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Selected Indices of Anaerobic Capacity and Their Changes during Special Judo Fitness Tests at Different Ambient Temperatures Performed among Judo Athletes

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Abstract: Background: Thermoregulatory processes play an important role during athletic competition. When athletes compete in an elevated ambient temperature, metabolic processes in their bodies become intensified. The main objective of the study was to determine changes in anaerobic total work (TW) and relative peak power (RPP) during a special judo fitness test at different ambient temperatures performed among judo athletes. Methods: The study included 15 judo athletes aged 20.7 ± 2.0 years, with a body height of 178 ± 6.3 cm, body mass totalling 76.3 ± 12.6 kg, VO_{2max} at 43.2 ± 7.8 $mL \cdot kg^{-1}$, and peak power of 12.1 $W \cdot kg^{-1}$. A complete set of results was obtained for 10 athletes. In the main part of the examinations, judo athletes performed five sequences (7.20 min each), alternating efforts on a leg cycle and arm cycle ergometer in a thermal chamber at 21 ± 0.5 °C and 31 ± 0.5 °C. The efforts differed from typical interval exercise by alternating upper- and lower-limb efforts, as well as with regard to the duration of those efforts. Each sequence was followed by a 15 min interval for rest. In each sequence, subjects performed four anaerobic tests with the upper and lower limbs. Results: In the first of five series of efforts performed with the lower limbs (LL) at an ambient temperature of 21 °C, statistically significant differences ($p < 0.001$) were found between the mean RPP values recorded during the first and third and fourth repetitions, and between the second versus third and fourth repetitions. Statistically significant differences were also observed between the first and fourth efforts performed by the LL at 31 °C ($p < 0.001$) and between the second and third performed using the upper limbs (UL) at an ambient temperature of 21 °C Conclusions: Varying ambient thermal conditions do not affect the size of generated relative peak power or the volume of work performed in pulsating anaerobic exercise.

Keywords: judo; peak power; physical capacity

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1. Introduction

The preparation of athletes of judo for sports competition should include the development of speed, strength, endurance, technical–tactical skills and volitional characteristics [1–4]. In this sense, special training programmes prepared by coaches and based primarily on scientific research in physiology and biochemistry contribute to athletic performance [5–7]. Such testing methods make it possible to determine the current level of endurance as well as speed/strength abilities and to define zones of exercise intensity. They also provide an opportunity to monitor physiological and biochemical changes induced by special physical training and changes in the rate of post-exercise recovery [8–10]. Exercise intensity and recovery intervals should be adjusted to individual potential capabilities and modelled after the completion of each preparation stage. Athletic performance is improved when all of these elements are developed simultaneously and reach an optimal level, which is usually associated with maximum levels of variables typical for determining the physical capacity of an athlete [11]. The nature of competition in judo requires very good psychophysical preparation, which suggests that attention should be paid to determining, through research, the level of functional, psychological and somatic variables that may affect the way an athlete competes and reaches the final result. It is also noteworthy to evaluate the same variables under different thermal conditions [12]. A high level of aerobic capacity (VO_{2max}) is one of the predictors of effective fighting, mainly in the second part of the combat [2,13–15]. Nonetheless, in specific judo fighting, more attention is paid to the processes of improving anaerobic capacity [13,16–18]. However, it should be noted that training programmes, especially those for young judo athletes, should include elements aimed at improving mechanisms of oxygen supply to tissues, which further determine recovery rate [1,19].

The effect of physical stimuli at different intensities, ranges and durations on an athlete's body has already been the subject of research, and empirical knowledge gained is applicable, allowing sports practitioners to optimise the preparation of athletes for competitions [20–25]. The majority of studies in the field of sports physiology and biochemistry have been focused on endurance athletes, while slightly less research has been carried out on mixed and anaerobic exercise performed with both the upper and lower limbs. As early as 1961, Åstrand and Saltin [26] found that different physiological responses occur while performing work that requires isolated involvement of the arms and legs or their simultaneous action. Elite rowers, kayakers and combat sports athletes are characterised by a high proportion of upper limb exercise during each training session. Differences in the level of physiological responses of the body to exercise result from less muscle mass in the upper compared to lower limbs [27–29]. The poorer venous blood return and lower oxygen extraction in the working upper limb muscles define the predominance of anaerobic metabolism in these efforts, accompanied by a greater accumulation of blood lactate [30]. In sports such as boxing, judo, wrestling, kickboxing, handball, basketball or ice hockey, where the upper and lower limbs are simultaneously engaged during a sports competition, greater changes in physiological and biochemical indices are observed compared to other sports. Exercise metabolism in judo athletes during training or competitive bouts is mainly based on anaerobic processes, which can significantly change when working at high ambient temperatures [23,31]. The best judo athletes compete in four to six bouts during a tournament. The mean global time for a single fight is 7.4 min. The temporal structure of the fight consists of alternating sequences comprising fighting tasks and rests [6,32]. However, due to the constant evolution of the sport, which is influenced by changes in fighting rules, this structure is changing. Therefore, it is almost impossible to construct a laboratory test mimicking a judo bout. In the present study, given the temporal structure of a single bout and tournament competition, an attempt was made to create exercise sequences that are similar to those observed during judo tournaments. International competitions are held in air-conditioned indoor arenas which ensure appropriate temperatures. However, increased external temperature and the associated general environmental, as well as meteorological conditions, have significant impacts on functional systems in the human body [33]. Furthermore, training at elevated temperatures can lead to a shift in metabolic thresholds, thus increasing the training load. In both amateur and elite sports, it is required to adopt appropriate hydration strategies to prevent hypohydration [34,35]. Therefore, it may be concluded that the thermal factor can affect physiological and biochemical responses and the course of the fight [7,36]. Furthermore, intense sweating at elevated temperatures causes a decrease in water supply, which leads to a decrease in plasma volume and electrolyte levels. When dehydration exceeds 2–3% of body mass, the ability to perform physical exercise is significantly reduced [37].

The paucity of studies on the effect of anaerobic efforts performed alternately with the upper and lower limbs at various ambient temperatures on changes in physiological and biochemical indices warrants further research on this topic. Previous research in this field has been focused on the effects of time of day and thermoregulation on performance in judo [33] or on analyses of lactate concentration in relation to varying skin temperature [38]. To date, there are no studies on evaluating the extent of anaerobic power changes during simulated competitive efforts in judo athletes.

The main objective of the study was to determine the level of changes in anaerobic total work (TW) and relative peak power (RPP) during a special judo fitness test at different ambient temperatures in judo athletes.

2. Materials and Methods

2.1. Participants

Of the eligible athletes aged 20.7 ± 2.0 years, 10 male individuals completed the full study programme. Among them, 5 were excluded: 4 due to illness and 1 because of injury. Participants were characterised by a mean body height (BH) of 178.0 ± 6.3 cm, mean body mass (BM) totalling 76.3 ± 12.6 kg, lean body mass (LBM) at 64.0 ± 10.4 kg, and the ratio of body surface area to body mass (BSA·BM-1) of 0.0249 $cm^2 \cdot kg^{-1}$ ± 0.0016. VO_{2max} (aerobic capacity) in the lower limb test was 43.2 ± 7.8 $mL \cdot min^{-1} \cdot kg^{-1}$ in relative values and 3.3 ± 0.6 $L \cdot min^{-1}$ in absolute terms, while peak power (anaerobic capacity) equalled 12.12 $W \cdot kg^{-1}$ in relative values and 933 W in absolute terms.

In the study, a group of 15 men selected from 20 professional judo athletes with good health status (confirmed by a medical certificate) were examined. The observation was based on the sample size determined using G*Power software 3.1.9.4. Inclusion criteria were chronological age, training experience and sports skill level (each of the athletes had placed at least 5th in national competitions) (Table 1). A full scope of testing was completed by 10 athletes. The experiment was approved by the Bioethics Committee at the Regional Medical Chamber in Kraków (No. 102/KBL/OIL/2011, 14 December 2011). The research was financed from funds for statutory research (7/BS/IFC/2011). Participants, as required by the Declaration of Helsinki, were informed about the purpose of the study, the methodology used, possible side-effects, and the possibility of withdrawing from the experiment at any stage without giving reason. Each participant signed their informed consent to participate in the study. The entire experiment was conducted under the supervision of a sports physician.

Table 1. Inclusion and exclusion criteria.

20 Professional Judo Competitors	
Included: 15	Excluded: 5
Inclusion criteria	Exclusion criteria
Age > 18 years	Age < 18 years
Good Health Status—Status Determined on the Basis of a Medical Examination by a Sports Physician	Diseases and injuries
High sports skill level	Low sports skill level
Training experience >10 years	Too short training experience
At least 5th place in national competitions	No success in national competitions
Examination started by 15 participants	
Full scope of tests completed by 10 participants	Full scope of tests not completed by 5 participants

2.2. General Experimental Design

Physical capacity tests were conducted in judo athletes during the competitive season. They took place in a thermal chamber and air-conditioned laboratory at the Department of Physiology and Biochemistry, University of Physical Education in Kraków. Based on the circadian rhythm, all tests were performed in the morning, no earlier than 2 h after a light meal. The examinations of judo athletes were divided into 2 parts: preliminary (stages I, II, and III) and main part (stages IV and V) (Figure 1).

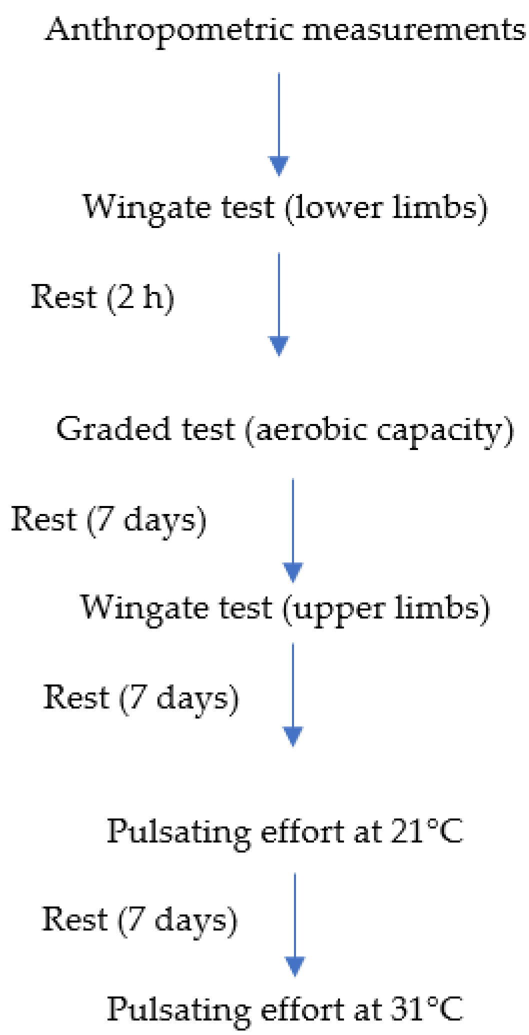

Figure 1. Study design.

2.3. Preliminary Study

STAGE I—examinations were performed in the morning, 2 h after a light meal.

During the first stage of the study, basic measurements of anthropometric variables (body height (BH) and body mass (BM)) were measured and used to calculate the Quetelet II index (BMI) according to Dubois [39]. Lean body mass (LBM) was also estimated. Body surface area (BSA) and the ratio of body surface area to body mass (BSA·BM-1) were also calculated. Blood pressure (BP) and heart rate (HR) were measured in the athletes for diagnostic purposes.

STAGES II and III—examinations were performed on the same day as Stage I after a 2 h interval.

In the preliminary study of Stage II, the participants performed exercise tests with the lower limbs (LL) to evaluate anaerobic and aerobic capacity. After 7 days, Stage III of the examinations started, in which the participants performed the same exercise tests once more, but using the upper limbs (UL).

Anthropometric variables were measured before the exercise tests in both stages. The Wingate test for LL and UL was used to evaluate anaerobic capacity indices [40]. The main effort was preceded by a 5 min warm-up on a cycle ergometer at an individually selected intensity of 50% VO_{2max} and a rate of 60 rpm, with 3, 5 s maximal accelerations at minutes 2, 4 and 5. Two min after the warm-up, participants performed a 30 s maximal effort. In the first case—LL, the external resistance was 8.3% of the participant's body mass, whereas in the second case—UL, this totalled 4.5% of body mass [40]. The load was selected based on a pilot study [1,6,29]. Total work (TW) and peak power output (RPP) were analysed during the test. Anaerobic capacity, which included both phosphagen and glycolytic components, was evaluated on the basis of analysis regarding the aforementioned indices using the Wingate test.

A minimum of 2 h after completing the Wingate Test, subjects performed the aerobic capacity test.

The graded test until refusal, routinely used at the Department of Physiology and Biochemistry, AWF, Kraków, was performed at an ambient temperature of 21 ± 0.5 °C and relative humidity of 40 ± 3%. In both cases, a 2 min warm-up on a cycle ergometer at a pedalling rate (RPM) of 60 revolutions per minute and intensity of 110 W for LL and 60 W for UL was implemented. Next, power was increased every 2 min by 20 W for the lower limb and 12 W for the upper limb test. The exercise continued until the participant declared he was not able to maintain the RPM at 60.

STAGES IV and V.

In the main part of the examinations, half of the judo athletes performed 5 restrictive sequences of pulsating efforts alternately on a leg cycle ergometer and hand cycle ergometer in a thermal chamber at 21 ± 0.5 °C (stage IV) and the other half at 31 ± 0.5 °C (Stage V), 50% ± 5% relative humidity. After 7 days, needed for the extinction of any effects of exercise, the subjects resumed stages IV and V. This time, the first group of participants performed exercises at 31 ± 0.5 °C, whereas the second group performed them at 21 ± 0.5 °C.

The efforts differed from typical interval exercises due to the alternating (pulsating) loading of the upper and lower limbs, varying in time, during anaerobic exercise series separated by 15 min rest intervals. A single series sequence of pulsating efforts was performed according to the pattern presented below and repeated 5 times (Table 2). The global duration of the experiment including 5 series of pulsating efforts and 4, 15 min intervals between each effort sequence was 96 min 20 s.

Table 2. Characteristics of a single series of alternate pulsating efforts.

NNLL	Interval	UL	Interval	LL	Interval	UL	Interval	LL	Interval	UL	Interval	LL	Interval	UL	Interval
15 s	30 s	15 s	30 s	30 s	60 s	30 s	60 s	20 s	45 s	20 s	45 s	15 s	30 s	15 s	30 s

UL—upper limbs, LL—lower limbs, s—second.

The pulsating efforts at both temperatures were preceded by a 30 min acclimation to thermal conditions followed by a 5 min warm-up with an individually selected load of 50% VO_{2max} at a rate of 60 rpm, with 3, 5-second maximal accelerations at minutes 2, 4 and 5. Total work (TW) and peak anaerobic power (PP) were analysed during a single pulsation exercise test series based on a modified version of the Wingate test for the lower (LL) and upper limbs (UL). The load was the same for each test sequence and totalled 8.3% of the participant's body mass for LL and 4.5% of body mass for UL, respectively. We also calculated the sum of work globally performed in all 5 pulsating effort test series (∑TW) and the total work performed by the upper (∑TWUL) and lower limbs (∑TWLL). Total work and its sum in the upper limb (∑TWUL) and lower limb (∑TWLL) tests for individual series of pulsating efforts and the global value of their sum (∑TTW) for pulsating efforts were evaluated. Analysis of the above parameters allowed for the evaluation of changes in fatigue patterns and verification of whether the temperature factor modified anaerobic capacity.

Blood lactate levels (LA) were measured before and after each of the 5 sequences of pulsating efforts (3rd minute) and after completion of the research programme (4th and 5th stages).

2.4. Measurement Technique

BH and BM measurements were used to calculate the Quetelet II index (BMI). The normal range adopted for the study group was 18.5–25.0 kg/m^2 A level below 18.5 was considered underweight, whereas a level above 25 was assumed as overweight.

Analysis of lean body mass (LBM) was performed with the JAWON MEDICAL IOI-353 (Korea) body composition analyser having the EC0197 certificate using the 8-electrode electrical bioimpedance method. The athletes were instructed to maintain their eating habits the day before the study. Blood pressure (BP) at the brachial artery was measured in a seated position using the routine Korotkow method to the nearest 5 mmHg (0.67 kPa).

Ambient temperature and relative humidity in the thermal chamber (Germany, ZPY) and physiological laboratory were controlled with a Harvia (Finland) thermohygrometer to the nearest 0.5 °C and 3%, respectively. Body height (BH) of the males was measured via the Martin-type anthropometer (USA) to the nearest 0.5 cm while body mass (BM) was estimated using the F 1505-DZA (Sartorius, Germany) electronic scale to the nearest gram.

Heart rate (HR) was telemetrically recorded in laboratory tests with a Polar Vantage NV and Polar 610S cardiac monitor (Polar Elektro, Finland).

The degree of body dehydration was estimated by measuring body mass (to the nearest 1 g) before and after the exercise sequence as well as the volume of excreted urine. A graded test for subjective exhaustion was performed on a Jeager ER 900 D leg cycle ergometer (Germany) and a Monark 891E hand cycle ergometer (Sweden).

Anaerobic (pulsating effort) tests performed in a thermal chamber at 21° and 31° for the lower and upper limbs were preceded by a warm-up on the Monark 827E (LL) and 881E (UL) cycle ergometers. The main part of the test was carried out on the Monark 875 E ergometer for the lower and 891E (Sweden) ergometer for the upper limbs.

2.5. Statistical Methods

The Statistica 9.0 package for Windows (StatSoft, Kraków, Poland) was used for the analysis of the numerical material. Other basic characteristics calculated in the study included arithmetic mean and standard deviation. Changes in parameters induced by the applied pulsating pattern of exercise, assuming normality of their distribution, were evaluated using multivariate analysis of variance. The normality of distributions was verified by means of the Shapiro–Wilk W test. If statistically significant differences were found, their strength was evaluated by applying the post hoc Tukey test. The level of statistically significant differences was set at $p < 0.05$ [41].

3. Results

Alternating pulsating efforts at two different ambient temperatures led to a decrease in the body mass of the study participants, mainly due to exercise-induced dehydration. To determine changes in body mass following the exercise, the athletes did not intake any fluids during exercise (Table 3).

Table 3. Mean and standard deviation of body mass (BM kg) at 2 temperatures in individual measurements before and after the series of pulsating efforts.

Temperature	Measurement	$\overline{x}$	SD
21 °C	Before	74.68	11.32
	After	73.70 #	10.99
31 °C	Before	74.87	11.29
	After	73.31 *	11.12

#—significant differences at $p < 0.05$ at 21 °C—differences between measurements; *—significant differences at $p < 0.05$ at 31 °C—differences between measurements.

3.1. Peak Power during Repeated Anaerobic Exercise Performed by the Lower Limbs (LL) and Upper Limbs (UL) at 21 °C and 31 °C

The main indicators of anaerobic capacity levels are total work (TW) and relative peak power (RPP).

In the first of five series of efforts performed with the lower limbs (LL) at an ambient temperature of 21 °C, statistically significant differences ($p < 0.001$) were found between the mean RPP values recorded during the first and third and fourth repetitions, and between the second versus third and fourth repetitions. Statistically significant differences were also observed between the first and fourth efforts performed by the LL at 31 °C ($p < 0.01$) and between the second and third performed using the upper limbs (UL) at an ambient temperature of 21 °C (Figure 2).

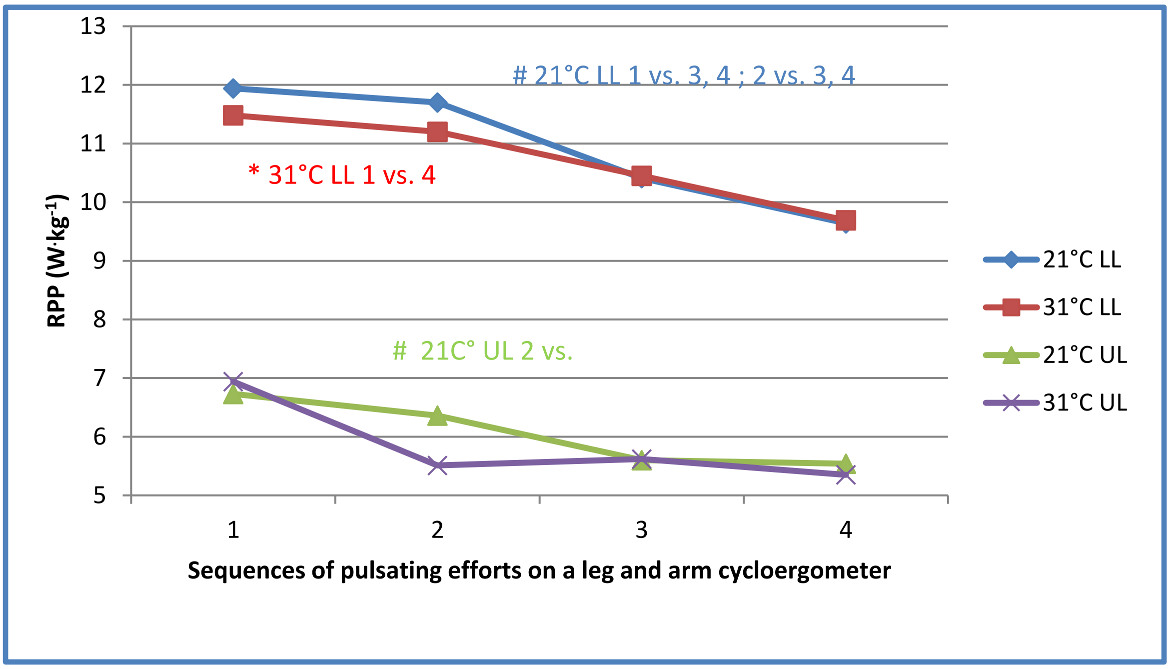

Figure 2. Relative peak power (RPP) values in the first of 5 series of physical exercises performed by the lower (LL) and upper limbs (UL) at ambient temperatures of 21 °C and 31 °C. #—significant differences at $p < 0.05$, 21 °C: differences between individual measurements; *—significant differences at $p < 0.05$, 31 °C: differences between individual measurements.

In the second series of efforts, statistically significant differences ($p < 0.001$) were found between the first and second, and between the third and fourth efforts performed by the lower limbs at 31 °C. The differences in upper limb exercises occurred between the first and fourth efforts at 21 °C and between the first versus second and third efforts at 31 °C (Figure 3).

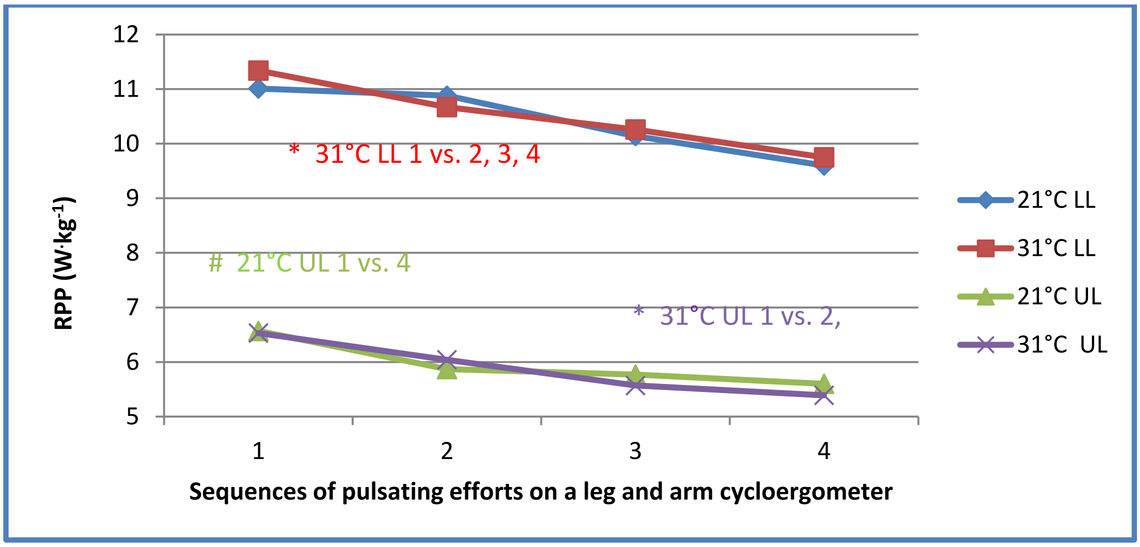

Figure 3. Relative peak power (RPP) values in the second of 5 series of physical exercises performed by the lower (LL) and upper limbs (UL) at ambient temperatures of 21 °C and 31 °C. #—significant differences at $p < 0.05$, 21 °C: differences between individual measurements; *—significant differences at $p < 0.05$, 31 °C: differences between individual measurements.

In the third series of lower limb efforts, statistically significant differences occurred between the first and fourth efforts at 21 °C. In upper limb efforts at 21 °C, a statistically significant difference ($p < 0.001$) was observed between the first and second, and between the third and fourth efforts. There were no statistically significant differences in the efforts performed using LL and UL at 31 °C (Figure 4).

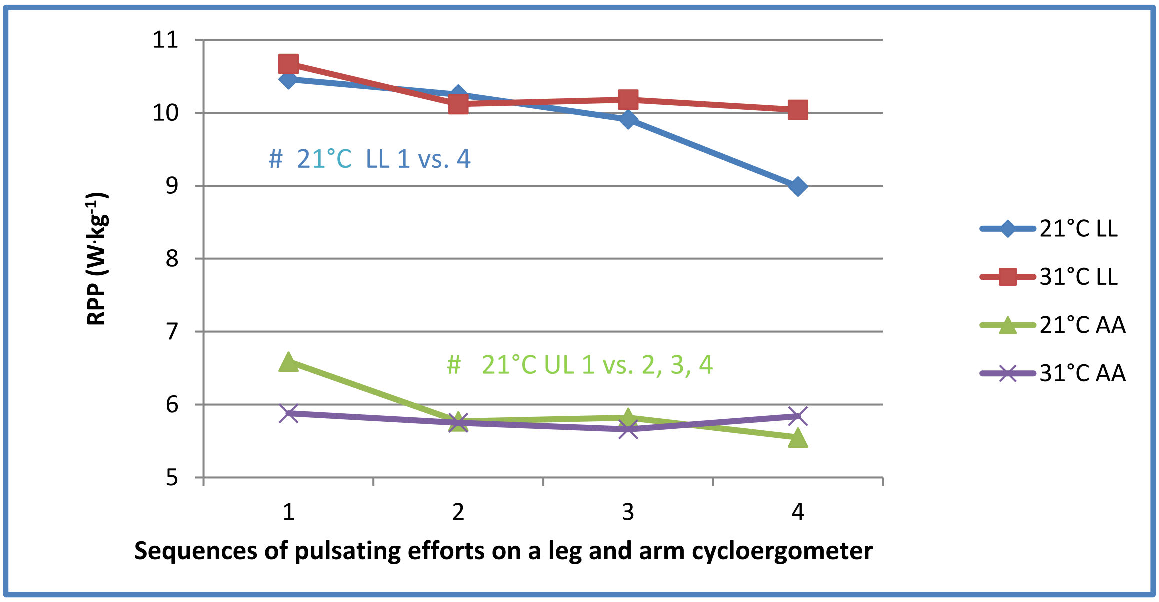

Figure 4. Relative peak power (RPP) values in the third of 5 series of physical exercises performed by the lower (LL) and upper limbs (UL) at ambient temperatures of 21 °C and 31 °C. #—significant differences at $p < 0.05$, 21 °C: differences between individual measurements.

In the fourth and fifth series of anaerobic efforts, statistically significant differences were found only at 31 °C. In the fourth series, this difference occurred between the first and second and in the fifth series between the first and third efforts (Figures 5 and 6).

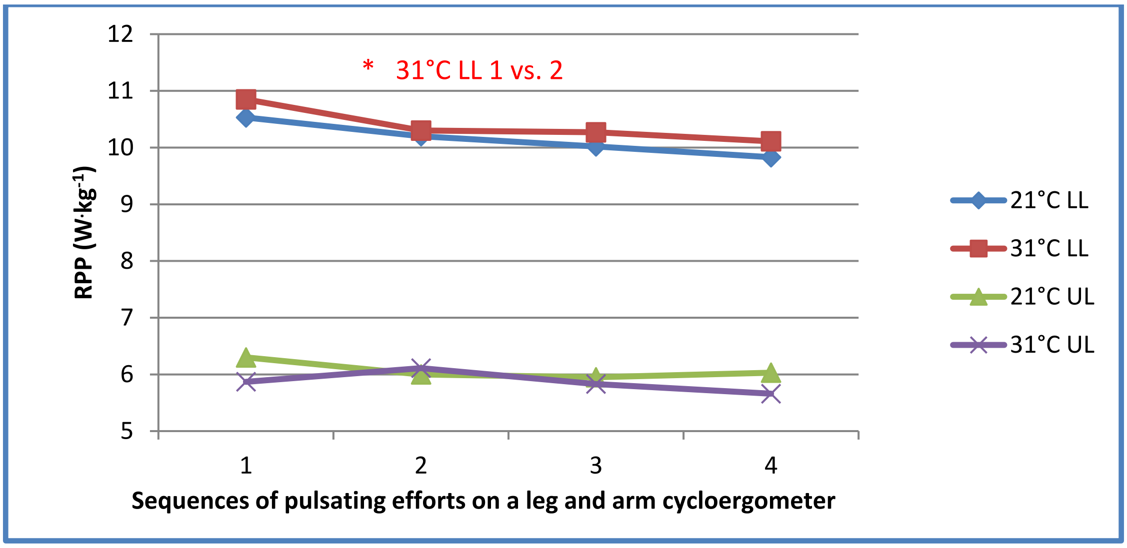

Figure 5. Relative peak power (RPP) values in the fourth of 5 series of physical exercises performed by the lower (LL) and upper limbs (UL) at ambient temperatures of 21 °C and 31 °C. *—significant differences at $p < 0.05$, 31 °C: differences between individual measurements.

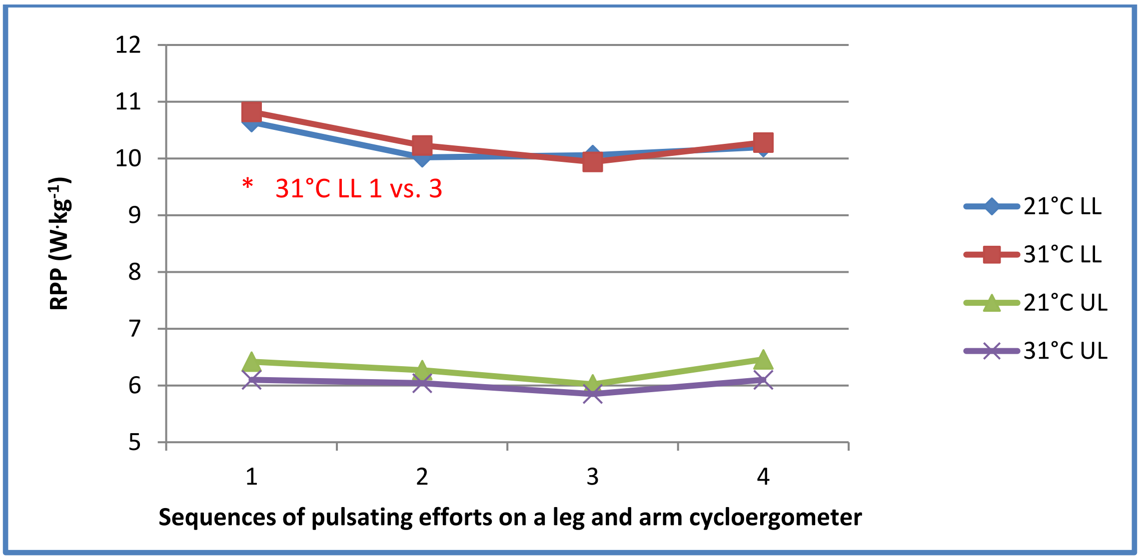

Figure 6. Relative peak power (RPP) values in the fifth of 5 series of physical exercises performed by the lower (LL) and upper limbs (UL) at ambient temperatures of 21 °C and 31 °C. *—significant differences at $p < 0.05$, 31 °C: differences between individual measurements.

3.2. Results of Total Work in Repeated Anaerobic Exercise at 21 °C and 31 °C Performed by the Lower (TW_{LL}) and Upper Limbs (TW_{UL}) and Values of Its Sum (T_{TW})

The mean values of total work performed by the lower (TW_{LL}) and upper limbs (TW_{UL}) and the mean values of total work carried out by the lower and upper limbs (T_{TW}) showed no statistically significant differences between the measurements, separately at 21 °C and 31 °C, as well as between 21 °C and 31 °C, and separately in the individual series of pulsating efforts performed at 21 °C and 31 °C (Table 4).

Table 4. Total work and its sum in the upper ($\sum TW_{UL}$) and lower limb ($\sum TW_{LL}$) tests during individual series of pulsating efforts and the global value of its sum ($\sum T_{TW}$) for pulsating efforts performed at 21 °C and 31 °C.

No.	21 °C			31 °C		
	TW_{LL} (kJ)	TW_{UL} (kJ)	$\sum TW$ (kJ)	TW_{LL} (kJ)	TW_{UL} (kJ)	$\sum TW$ (kJ)
1	386.6	220.6	607.2	386.9	224.4	611.3
2	367.7	212.4	580.1	375.6	214.7	590.2
3	352.4	212.3	564.8	365.2	207.4	572.6
4	350.3	218.1	568.4	367.6	213.3	580.8
5	349.7	225.0	574.7	358.4	214.7	573.1
$\sum$	1806.8	1088.5	2895.2	1853.7	1074.3	2928.0

The total work (ΣTTW) performed by the athletes at an ambient temperature of 21 °C was 2895.21 kJ and 2928 kJ at 31 °C during 5 series of pulsating efforts (each series consisted of alternating efforts on a leg and arm cycle ergometer at maximum intensity) (Table 2).

3.3. Selected Blood Biochemical Indices Recorded before and after Pulsating Exercise and before and after Each of 5 Series of This Exercise at 21 °C and 31 °C

Blood lactate (LA) levels obtained before exercise at ambient temperatures of 21 °C and 31 °C totalled 2.06 mmol·L^{-1} and 2.09 mmol·L^{-1}, respectively, and 16.58 mmol·L^{-1} and 16.25 mmol·L^{-1} after the last series of pulsating efforts. In the first hour after repeated anaerobic exercise, the absolute values of this index at an ambient temperature of 31 °C were significantly higher ($p < 0.001$) than at 21 °C (Table 5). Statistically significant differences in lactate levels are shown in Table 5, separately for 21 °C and 31 °C between measurements, and in Table 6 between 21 °C and 31 °C, separately for each measurement.

Table 5. Differences in blood lactate levels obtained between measurements, separately for temperatures of 21 °C and 31 °C (ANOVA, planned comparisons).

LA (mmol·L^{-1})		Rest	After 1st Effort	Before 2nd Effort	After 2nd Effort	Before 3rd Effort	After 3rd Effort	Before 4th Effort	After 4th Effort	Before 5th Effort	After 5th Effort
21 °C	After 1st effort	<0.001									
	Before 2nd effort	<0.001	<0.001								
	After 2nd effort	<0.001	0.534	<0.001							
	Before 3rd effort	<0.001	<0.001	0.825	<0.001						
	After 3rd effort	<0.001	0.474	<0.001	0.498	<0.001					
	Before 4th effort	<0.001	<0.002	0.296	<0.001	0.412	<0.001				

Table 5. *Cont.*

LA (mmol·L^{-1})		Rest	After 1st Effort	Before 2nd Effort	After 2nd Effort	Before 3rd Effort	After 3rd Effort	Before 4th Effort	After 4th Effort	Before 5th Effort	After 5th Effort
	After 4th effort	<0.001	0.414	<0.001	0.363	<0.001	0.478	<0.002			
	Before 5th effort	<0.001	<0.001	0.044	<0.001	0.130	<0.001	0.081	<0.001		
	After 5th effort	<0.001	0.202	<0.001	0.087	0.002	0.266	<0.001	0.584	<0.001	
	After 1 h	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
31 °C	After 1st effort	<0.001									
	Before 2nd effort	<0.001	<0.001								
	After 2nd effort	<0.001	0.014	<0.001							
	Before 3rd effort	<0.001	<0.001	0.922	<0.001						
	After 3rd effort	<0.001	0.010	<0.001	0.460	<0.001					
	Before 4th effort	<0.001	0.002	0.480	<0.001	0.368	<0.001				
	After 4th effort	<0.001	0.539	<0.001	0.500	0.002	0.194	<0.001			
	Before 5th effort	<0.001	<0.001	0.757	<0.001	0.873	<0.001	0.094	<0.001		
	After 5th effort	<0.001	0.555	0.004	0.152	0.015	0.032	0.002	0.118	<0.001	
	After 1 h	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 6. Differences in lactate levels between 21 °C and 31 °C, separately for each measurement (ANOVA, planned comparisons).

Measurement	*p*
sp	0.314
After 1st effort	0.382
Before 2nd effort	0.649
After 2nd effort	0.662
Before 3rd effort	0.751
After 3rd effort	0.481
Before 4th effort	0.537
After 4th effort	0.871
Before 5th effort	0.409
After 5th effort	0.748
After 1 h	<0.001

4. Discussion

The main objective of the study was to determine post-exercise physiological changes in judo athletes under varying thermal conditions. The research concerned determining the level of change in total anaerobic work (TW) and relative peak power (RPP) during a special judo fitness test. During the tests, the dynamics of changes in anaerobic capacity indices were defined in sets of exercises with different loads and varying ambient temperatures.

Kubica [27] found that in trained individuals, homeostasis is restored more quickly after physical work, thus reducing recovery time and allowing for subsequent physical activity. Åstrand and Rodhal [21] and Ferretti et al. [42] indicated that endurance training improves the function of oxygen supply mechanisms and, consequently, ATP resynthesis via oxidative phosphorylation. Thermoregulatory mechanisms also become improved [43,44]. The results of our study showed that specialised stimuli used in the training of judo athletes significantly develop the anaerobic efficiency of the human body, while they do not modify the aerobic capacity (VO_{2max}) [10,45]. Furthermore, the level of relative peak power (PP) and total work (TW), as well as the level of VO_{2max} are significantly related to the way of conducting the fight [2]. The thermal factor can also have a significant effect on physiological and biochemical changes and the effectiveness of the fight. In the opinion of the authors, the results of the present research have practical implications for training staff in designing training programmes and for athletes of combat sports.

In terms of body height, body mass and body composition, the judo athletes from Poland participating in the study were similar to those from other countries [46]. During judo competitions, the athlete should be able to perform short bouts of physical exercise at peak power. The very frequent choice of the Wingate test to assess the anaerobic capacity of judo athletes is not coincidental, as it is highly specific for the assessment of anaerobic capacity since the contribution of anaerobic processes in such an effort can reach up to 90% [47]. The peak power and total work recorded in the Wingate test highly correlate with the effectiveness of athletes during the fight [19].

Sikorski et al. [48] demonstrated a high correlation between post-exercise LA and the temporal structure of the bout. Correlations between post-exercise LA levels and the course of the judo fight have also been demonstrated in previous studies [48,49]. Moreover, in many of them, it was found that it is the high efficiency of glycolytic (anaerobic lactate) processes that may play a decisive role in combat sports, including judo, and that the level of oxygen supply to tissues, which determines the resynthesis of ATP through oxidative phosphorylation, affects an athlete's performance, having a significant impact on the course of the fight [6,50].

The main parameters of anaerobic capacity are relative peak power (RPP) and total work (TW). The tested athletes had a peak power of 12.12 ± 0.87 W·kg^{-1} in the test performed with LL. These values were higher than those of Polish judo athletes, who achieved results of 11.46 ± 1.17 W·kg^{-1} [49], similar to national team members from Canada, Brazil and Great Britain [46]. For UL, this value reached 7.00 ± 0.56 W·kg^{-1}, which was 1.79 W·kg^{-1} lower than that obtained for the Polish national team athletes [49]. Team members from Canada [13,15], Brazil [51] and Great Britain [52] also showed higher values of peak power obtained in the Wingate test performed with the upper limbs. Total work (TW) was 285.27 ± 17.73 J·kg^{-1} in the LL test and 173.55 ± 13.50 J·kg^{-1} in the UL test. Relative total work (TW J·kg^{-1}) in handball (245.27 ± 16.1 J·kg^{-1}), soccer (251.7 ± 16.0 J·kg^{-1}) and volleyball players (279.9 ± 14.0 J·kg^{-1}) was lower than in the case of the studied judo athletes [50]. According to the standards proposed by Zdanowicz and Wojczuk, [50], the tested athletes had a high level of relative peak power (RPP) and a very high total work (TW). Given the nature of the work performed by judo athletes in single bouts and the nature of judo tournaments, athletes should exhibit, among others, high glycolytic capacity. During the 30-second version of the Wingate test, the work performed is based on anaerobic processes, which reach 87%, while the contribution of aerobic processes does not exceed 13% [50]. In the first stage, phosphagen sources are used, sufficient for a few seconds of muscle work, and then the processes of anaerobic glycolysis are activated to provide a further portion of energy (anaerobic lactate system). In the judo athletes under study, blood lactate concentration at 3 min after the 30 s anaerobic exercise performed by the LL was, on average, 14.11 ± 1.37 mmol·L^{-1}, with these values lower compared to Polish team members (18.8 ± 2.4 mmol·L^{-1}). The values of maximum blood lactate concentrations after the Wingate test performed with UL and LL were at similar levels. However, when converted per unit of work, they were higher for UL compared to LL efforts. This may indicate a different composition of UL and LL muscle fibres (predominance of type I fibres in leg muscles). In the examination of both male and female combat sports athletes, it was found that the LA-to-MP ratio for both genders was higher for UL compared to LL. This suggests that muscle energy generation in the upper limbs is more dependent on carbohydrate metabolism [53].

The nature of the competitive effort regarding judo athletes requires comprehensive preparation to fight effectively [4]. Popular laboratory tests used to assess physical performance can determine the efficiency of energy processes (phosphagen, glycolytic and aerobic). This gives coaches the opportunity to compare the exercise capacity of athletes and monitor the dynamics of their changes over the training macrocycle. Due to technical limitations, these laboratory tests are generally conducted at room temperature, when the athlete's body is only loaded with endogenous heat. There is little information about the physiological and biochemical responses during such tests at elevated ambient temperatures when the athlete's body must cope with the accumulated heat of exo- and endogenous origin. In light of the available data concerning the effect of environmental conditions on the exercise capacity of the athlete's body, it can be presumed, taking into account that judo tournaments are played not only in a thermoneutral environment (21–23 °C) but also in an environment with increased temperature (30–33 °C), that the knowledge of these responses is necessary to develop an optimal program and implement modern training technologies. Based on our previous research, it is known that the thermal factor of exogenous origin affects muscle energy efficiency and fatigue processes during athletic competitions and has a significant impact on the course of a sports fight.

In judo athletes, exercise tests are not highly specific, due to the fact that they are most often performed on leg cycle ergometers. In the present study, an attempt to solve this problem was made by instructing athletes to work on a cycle ergometer with alternating use of the lower (LL) and upper limbs (UL). The authors' sequence of anaerobic interval efforts included the temporal structure of both single and competitive bouts. Such an effort, although it does not reflect the actual load on the body as in a competitive fight, is to a large extent similar. The series of pulsating anaerobic exercises were performed on the leg and arm ergometers in an attempt to mimic single and competitive judo bouts in terms of time and intensity. In competitive settings, an athlete performs an average of five bouts of varying intensity, with an exercise duration of about 8 min [17,48,54]. It should be emphasized that anaerobic interval efforts performed by the upper and lower limbs engaged more muscle chains than when they are applied selectively, which also resulted in greater changes in physiological and biochemical indices. The experimentally obtained data on the functional properties of a judo athlete's body, as shown by the authors' previous research, are often correlated with the athlete's sports skill level [51,55]. In sports competitions, judo athletes very often use their upper limbs to perform throws or other technical actions that are decisive in the course of the fight [56,57]. Therefore, in the authors' opinion, analysis of exercise capacity for UL efforts should become a part of tests evaluating exercise capacity among athletes of combat sports, including judo.

In the first and third series of anaerobic LL exercises at 21 °C, there was a statistically significant ($p < 0.001$) decrease in relative peak power (RPP) between the first and fourth repetitions. There were no statistically significant differences in RPP between the first and fourth repetitions of anaerobic exercise in the second, fourth and fifth series. A similar pattern of results was observed during the effort series at 31 °C. Statistically significant changes in RPP occurred between the 1st and 4th repetitions in the first, second, third and fifth series, and in the fourth series between the first and second repetitions of anaerobic exercise.

UL efforts at 21 °C showed statistically significant differences between the second and third repetitions of anaerobic efforts in the first series of tests, and between the first and fourth repetitions in the second and third series. In the fourth and fifth series, there were no statistically significant differences between RPP recorded in individual repetitions of the anaerobic efforts at 21 °C. A similar pattern of changes was observed in the following studies, in which it has been shown how the exercise intensity during the exercise tests decreased with increasing relative ambient temperature. This is likely due to fatigue caused by changing thermal conditions [58,59]. At 31 °C, differences occurred only between repetitions in the second series of anaerobic efforts between the first versus second and third repetitions. No significant differences were observed in the other series.

Although inconsistent with some suggestions of previous researchers, this pattern of results demonstrates that in anaerobic interval exercise, the thermal factor of exogenous origin (different ambient temperature) did not differentiate between the anaerobic exercise capacity of judo athletes [60].

It is virtually impossible to develop an anaerobic test for judo athletes that reliably simulates a competitive fight. This is due to the high complexity of movements and the inability to programme direct contact with the opponent, which is known to affect the extent of micro- and macro-injuries to the musculoskeletal system. The efforts proposed in the study are performed at the highest possible intensity of anaerobic metabolism during work with LL and UL. The mean values of total work carried out by the lower (TWLL) and upper limbs (TWUL) and its value when performed by the lower and upper limbs (TTW) showed no statistically significant differences between series at 21 °C and 31 °C, and between 21 °C and 31 °C, separately in each series.

This pattern of results indicates that the series of pulsating efforts at room and elevated ambient temperatures equally affect the fatigue processes in an athlete's body, which is manifested by a statistically insignificant difference in the sum of total work performed at 21 °C and 31 °C, amounting to only 1.12%.

Tracking changes in phosphagen and glycolytic power during repeated anaerobic exercise allows for the analysis of energy metabolism in fighting conditions, as emphasized in their study by Lech et al. [17], showing a high correlation between peak power and amount of work performed and performance during a fight.

The nature of tournament bouts indicates that judo athletes very often compete in consecutive bouts over a period when disturbances of body homeostasis are very large and may affect the effectiveness of actions. Mickiewicz et al. [48] found that short intervals between competitive bouts can influence judo athletes to enter the next bout when blood lactate levels are even at 16.1 mmol·L^{-1}. The observations made in the study reveal that athletes entered successive series of anaerobic exercise at 21 °C, with lactate levels ranging from 12.38 mmol·L^{-1} to 13.98 mmol·L^{-1}, and at 31 °C from 13.28 mmol·L^{-1} to 14.12 mmol·L^{-1}. Differences between lactate concentrations at 21 °C and 31 °C for individual measurements did not demonstrate any statistically significant differences. This may suggest that in the anaerobic exercise series, the thermal factor did not modify exercise metabolism. Resting LA levels were within the physiologically normal range. One hour after the completion of these efforts at 31 °C, lactate levels were significantly higher ($p < 0.001$) than at 21 °C. The low values of LA levels indicate good post-exercise recovery of the tested athletes. The higher (by 26.8%) blood lactate level in the first hour following exercise at 31 °C indicates the intensification of anaerobic metabolic processes, mainly due to the elevated temperature, which contributes to a shift in the acid–base balance towards acidosis resulting from water loss and reduced blood flow in muscles [11,22]. This is manifested by a decrease in blood pH and a decrease in bicarbonate levels which, in turn, increases the demand for oxygen and forces more pulmonary ventilation.

During the pulsating exercise performed at two different ambient temperatures, the body's aerobic potential may play an important role, which is probably due to the intervals applied between successive series of pulsating efforts and the temporal structure of a single series of anaerobic efforts. In an abundance of caution, it can be concluded that the proposed exercise provides information on anaerobic lactic and anaerobic lactate capacities and may allow for the assessment of aerobic potential and tolerance to a thermal stimulus of exogenous origin using appropriate testing techniques.

Therefore, the results of the series of pulsating exercises provide important insight into the anaerobic endurance capacity of judo athletes and information about the course of fatigue build-up and the rate of recovery. A literature search reveals a dearth of studies focused on assessing the size of variation regarding physiological response in judo athletes to sets of anaerobic interval efforts reflecting the competition structure of a judo fight at elevated ambient temperatures.

Study Limitations

The main limitation of the study was the relatively small group of judo athletes due to the elite level of the participants. Furthermore, due to the challenging conditions of exercise at elevated temperatures, some athletes (n 5) failed to complete all tests. An additional limitation was a lack of body core temperature measurements, which could not be taken for organisational reasons.

5. Conclusions

The main objective of the study was to determine the level of changes in anaerobic capacity indices such as total work (TW) and relative peak power (RPP) during pulsating anaerobic exercise at different ambient temperatures. Based on previous research, it is known that the thermal factor of exogenous origin affects the energy efficiency of muscles and the course of fatigue processes.

Learning about the dynamics of changes concerning anaerobic capacity indices in each of the five exercise sets at different ambient temperatures can have important practical value, as it provides an opportunity to optimally programme the intensity of interval judo efforts that correspond to the physiological structure of a judo fight. Relative peak power (RPP) and total work (TW) at both temperatures in each series of LL and UL tests were generally not significantly different.

After LL and UL exercise at elevated temperatures, weight loss due to dehydration was greater than at room temperature (amounting to more than 2% BM).

Based on the results, the following conclusions were drawn: varying ambient thermal conditions do not affect the size of relative peak power generated or the volume of work performed in pulsating anaerobic exercise.

Practical Implications

The results have practical implications. The individual components of the training structure, allow for the programming of anaerobic training loads while adapting them to the changing physiological and biochemical structure of the fight and the thermal conditions of the environment. Therefore, in the periodisation of judo training, it is worth introducing training sessions at elevated temperatures in order to adapt athletes to increased physical stress caused by thermal exposure.

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References

1. Lech, G.; Tyka, A.; Pałka, T.; Krawczyk, A. The physical capacity and the course of fights and the sports level of judo juniors. *Arch. Budo.* **2010**, *6*, 1–6.
2. Pałka, T.; Lech, G.; Tyka, A.; Pilch, W.; Wiecha, S. Wydolność fizyczna i morfologiczna budowa ciała profesjonalnych judoków i nietrenujących mężczyzn. *Antropomotoryka* **2010**, *20*, 85–89.
3. Lopes-Silva, J.P.; Panissa, V.L.G.; Julio, U.F.; Franchini, E. Influence of Physical Fitness on Special Judo Fitness Test Performance. *J. Strength Cond. Res.* **2021**, *35*, 1732–1738. [CrossRef]
4. Błach, W.; Rydzik, Ł.; Błach, Ł.; Cynarski, W.J.; Kostrzewa, M.; Ambroży, T. Characteristics of Technical and Tactical Preparation of Elite Judokas during the World Championships and Olympic Games. *Int. J. Environ. Res. Public Health* **2021**, *18*, 5841. [CrossRef] [PubMed]
5. Lech, G.; Sterkowicz, S. The commencement age of training and its effects on technical preferences and achievements attained by judo contestants. *Hum. Mov.* **2004**, *5*, 42–47.
6. Lech, G.; Tyka, A.; Pałka, T.; Krawczyk, R. The physical efficiency and the course of fights and the sports level of judo contestants. *Med. Sport Pract.* **2007**, *8*, 81–85.
7. Pałka, T.; Błach, W.; Lech, G.; Pilch, W.; Tyka, A.; Mucha, D.; Tota, Ł.; Ambroży, T.; Skalska-Izdebska, R. Differences in the levels of physiologicalbiochemical responses during physical exercise involving the lower and upper extremities in judo competitors. *J. Combat Sport. Martial Arts* **2016**, *7*, 7–15. [CrossRef]
8. Rydzik, Ł. Indices of technical and tactical training during kickboxing at different levels of competition in the K1 Formula. *J. Kinesiol. Exerc. Sci.* **2022**, *31*, 1–5. [CrossRef]
9. Ouergui, I.; Hammouda, O.; Chtourou, H.; Gmada, N.; Franchini, E. Effects of recovery type after a kickboxing match on blood lactate and performance in anaerobic tests. *Asian J. Sports Med.* **2014**, *5*, 99–107.
10. Franchini, E.; Sterkowicz, S.; Szmatlan-Gabrys, U.; Gabrys, T.; Garnys, M. Energy System Contributions to the Special Judo Fitness Test. *Int. J. Sports Physiol. Perform.* **2011**, *6*, 334–343. [CrossRef]
11. Górski, J. Fizjologia wysiłku i treningu fizycznego. *Wydaw. Lek. PZWL* **2019**, *28*, 74–148.
12. Almeida, H., Jr.; de Andrade Bastos, A.; Martins, F.J.A.; de Souza, R.F.; Martins, C.O.D.; da Silva, A.G.; Sousa, T.A.; Regi, R.P. Comparison of the thermal profile of Judokas and Brazilian Jiu-Jitsu athletes. *J. Phys. Educ. Sport* **2019**, *19*, 3–7. [CrossRef]
13. Thomas, S.G.; Cox, M.H.; LeGal, Y.M.; Verde, T.J.; Smith, H.K. Physiological profiles of the Canadian National Judo Team. *Can. J. Sport Sci.* **1989**, *14*, 142–147. [PubMed]
14. Quintero, A.M.; da Orssatto, L.B.R.; Pulgarín, R.D.; Follmer, B. Physical performance, body composition and somatotype in Colombian judo athletes. *Ido Mov. Cult.* **2019**, *19*, 56–63. [CrossRef]
15. Little, N.G. Physical performance attributes of junior and senior women, juvenile, junior, and senior men judokas. *J. Sports Med. Phys. Fit.* **1991**, *31*, 510–520.

16. Franchini, E.; Julio, U.F.; Panissa, V.L.G.; Lira, F.S.; Gerosa-Neto, J.; Branco, B.H.M. High-Intensity Intermittent Training Positively Affects Aerobic and Anaerobic Performance in Judo Athletes Independently of Exercise Mode. *Front. Physiol.* **2016**, *7*, 268. [CrossRef]
17. Lech, G.; Jaworski, J.; Krawczyk, R. The Level of Motor Co-Ordination Abilities and the Course of Fights as Well as the Level of Achievements by Senior Judoists. *J. Kinesiol. Exerc. Sci.* **2007**, *17*, 63–71.
18. Wolska, B.; Smulskij, V.; Jagiełło, W. The Level of Aerobic and Anaerobic Capacity and the Results of a Special Mobility Fitness Test of Female Judo Contestants. *Balt. J. Health Phys. Act.* **2009**, *1*, 4858. [CrossRef]
19. Lech, G.; Tyka, A.; Pałka, T.; Krawczyk, R. Effect of physical endurance on fighting and the level of sports per formance in junior judokas. *Arch. Budo.* **2010**, *6*, 1–6.
20. Armstrong, L.E.; Maresh, C.M. The Induction and Decay of Heat Acclimatisation in Trained Athletes. *Sport. Med.* **1991**, *12*, 302–312. [CrossRef]
21. Åstrand, P.O.; Rodahl, K. *Textbook of Work Physiology: Physiological Bases of Exercise*, 3rd ed.; Mc Graw-Hill: New York, NY, USA, 1986.
22. Kubica, R.; Tyka, A.; Żuchowicz, A.; Jałocha, W.; Pałka, T.M.B. The effect of different ambient temperature conditions on the level of threshold (AT–TDMA). *Med. Sport.* **1998**, *2*, 90–91.
23. Pałka, T.; Tyka, A.; Maciejczyk, M.; Bawelski, M.; Cisoń, T.; Pilch, W.; Żmuda, M. Wpływ treningu fizycznego o intensywności podprogowej w dwóch różnych temperaturach otoczenia na sprawność wysiłkowych mechanizmów termoregulacyjnych u mężczyzn. *Med. Sport.* **2006**, *4*, 79–82.
24. Alm, P.; Yu, J.G. Physiological characters in mixed martial arts. *Am. J. Sport. Sci.* **2013**, *1*, 12–17. [CrossRef]
25. Bompa, T.O.; Buzzichelli, C.A. *Periodization: Theory and Methodology of Training*; Human Kinetics: Champaign, IL, USA, 2018.
26. Åstrand, P.O.; Saltin, B. Maximal oxygen uptake and heart rate in various types of muscular activity. *J. Appl. Physiol.* **1961**, *16*, 977–981. [CrossRef] [PubMed]
27. Kubica, R. *Fizjologiczna Analiza Wybranych Wysiłkowych Mechanizmów Adaptacyjnych*; Zdrowie i Kultura Fizyczna—Warsztaty Badawcze; AWF Warszawa: Warszawa, Poland, 1989.
28. Sterkowicz, S.; Zuchowicz, A.; Kubica, R. Levels of anaerobic capacity and results for Special Judo Fitness test in judo competitors. *J. Hum. Kin.* **1999**, *2*, 115–135.
29. Pałka, T.; Lech, G.; Tyka, A.; Tyka, A.; Sterkowicz-Przybycień, K.; Sterkowicz, S.; Cebula, A.; Stawiarska, A. Differences in the level of anaerobic and aerobic components of physical capacity in judoists at different age. *Arch. Budo.* **2013**, *9*, 195–203.
30. Lawler, J.; Powers, S.K.; Dodd, S. A time-saving incremental cycle ergometer protocol to determine peak oxygen consumption. *Br. J. Sports Med.* **1987**, *21*, 171–173. [CrossRef]
31. Tyka, A.; Żuchowicz, A.; Kubica, R.P.T. Effect of ambient temperature on mechanical power at anaerobic threshold. *Med. Sci. Sport. Exerc.* **2000**, *32*, 155.
32. Sterkowicz, S.; Maslej, P. Analiza przebiegu walki judo na podstawie jej struktury czasowej-badania porównawcze. *Sport Wyczyn.* **1999**, *37*, 33–38.
33. Chtourou, H.; Aloui, A.; Hammouda, O.; Chaouachi, A.; Chamari, K.; Souissi, N. The effect of time-of-day and judo match on short-term maximal performances in judokas. *Biol. Rhythm. Res.* **2013**, *44*, 797–806. [CrossRef]
34. Ceylan, B.; Barley, O.R.; Balci, S.S. Changes in body mass and hydration status in judo athletes before and after a top-level competition: A descriptive case study. *Phys. Sportsmed.* **2022**. [CrossRef] [PubMed]
35. Ceylan, B.; Taşcan, M.B.; Simenko, J.; Balcı, Ş.S. Habit or lack of education? Hypohydration is present in elite senior judo athletes even during a weight-stable training camp. *Int. J. Sports Sci. Coach.* **2022**, 174795412211224. [CrossRef]
36. Pałka, T.; Lech, G.; Tota, Ł.; Tyka, A.; Pilch, W.; Mucha, D.; Bujas, P.; Ambroży, T.; Renata, S.-I.; Tyka, A. The level of selected indicators of anaerobic capacity in judo players and the range of their changes during simulated tournament fights. In Proceedings of the Third International Scientific Conference "Motor Abilities in Sports—Theoretical Assumptions and Practical Implications", Kraków, Poland, 19–21 September 2019.
37. Szyguła, Z. Profilaktyka i postępowanie w schorzeniach spowodowanych wysiłkiem w gorącym otoczeniu. *Med. Sport.* **1997**, *1*, 55–57.
38. Gomes Moreira, D.; José Brito, C.; de Almeida Ferreira, J.J.; Bouzas Marins, J.C.; López Díaz de Durana, A.; Couceiro Canalejo, J.; Butragueño Revenga, J.; Sillero-Quintana, M. Lactate Concentration Is Related to Skin Temperature Variation after a Specific Incremental Judo Test. *J. Strength Cond. Res.* **2021**, *35*, 2213–2221. [CrossRef] [PubMed]
39. Du Bois, D.; Du Bois, E.F. A formula to estimate the approximate surface area if height and weight be kno. *Arch. Int. Med.* **1916**, *17*, 863–871. [CrossRef]
40. Dotan, R.; Bar-Or, O. Load optimization for the wingate anaerobic test. *Eur. J. Appl. Physiol. Occup. Physiol.* **1983**, *51*, 409–417. [CrossRef]
41. Stanisz, A. *Przystępny Kurs Statystyki*; StatSoft Polska Sp. z o.o.: Kraków, Poland, 2001.
42. Ferretti, G.; Ishii, M.; Moia, C.; Cerretelli, P. Effects of temperature on the maximal instantaneous muscle power of humans. *Eur. J. Appl. Physiol. Occup. Physiol.* **1992**, *64*, 112–116. [CrossRef]
43. Nielsen, B. Termoregulation in reast end exercise. *Acta Physiol. Scand. Suppl.* **1969**, *323*, 1–74.
44. Gleeson, M. Temperature Regulation during Exercise. *Int. J Sport. Med.* **1998**, *19*, 96–99. [CrossRef]

45. Lech, G.; Sterkowicz, S.; Żuchowicz, A.R.W. Wydolność fizyczna a przebieg i rezultaty walki judo juniorów. *Ann. Univ. Mariae Curie-Skłodowska* **2006**, *60*, 190–193.
46. Franchini, E.; Del Vecchio, F.B.; Matsushigue, K.A.; Artioli, G.G. Physiological Profiles of Elite Judo Athletes. *Sport. Med.* **2011**, *41*, 147–166. [CrossRef]
47. Bar-Or, O. The Wingate Anaerobic Test an Update on Methodology, Reliability and Validity. *Sport. Med. Int. J. Appl. Med. Sci. Sport Exerc.* **1987**, *4*, 381–394. [CrossRef]
48. Sikorski, W.; Mickiewicz, G.; Majle, B. Łaksa Cz. Struktura walki judo i jej wpływ na wydolność zawodnika. *Sport Wyczyn.* **1988**, *9*, 15–19.
49. Mickiewicz, G.; Starczewska, G.; Borkowski, L. Fizjologiczna charakterystyka zawodników kadry narodowej judo. *Sport Wyczyn.* **1988**, *9*, 46–50.
50. Zdanowicz, R.; Wojczuk, J. Wydolność beztlenowa zawodników i zawodniczek judo. *Sport Wyczyn.* **1984**, *12*, 29–36.
51. Franchini, E.; Takito, M.Y. Physical Fitness and Anthropometrical Differences. *Biol. Sport* **2005**, *22*, 315–328.
52. Sharp, N.C.C.; Koutedakis, Y. Anaerobic power and capacity measurements of the upper body in elite judo players, gymnasts and rowers. *Aust. J. Sei. Med. Sport.* **1987**, *19*, 9–13.
53. Hübner-Wozniak, E.; Kosmol, A.; Lutoslawska, G.; Bem, E. Anaerobic performance of arms and legs in male and female free style wrestlers. *J. Sci. Med. Sport* **2004**, *7*, 473–480. [CrossRef]
54. Sikorski, W.; Łaksa, C. Analiza Mistrzostw Świata w Judo–Maastricht (Holandia) 1981. *Sport Wyczyn.* **1982**, *4*, 28–35.
55. Vidal Andreato, L.; Franzói de Moraes, S.M.; Lopes de Moraes Gomes, T.; Del Conti Esteves, J.V.; Vidal Andreato, T.; Franchini, E. Estimated aerobic power, muscular strength and flexibility in elite Brazilian Jiu-Jitsu athletes. *Sci. Sports* **2011**, *26*, 329–337. [CrossRef]
56. Sterkowicz, S.; Lech, G.; Blecharz, J. Effects of laterality on the technical/tactical behavior in view of the results of judo fights. *Arch. Budo.* **2010**, *6*, 173–177.
57. Chwała, W.; Ambroży, T.; Sterkowicz, S. Three-dimensional analysis of the ju-jitsu competitors' motion during the performance of the ippon-seoi-nage throw. *Arch. Budo. Sci. Martial Arts Extrem. Sport.* **2013**, *9*, 41–53.
58. Tyka, A.; Wiecha, S.; Pałka, T.; Cisoń, T.; Szyguła, Z.; Tyka, A. Effects of Ambient Temperature on Physiological Responses to Incremental Exercise Test. *J. Hum. Kinet.* **2010**, *26*, 57–64. [CrossRef]
59. Pałka, T.; Tyka, A.; Maciejczyk, M.; Cisoń, T.; Pilch, W.; Żmuda, M. Effect of Physical training in two different temperatures on exercise thermoregulation in men. *Med. Sport Pract.* **2006**, *7*, 79–82.
60. Cisoń, T. Wpływ Odwodnienia Wysiłkowego Oraz Różnych Strategii Nawadniania Organizmu Podczas Pracy Fizycznej i po Wysiłku na Wielkość Mocy Maksymalnej i Wybranych Wskaźników Fizjologiczno-Biochemicznych Krwi. Ph.D. Thesis, University of Physical Education, Kraków, Poland, 2010.