

**Background and Study Aim:** An athlete's effectiveness during competitions is determined by the level of not only motor preparation, but also technical, tactical and psychological preparation. The aim of study was knowledge about putative seasonal differences in maximal power of upper and lower limbs in a group of male Brazilian ju-jitsu athletes across 12 months.

**Material and Methods:** Thirteen male Brazilian ju-jitsu (BJJ) practitioners of body mass from 67- to 100.1 kg and aged 22.4-25.6 years were subjected to the study. Assessment of their anaerobic power with the use of supramaximal (10s) legs cycling and arms cranking tests four times in a year. Examination of cycling test was performed using MONARK ergometer, and cranking test using the same type ergometer adopted to effort with upper limbs. The whole study has been undertaken in winter (January) and subsequent in spring (May), summer (July) and autumn (October). Log-transformed data were analysed using two-way (limb × season) analysis of variance ANOVA, followed by Bonferroni correction as post-hock test.

**Results:** The study did show well reproducibility of all the biomechanical factors of power and, thus, there were no significant differences between the four examinations. However, athletes showed slightly tendency of progressive improving their lower and upper power of limbs from test to test. In the 4th testing relative maximal lower limbs power was on average higher by 3% (11.44 Watt/BM) than that in the 1st one (11.09 Watt/BM), and for upper limbs the relevant progress accounted 5% (8.75 Watt/BM vs 8.33 Watt/BM). Time to peak power for lower limbs ranged from 3.04 to 6.09 seconds, and for upper limbs from 2.12-5.98 seconds. Time to peak power significantly depended on body mass for lower limbs, and for upper limbs. As expected, power and work output were significant higher for legs cycling as compared to arm cranking at every examination. Moreover upper limbs showed higher susceptibility to fatigue as was expressed as co-called fatigue index. Given the mean value from four tests, fatigue index for were 11.15% and 15.92% for lower and upper limbs respectively. There were significant between-athlete differences in ratio of upper body maximal power-to-lower body maximal power, and that feature did not depend on the season.

**Conclusions:** BJJ athletes who regularly train throughout all the year exhibited lack of significant differences in performance of ultra-short, supramaximal efforts. The above refer both to upper and lower limbs. Slightly, non-significant improving of tests performance may be

**INNOAGON** – (innovative agonology) is an applied science dedicated to promotion, prevention, and therapy related to all dimensions of health and the optimization of activities that increase the ability to survive (from micro to macro scales) [68, 69].

explained by better adaptation and higher motivation to these physical efforts. Subject of higher body mass and maximal absolute power can overcome wheel inertia faster and reach peak power earlier. Athlete did exhibit significant various proportions between their maximal powers generated by upper and lower limbs independently on the season.

**Keywords:** arms cranking, leg cycling, combat sports, INNOAGON, Wingate test

## 1. Introduction

Repeated measurements of anaerobic capacity of the upper and lower limbs are of great diagnostic importance in competitive athletes for assessing training effects in various phases of preparation for competitions and throughout the annual training and competition cycle. The most commonly used research tool in laboratory conditions are short, maximal all-out efforts performed on an ergometer equipped with a sensitive recorder of instantaneous power. From this variable, other mechanical indicators are calculated, such as mean power, total work out put, time to peak power and fatigue index. This type of test is defined as the Wingate Anaerobic Test (WAnT) and when used, a standard procedure applies regarding warm-up before the test and braking force of flywheel [1]. In addition, verbal encouragement is always used by the person conducting the test from the beginning to the end of the effort [2]. The planned duration of WAnT ranges from 10 to 60 seconds [3-9]. Interestingly, the works cited above revealed that the same subjects achieve a lower peak power when the test time is longer. This may suggest that anticipation of longer-lasting effort and greater fatigue before its completion encourages subjects to use their own energy resources cautiously. In the case of performing WAnT lasting 30 seconds by combat sports athletes, studies have shown three sources of energy systems responsible for generating mechanical power. Their relative share decreases in the following order: from the phosphagen system (ATP-PC), then the anaerobic lactate glycolysis system, to aerobic processes [10].

Very high precision of measurements and frequency of instantaneous power recording (1000 Hz) and adherence to the recommended procedure allow for comparative studies of mechanical indicators of athletes of both sexes, different disciplines and sports class. A comparison of anaerobic power results in WAnT obtained by athletes of different disciplines is included in review papers [11, 12]. These data classify athletes of both sexes according to the level of WAnT performance. The peak power for elite athletes is >11.07 Watt/kg of body weight for women and >13.74 Watt/kg of body weight for men. According to the latest studies, elite athletes of both sexes achieve a significantly higher peak power (>16 Watt/ kg) [13]. There is a simple explanation for this phenomenon, that anaerobic capacity depends on the type of training adapted to the structure of the starting effort. In those sports where endurance is more required than the highest power, anaerobic capacity will be lower. This is confirmed by a comparison of groups of sprinters and athletes training for medium and long distance runs. Sprinters running distances from 100 to 400 m develop greater power in the WAnT than runners running longer distances (>800 m) [14].

High precision of instantaneous power measurements, high frequency of its recording (1000 Hz) and very good repeatability of results demonstrated in three consecutive days make it possible to compare the anaerobic capacity of different groups of athletes [15]. There are many factors that must be taken into account in comparative studies, because they significantly affect the test result. Unfortunately, despite the established methodology of the WAnT test, the authors use different values of braking force of flywheel. In previous studies, the value of this indicator for the lower limb test was 7.5% of the subject's body weight. Currently, such a value is also used, but for competitive athletes, especially those who train strength and/or speed, the value of this load is too low, does not allow for optimal use of the power potential and provides underestimated results of maximum power. Studies have shown that with a higher braking force, from 8.0 to 11% of body weight, athletes achieve a higher peak power for the lower limbs [16-19]. The optimal relative braking force for the upper limbs is 6.5% of body weight in athletes and about 5.5% in men practicing physical recreation [20]. For this reason, comparative results between sports are valuable, conducted using the same, standardized procedure, according to which the duration of WAnT and the braking force of the flywheel are identical. In the absence of standardization of the protocol and different ergometers, reliable comparisons between sports are impossible [21]. Another methodological requirement is the same time of day of performing the test effort. It has been revealed that in most competitive athletes from different disciplines the ability to perform maximal effort in the morning and before noon is slightly lower than in the afternoon or evening [22-24]. A detailed analysis of exercise and cognitive abilities takes into account the determination of the specific chronotype of each athlete [25]. In order to reduce the time-dependent changes in physical and mental abilities, various procedures are used in coaching practice, among which the most effective is an intensive morning warm-up [26].

For diagnostic purposes, anaerobic capacity is often tested in professional athletes several times a year. This is particularly the case before and after an important training period, which allows for monitoring the training effects. The literature describes both significant fluctuations in the level of WAnT performance and the lack of such changes in subsequent periods. In people who do not practice sports and lead a sedentary lifestyle, seasonal changes in physical capacity may reflect changes in physical activity dependent on the season and related environmental factors, i.e. weather, day length and temperature. In our latitude, most people who do not practice sports are less active in winter than in summer [27-28], which in men may be related to seasonal changes in testosterone concentrations in the blood [29].

However, in competitive athletes practicing summer sports, the season and seasonal changes in androgens cannot determine training plans and activities. Therefore, it can be expected that changes in physical workload and consequently anaerobic capacity depend more on the dates of competitions than on the season. Measurements of anaerobic capacity several times a year are still the subject of research in various sports disciplines. The most attention has been paid to endurance athletes. Long-distance runners show a significant decrease in anaerobic power at the end of the competition season, on average from 11.8 to 1. Watt/kg, but do not lose aerobic capacity [30]. Tennis players have been shown to significantly reduce peak power from 8.35 to 7.80 Watt/kg due to a 5-week unsupervised training performed during the break between competitions [31]. Football players demonstrated a slight decrease in maximal anaerobic power on a cycle ergometer after the competition season, by 4.7%, but significant improvement in 10 and 30 m sprints [32]. In sports requiring both anaerobic and aerobic capacity, the training period had a varied effect on changes in anaerobic capacity. No changes in anaerobic capacity were demonstrated after a multi-week preparatory period including endurance training and intensive strength training in cyclists and handball players [33, 34]. In turn, a monotonic increase in maximal power was observed in the next five terms of the annual training cycle in beach volleyball players [35].

Divergent results of changes in the level of performance of the WAnT test are presented by combat sports athletes. In the wrestling athletes, there was no decrease in the average power and work in the WAnT during the competition season, but a significant decrease in the maximum anaerobic power and this decrease corresponded to a decrease in the resting testosterone concentration in the blood [36]. In turn, judo athletes showed a slight increase in the maximum power by 7%, and a significantly higher concentration of resting testosterone by 18% after a 4-month preparation period for the main start of the year, i.e. the European Championships [37].

Studies of changes in anaerobic capacity 4 times in the annual training cycle in women practicing fencing revealed statistically insignificant average changes in the maximum power, average power and work performed on subsequent dates [38]. In the literature, the analysis of seasonal changes in maximum power using the laboratory WAnT effort is most often limited to testing the exercise capacity of the lower limbs. There is a lack of data covering seasonal changes in the maximum anaerobic power of the upper and lower limbs in the same athletes. The aim of study was knowledge about putative seasonal differences in maximal power of upper and lower limbs in a group of male brazilian jiu-jitsu athletes across 12 months.

## 2. Materials and Methods

### Participants

Thirteen Brazilian Jiu-Jitsu (BJJ) athletes who trained regularly 3 to 4 times per week, participating in evening training sessions lasting 1.5 hours, underwent maximal power testing of the upper and lower limbs four times over a period of one year. At the first examination, their mean age was 28.1 ±4.8 (20.6-34.1) years, experience 12.9 ±4.7 (5-18) years, mean body weight 80.0-8.6 (67.2-100.2) kg, and height 178.0 ±6.1 (168-188) cm. The standard laboratory effort of 10 seconds WAnT was used for testing, using the Upper Monark Exercise AB, Vensbro for the upper limb test and the Monark 894E Sports and Medical Vensbro Sweden 894E for the lower limb test, both coupled to a program monitoring the generated power continuously at a frequency of 1000 Hz. The relative braking force of the flywheel in the upper limb test was 6.0% of body weight, and in the lower limb test 8.7% of body weight. Both tests were performed on the same day, before noon (9:30-11:00) with a 1.5 hour break between the efforts in a randomized order, in a seated position, using the same loud encouragement throughout the effort and a standard warm-up before the tests. The first test was performed in late January, the next in early May and the next two in late July and October. The laboratory room was equipped with air conditioning ensuring a constant temperature of about 22$^0$C.

### Statistical analysis

Statistical calculations were performed using SOFTWARE STATISTICA v. 13.3. After logarithmic transformation of kinematic data, the results from the four terms were analyzed using two-way ANOVA with repeated measures (season x limbs) after Bonferroni correction as a post-hoc test. Additionally, individual results of the ratio of maximum power for the upper limbs to maximum power for the lower limbs and seasonal changes were analyzed. In order to verify the hypothesis that the ratio of maximum power for the upper limbs to maximum power for the lower limbs differentiates the subjects and depends on the season, two-way ANOVA with repeated measures (person x season) was used. The relationships between kinematic indices in the test performed with the lower and upper limbs were expressed by linear correlation coefficients. The list of recorded kinematic variables and abbreviations is given in Table 1.

**Table 1.** Values of kinematic variables recorded during WAnT 10s.

| Kinematic variable | Unit |
|---|---|
| Peak Power Output (PPO) | Watt |
| Mean Power Output (MPO) | Watt |
| Relative (RPPO) | Watt/BM |
| Relative (RMPO) | Watt/BM |
| Work Output (WO) | kJ |
| Relative WoOu/BM (RWO) | J/BM |
| Fatigue Index (FI) = [(PPO-lowest PPO)/PPO] × 100% | % |
| Time to PPO (TPPO) | second |
| Upper PPO-to-Lower limbs PPO ratio (UPPO/LPPO) | dimensionless |
| BM-Body Mass | kg |

## 3. Results

Significantly higher power and work performed by the lower limbs than by the upper limbs were observed in all dates. Furthermore, no significant changes were observed in all kinematic variables in both types of tests conducted in different seasons. Only a slight increase in the values of kinematic variables was noted in the annual training cycle. The values of PPO, RPPO, MPO and RWO in the lower limb tests in the last examination in October were slightly higher, on average about 3.2%, than in the first examination in January. At the same time, in the same time interval, the time needed to achieve maximum power (TPPO) was shortened by 17% and the index increased by 20%. Similar directions of changes were noted in the upper limb tests in different seasons. In the last date, i.e. in October, the values of PPO, RPPO, MPO were higher than the initial ones, i.e. in January by 4.8, 5.0 and 11.9%, respectively, while the value of TPPO was extended by about 6.0%. These changes were not statistically significant. The mean FI value calculated from 4 measurements was 35.5% higher for the upper limbs test than for the lower limbs (Tables 2, 3, 4).

**Table 2.** Descriptive statistics with means and standard deviations for the kinematics variables of Wingate performance by upper limbs in four seasons.

| Kinematic variable | Wingate performance by upper limbs | | | |
|---|---|---|---|---|
| | February | May | July | October |
| PPO | 668 ±108 | 667 ±94 | 703 ±105 | 701 ±91 |
| MPO | 622 ±107 | 623 ±93 | 697 ±103 | 696 ±91 |
| RPPO | 8.33 ±0.71 | 8.38 ±0.61 | 8.76 ±0.70 | 8.75 ±0.67 |
| RMPO | 8.30 ±0.74 | 8.32 ±0.56 | 8.66 ±0.73 | 8.70 ±0.65 |
| WO | 5.79 ±0.81 | 5.72 ±0.66 | 5.99 ±0.79 | 6.03 ±0.62 |
| RWO | 72.6 ±5.8 | 72.1 ±4.8 | 74.5 ±6.4 | 75.5 ±5.9 |
| FI | 15.53 ±5.66 | 14.85 ±4.55 | 17.13 ±4.49 | 16.17 ±5.44 |
| TPPO | 4.649 ±0.988 | 5.12 ±1.066 | 5.236 ±0.908 | 4.948 ±1.989 |

**Table 3.** Descriptive statistics with means and standard deviations for the kinematics indicators of Wingate performance by lower limbs in four seasons.

| Kinematic variable | Wingate performance by lower limbs | | | |
|---|---|---|---|---|
| | February | May | July | October |
| PPO | 882 ±102 | 884 ±106 | 902 ±108 | 912 ±113 |
| MPO | 875 ±103 | 876 ±104 | 893 ±107 | 904 ±112 |
| RPPO | 11.09 ±0.82 | 11.06 ±0,75 | 11.32 ±0.69 | 11.44 ±0.68 |
| RMPO | 11.002 ±0.81 | 10.96 ±0.73 | 11.21 ±0.68 | 11.34 ±0.67 |
| WO | 7.82 ±0.81 | 7.79 ±0.80 | 7.94 ±0.88 | 7.96 ±0.85 |
| RWO | 98.6 ±7.7 | 97.6 ±6.2 | 99.8 ±6.4 | 100 ±6.1 |
| FI | 10.15 ±3.21 | 11.25 ±3.58 | 11.02 ±1.97 | 12.23 ±3.02 |
| TPPO | 6.018 ±0.844 | 6.594 ±1.018 | 5.243 ±0.779 | 5.002 ±0.765 |

**Table 4.** Comparisons of the kinematic variables recorded during leg cycling and arm cranking in four seasons.

| Kinematic variables | Source of variation | F-values | p-value | Effect size η ² | Power test α |
|---|---|---|---|---|---|
| PPO | limbs | **107.4** | **p<0,000** | **0.528** | **1.000** |
| | seasons | 0.791 | 0.550 | 0.022 | 0.195 |
| MPO | limbs | **106.2** | **p<0.000** | **0.524** | **1.000** |
| | seasons | 0.691 | 0.562 | 0.021 | 0.191 |
| RPPO | limbs | **385.2** | **p<0.000** | **0.800** | **1.000** |
| | seasons | 2.21 | 0.088 | 0.066 | 0.552 |
| RMPO | limbs | **365.0** | **p<0.000** | **0.792** | **1.000** |
| | seasons | 2.011 | 0.118 | 0.059 | 0.501 |
| WO | limbs | **168.5** | **p<0.000** | **0.637** | **1.000** |
| | seasons | 0.585 | 0.626 | 0.018 | 0.167 |
| RWO | limbs | **435.4** | **p<0.000** | **0.819** | **1.000** |
| | seasons | 1.232 | 0.304 | 0.037 | 0.320 |
| FI | limbs | **31.62** | **p<0.000** | **0.248** | **0.999** |
| | seasons | 0.681 | 0.567 | 0.021 | 0.189 |
| TPPO | limbs | **6.441** | **0.013** | **0.063** | **0.710** |
| | seasons | 0.875 | 0.457 | 0.027 | 0.234 |

NOTE: **η²** – the indicator that quantifies the proportion of total variance in dependent variable that is explained by an independent variable

There were obvious differences in UPPO/LPPO between individuals, but no seasonal changes. Individual intra-subject variability expressed as the coefficient of variation (CV) ranged from 1.3 to 7.9% (Table 5).

**Table 5.** Descriptive statistics with means and standard deviations for UPPO/LPPO values among the individuals in four seasons – ordinal variable from the highest mean.

| Variable | Athlete code | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | A | B | Ca | Cb | Cc | Da | b | E | F | G | H | Ia | Ib |
| Mean | 0.83 | 0.81 | 0.80 | 0.80 | 0.80 | 0.79 | 0.79 | 0.78 | 0.76 | 0.74 | 0.72 | 0.67 | 0.67 |
| SD | 0.04 | 0.03 | 0.04 | 0.02 | 0.02 | 0.01 | 0.04 | 0.02 | 0.06 | 0.02 | 0.03 | 0.01 | 0.01 |
| CV% | 4.8 | 3.7 | 5.0 | 2.5 | 2.5 | 1.3 | 5.1 | 2.6 | 7.9 | 2.7 | 4.2 | 1.5 | 1.5 |

No significant seasonal changes and very large inter-individual variability of the UPPO/LPPO index were observed (Table 6).

**Table 6.** Comparison of the individual and seasonal differences in UPPO/LPPO values.

| Source of variation | F-value | p-value | Effect size η² | Power test α |
|---|---|---|---|---|
| subject | **13.81** | **p<0.000** | **0.822** | **1.000** |
| seasons | 1.252 | 0.307 | 0.093 | 0.305 |

It was observed that body mass determined the peak power values of the lower and upper limbs and the time to achieve the peak power. The coefficient of determination (R2) shows that body mass explains 68.7% of the variance of the peak power of the lower limbs and 72.9% of the variance of the peak power of the upper limbs, and 11.0% and 32.8% of the variance of the time to achieve the peak power for the lower and upper limbs, respectively (Table 7).

**Table 7.** Matrix of linear correlation coefficients between the kinematic variables (Var) recorded during anaerobic test performed by lower limbs (LL) and upper limbs (UL).

| Variable | test | PPO | RPPO | WO | RWO | MPO | RMPO | FI | TPPO |
|---|---|---|---|---|---|---|---|---|---|
| BM | LL | **0.829** | −0.199 | **0.795** | **−0,400** | **0,831** | −0,196 | **0,582** | **−0,332** |
| | UL | **0,854** | 0.147 | **0.815** | −0.122 | **0.854** | 0.154 | **0.617** | **−0.573** |
| PPO | LL | 1 | **0.381** | **0.983** | 0.160 | **0.997** | **0.383** | **0.584** | **−0.279** |
| | UL | - | **0.637** | **0.961** | **0.330** | **0.998** | **0.626** | **0.683** | **−0.406** |
| RPPO | LL | - | **1** | **0.405** | **0.939** | **0.379** | **0.999** | 0.077 | 0.063 |
| | UL | - | - | **0.629** | **0.824** | **0.638** | **0.969** | **0.374** | 0.081 |
| WO | LL | - | - | 1 | 0.236 | **0.981** | **0.405** | **0.443** | −0.256 |
| | UL | - | - | - | **0.455** | **0.960** | **0.623** | **0.482** | **−0.440** |
| RWO | LL | - | - | - | 1 | 0.156 | **0.937** | −0.241 | 0.142 |
| | UL | - | - | - | - | 0.329 | 0.865 | −0,117 | 0.139 |
| RMPO | LL | - | - | - | - | - | 1 | 0.086 | 0.066 |
| | UL | - | - | - | - | - | - | **0.362** | 0.087 |
| FI | LL | - | - | - | - | - | - | 1 | −0.280 |
| | UL | - | - | - | - | - | - | - | −0.262 |

Significant values for correlation coefficients are shown in bold.

## 4. Discussion

Anaerobic capacity of BJJ athletes has recently been the subject of several original studies and one meta-analysis. The results of maximal anaerobic power of the lower and upper limbs obtained in our experiment were compared with the data presented in the publication by Andreato et al. [39], where anaerobic power of the upper and lower limbs was tested using the Wingate 30 sec. A single study of BJJ athletes, among whom were participants of national and international competitions, including black belts, revealed a relative maximal power for the lower limbs of 11.9 ±1.4, which is a value slightly higher compared to those recorded in our studies using the 10-s test. In turn, clear differences between the groups appeared when the mean powers of the lower and upper limbs were compared. In the group tested with the 30-s test, the mean powers of the upper and lower limbs were significantly lower than in the group tested with the 10-s test. These discrepancies between maximum and average power in different tests are a consequence of the significantly more physically tiring longer test, which generated a higher FI for the lower limbs, 57.5%, and the upper limbs, 63.1% [39] than the results recorded in our study. However, it is worth noting that in both experiments, greater post-exercise fatigue of the upper limbs was revealed. In turn, in other studies on the maximum anaerobic power of the lower limbs of BJJ athletes with different sports level and sports experience, it was revealed that they achieved higher results of explosive power defined by the level of vertical jump performance. There were also no statistically significant, season-dependent changes in kinematic indicators in the anaerobic 10-second test of the lower and upper limbs. The premise for accepting such a hypothesis were the results of studies, where the greater discriminatory power of better from weaker athletes was the average power, not the maximum [40].

In our research, it is worth paying attention to the small differences between maximum and average power and the relatively small fatigue index compared to these indicators, which are recorded in the Wingate 30s test. Only a very large increase in training activity in the three months preceding the competition period can cause a visible increase in maximum power in the Wingate 10s [41]. The important role of strength and anaerobic capacity in the success of athletes training BJJ is confirmed by publications [42-44]. Another explanation for the lack of season-dependent changes in kinematic variables in the athletes we studied was the relatively constant and not very high training loads throughout the season, which is typical for athletes with a regional or amateur level of training. In contrast to such a level, competitive athletes implement a training program with a greater variability of volume and intensity of exercises dictated by different phases of preparation for competitions. Changes in instantaneous power during the Wingate test are two-phase. First, athletes must overcome the inertia of the flywheel before reaching the peak of power, which requires several seconds on average. In our study, it was significantly negatively correlated with both body mass and maximum power. A significant and negative correlation between the peak power and the time to achieve it ($r = -0.33$) in the Wingate 30s test was also demonstrated by other researchers [45]. Interestingly, the sampling rate from power output has an impact on the result of the measurement of maximum power and the time to achieve it. In studies of physically active men who did not practice sports, the sampling rate from power output was underestimated and the time to achieve it was delayed [46]. In our study, the frequency of power measurements was very high, 1000 Hz, which guaranteed obtaining reliable results of kinematic variables. After reaching the peak power, the second phase of changes occurs, a monotonic decrease in power, until the end of the effort. The decrease in power is parallel to the decrease in intracellular phosphocreatine resources and the accumulation of hydrogen ions in muscles [47].

On the one hand, success in BJJJ and other combat sports is determined not only by the level of anaerobic capacity but also the level of general physical fitness and its individual components, sometimes indirectly [48-56], while on the other hand, as well as the professional competence of the trainer, and increasingly this work is performed by experts dealing with motor preparation [57, 58]. This type of cooperation consequently reduces the risk and avoids injuries during training and competitions [59, 60] but also faster regeneration of trainees [61-64].

In the introduction to this work, we devoted a little more attention to the issues of exercise physiology not only because of their importance from the perspective of the effectiveness of training control in combat sports. Similarly, the discussion of the results refers to the practice of training that goes beyond the specifics of combat sports. We are aware of the mission of the journal in which this work is published. For people interested in physical effort repeated for health purposes and to strengthen the sense of personal security, this knowledge can help them understand the basic difference between preparation for the most important competitions in a given annual cycle and optimal readiness to undertake necessary defense against physical aggression from anyone even at the least expected moment. Hence, among others, the example of BJJ athletes (combat sport offering motor solutions useful in numerous self-defense situations). In sports, the calendar of competitions is known and there are criteria for qualifying candidates due to the rank of these competitions in the system of appropriate associations (federations), up to the global scale. Not all sports disciplines (such as BJJ) have Olympic status. This does not mean that coaches of this category of sports, and even personal trainers, do not need in-depth physiological knowledge of extreme efforts. On the contrary, it is a necessary condition for reducing the risk of losing health or even life during physical exertion. The lack of the habit of permanent professional control not only of extreme physical exertion in laboratories and during sports training (since people undertake them outside of sports), but above all as basic stimuli stimulating biological development in ontogeny and maintaining optimal physical efficiency of the body in adult life, is one of the most pressing public health problems of global importance.

Critics of the physical education paradigm and at the same time authors of the interim project physiotherapist in every school' (the ultimate goal is to replace PE with preventive medicine in every type of school) make a fundamental accusation against the authors of the current PE core curriculum for primary schools, that the criteria of physical effort intensity during PE lessons were ignored [65]. Although Michał Kruszewski et al [66] do not formulate the empirical argumentation regarding test fights between girls and boys in the very safe formula of fun forms of combat as a criticism of the physical education paradigm, it is an important supplement to the shortcomings of PE with the missing element of preparation to repel violence and physical aggression from anyone. In our opinion, the above criticism, together with the results of these studies, as well as previously published evidence (using swimming as an example [67]) that it is necessary to carefully implement methods and indicators useful in professional sports training into the area of health-related physical activity, are consistent with the offer of INNOAGON – a new applied science that fills the competence gap (in the research and educational sense) at the interface of medical studies, physical education, sport, physiotherapy, special education, psychology and several others [68-75].

## 5. Conclusions

BJJ athletes who regularly train throughout all the year exhibited lack of significant differences in performance of ultra-short, supramaximal efforts. The above refer both to upper and lower limbs. Slightly, non-significant improving of tests performance may be explained by better adaptation and higher motivation to these physical efforts. Athlete of higher body mass and maximal absolute power can overcome inertia of flywheel faster and reach peak power earlier. There are inter-individual differences in various kinematic variables resulting from, among others, different body mass and disproportion between the maximum power of the lower and upper limbs expressed as a new, non-applied up to date in the scientific studies indicator: UPPO/LPPO. In the examined athletes, it is recommended to improve the strength and power of the upper limbs in which the UPPO/LPPO value was too low.

**Data Availability Statement:** The data supporting this study's findings are available from the corresponding author upon reasonable request.

**Ethical approval:** This study was approved by the Bioethics Committee at the Institute of Sport-National Research Institute (Nr. KEBN-20-54-HM) All procedures followed the ethical standards of the Declaration of Helsinki.

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Authors:
1. Artur Litwiniuk: : https://orcid.org/0000-0002-1351-740X
2. Juris Grants: : https://orcid.org/0000-0003-3116-9119
3. Behnam Boobani: : https://orcid.org/0000-0001-8061-5088
4. Oscar Romero Ramos: : https://orcid.org/0000-0002-7933-8893
5. Wieslaw Blach: : https://orcid.org/0000-0002-3559-9151
6. Zbigniew Obminski: : https://orcid.org/0000-0002-3754-9748

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