Journal of Physical Education and Sport ® (JPES), Vol. 24 (issue 8), Art 217, pp. 1953 - 1963, August 2024
online ISSN: 2247 - 806X; p-ISSN: 2247 – 8051; ISSN - L = 2247 - 8051 © JPES

Original Article

Analysis of physical fitness, body composition, and structure of polish national Ju-jitsu team members in relation to performance in competitions

TADEUSZ AMBROŻY[1], ŁUKASZ RYDZIK[2*], KRZYSZTOF KASICKI[3], ZBIGNIEW MAŁODOBRY[4], ANDRZEJ KĘDRA[5]
[1,2]Institute of Sports Sciences, University of Physical Education, 31-571 Kraków, POLAND;
[3]Faculty of Medicine and Health Sciences, Andrzej Frycz-Modrzejewski Kraków University, 30-705 , Kraków, POLAND;
[4]University of Rzeszów, POLAND
[5]Department of Sport Science Faculty of Social Sciences, Vincent Pol University in Lublin, 20-816 Lublin, POLAND;

Published online: August 31, 2024
Accepted for publication : August 15, 2024
DOI:10.7752/jpes.2024.08217

Abstract
Background: This study aimed to investigate the impact of body composition and physical fitness on the performance of athletes in the Polish National Ju-Jitsu Team and their effects on performance in competitive bouts. The focus was on understanding the relationship between physical and physiological parameters and the athletes' effectiveness during three phases of a ju-jitsu fight: standing, transition, and ground fighting. **Methods:** The study involved 10 national team athletes who were assessed for body composition, physical fitness, and technical-tactical skills. Various fitness tests, body composition measurements, and statistical analyses were employed to determine correlations between these factors and performance in each fight phase. **Results:** The findings indicated no significant correlations between body composition and performance in the first and second phases of the fight. However, significant correlations were observed in the third phase (ground fighting), where specific body composition parameters were linked to better performance. The study highlighted the importance of specialized training, particularly in endurance, speed, and strength maintenance, to prevent fatigue during fights. **Conclusions:** The results suggest that tailored training programs focused on the identified areas of improvement could enhance overall competition performance. While body composition did not correlate with performance in all fight phases, its impact in the third phase underscores the need for further research. These findings are crucial for optimizing training strategies for ju-jitsu athletes. Coaches should prioritize the development of special fitness, especially during the transition phase, and ensure comprehensive strength preparation to improve athletes' performance in competitions.
Keywords: ju-jitsu, physical fitness, body structure, martial arts, tactical skills

Introduction

Comprehensive physical fitness, as well as proper body structure and proportions, play a crucial role in ju-jitsu fights. Questions regarding the relationship between indicators such as efficiency, activity, and effectiveness with the athlete's level of fitness are often considered by coaches when planning and organizing the training process. Selecting training methods without determining these relationships can impact the athlete's performance(Ambroży et al., 2021a; Ambroży T et al., 2014; Andrade et al., 2019; Manolachi et al., 2023; Staller, 2013).

The motor requirements for ju-jitsu athletes include both comprehensive and specialized motor preparation(Marques Junior, 2020). Comprehensive preparation involves developing all fundamental elements of an athlete's motor skills, referred to as general physical preparation (GPP)(Ambroży et al., 2017; Andrade et al., 2019; Kędra et al., 2023; Zaggelidis et al., 2019). GPP serves as the foundation for an athlete's development, upon which specialized physical preparation (SPP)(James, 2014; Sterkowicz-Przybycień K, Ambroży T, Jasiński M, 2014) and proper preparation for specific competitions are built. During the GPP phase, athletes work on developing strength, speed, endurance, and flexibility, which, once they reach an adequate level, should serve as the basis for teaching, refining, and developing technical skills according to the specifics of the sport (Adam M., Tabakov S., Blach L., Smaruj, 2013; Galan D. & Rata G., 2016; Staller, 2013; Terry, 2006). Depending on the weight category, body type, body proportions, and limb length may influence the techniques used in the fight. An optimal level of muscle mass with minimal fat is also desirable(Mala et al., 2019; Podstawski et al., 2017; Sterkowicz-Przybycień et al., 2014).

Sports combat in ju-jitsu (Figure 1) is characterized by high variability in technical-tactical actions(Ambroży et al., 2021b) and the level and nature of exertion(Ambroży et al., 2023; Kędra et al., 2023; Wąsacz & Pociecha, 2021; Zaggelidis et al., 2019), which requires athletes to adapt to high training loads and

Corresponding Author: ŁUKASZ RYDZIK, E-mail: lukasz.rydzik@awf.krakow.pl

coaches to use optimal evaluation tools to assess physical fitness levels. Ju-jitsu is an intermittent sport with predominantly anaerobic exertion (Ambroży T. et al., 2007), where dynamic and maximal strength, coordination, especially in terms of reaction time and speed changes, and appropriate aerobic efficiency play a key role(Ambroży T., 2008; Ferreira Marinho et al., 2016). To maintain high performance during combat and avoid fatigue, it is essential to maintain an adequate level of muscular energy, which allows for generating the required strength. These factors depend on aerobic capacity, which underlies all endurance-related movements(Blagrove, 2022; Halson, 2014; Ronikier A., 2001). Additionally, there is a relationship between endurance and body composition(Heydenreich et al., 2017; Sidney et al., 1977).

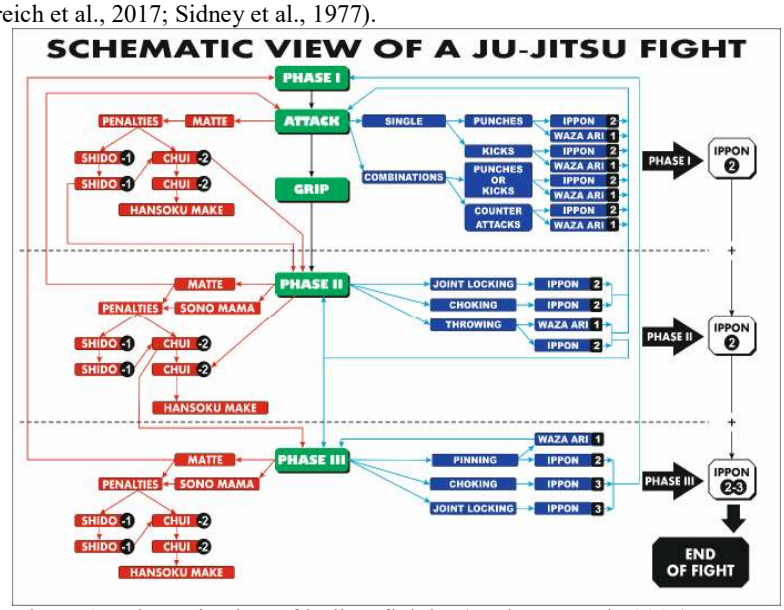

Figure 1. Schematic view of ju-jitsu fighting(Ambroży et al., 2017)

To effectively develop an athlete's potential, it is necessary to monitor their progress through the use of appropriate fitness tests and body composition assessments(Szopa J. et al., 2000; Thornton et al., 2019). The timing of these evaluations within the training cycle is also important, as it can allow for adjustments to training plans, indirectly affecting their outcomes(Brown et al., 2023; Dos'Santos et al., 2019; Sozański, 1999). In the case of this study, tests and measurements were conducted before the main competitions, enabling trials to be performed at maximum intensity in a group of athletes optimally prepared for competition.

The results of the conducted studies can provide valuable practical implications for athletes and coaches. Implementing the findings can help optimize the physical fitness levels and control the body mass and composition of ju-jitsu athletes, which can ultimately lead to greater sports success.

The aim of the study is to analyze the level of physical fitness, body structure, and composition of Polish National Team members in relation to the course of ju-jitsu sports combat, assessed using technical and tactical indicators.

Materials and Methods

Participants The analysis of body composition and fitness levels was conducted on a group of 10 members of the Polish National Team, where the average height of the examined athletes was 181.2 cm, the average age was 28 years (27.7), and the training experience was 19 years (18.8). Additionally, the athlete's degree of mastery was taken into account (Table 1).

Table 1. Inclusion and Exclusion Criteria

10 professional ju-jitsu athletes	
Inclusion Criteria	Exclusion Criteria
Membership in the Polish National Team in Ju-Jitsu	Athletes who are not members of the Polish National Team in ju-jitsu are excluded from the study
Participants must be between the ages of 25-35	Athletes with current injuries, chronic illnesses, or other health issues that may affect the study results are excluded
Participants must have at least 15 years of training experience in ju-jitsu	Individuals with less than 15 years of training experience in ju-jitsu are not eligible for the study
Participants must provide written consent to participate in the study and for their personal data to be processed for research purposes	ndividuals who do not provide written consent to participate in the study and for their personal data to be processed are excluded
Participants must have regularly participated in training and sports competitions over the past two years	Individuals who have not regularly participated in training and sports competitions over the past two years are excluded from the study

The research material for evaluating the course of the fight consisted of multimedia recordings of sports fights that took place during the Senior World Ju-Jitsu Championships (fighting formula) on November 25th and 26th, 2016, in Wrocław. The competition was conducted in accordance with the regulations of the International Ju-Jitsu Federation (JJIF).

Measurement of body structure and general and special Physical Fitness

Body mass was measured using a Tanita BC-601 body composition monitor (Tanita, Tokyo, Japan), whereas the body height was measured using a SECA 2017 body height meter (Seca, Hamburg, Germany).

The physical fitness measurements were conducted using general and specific fitness tests previously utilized with ju-jitsu athletes(Ambroży et al., 2017, 2021a; Brooks et al., 2005; Nowak M & Ambroży T, 2015; Sterkowicz & Ambroży T., 1992; Wąsacz et al., 2022). The trials were carried out in October during the athletes' stay at a sports camp prior to the 2016 World Championships:

1. Classic squat with a barbell. External resistance equal to the body weight of the exerciser. The result is the number of squats performed.
2. Classic squat with a barbell with maximum external resistance (the best possible result of the exerciser in kg).
3. Classic bench press with a barbell with external resistance equal to the body weight of the exerciser. The result is the number of bench presses performed.
4. Classic bench press with a barbell with maximum external resistance (the best possible result of the exerciser in kg).
5. Special Throwing Ability Test (TSSR).

Before starting the test, a warm-up should be performed, which includes 5 minutes of jogging (moderate intensity), several repetitions of the *Ippon Seoi Nage* throw at a slow pace to get accustomed to the distance and exercise partners.

The test consists of three effort periods (A = 15s, B and C = 30s each) separated by 10-second breaks. In each period/series of throws, the thrower *(tori*) is evaluated based on the maximum number of *Ippon Seoi Nage* throws performed on two partners (*uke* A and B; standing on the mat 6 meters apart). The test scheme is presented in Figure 2.

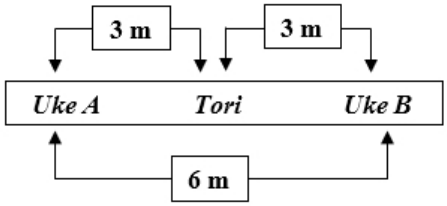

Figure 2**.** Diagram of the Special Throwing Ability Test (TSSR)

Special Judo Fitness Test (SJFT)(Drid et al., 2012)

Both *uke* A and B should have similar body weight and height as *tori* (the one being tested). Immediately after the end of period C and after 1 minute, the heart rate is measured.

Required equipment: adhesive tape to mark the 6 m distance on the mat for *uke* and the starting point for the thrower, a stopwatch to measure time, and a protocol to record the results. The exertion response was recorded using a heart rate monitor S-610i (Polar, Finland).

Measuring the Indicators of Technical and Tactical Training

Analysis of bouts was performed based on digital recordings of tournament fights of the athletes in 2016. Three fights of each athlete were analyzed . The recordings were made using three cameras (Sony HDR-CX115, Manufacturer, Tokyo, Japan). The video editing program Movavi Video Editor 14 was used to process the images. The setting of the cameras allowed for continuous observation of the fighting athletes, judges, and the scoreboard. A single spreadsheet was developed as a primary research tool. The data from the spreadsheets were entered into Excel software. Then, the values of indices of technical and tactical skills were calculated for all three stages of the bout. The formulas for calculating the indices were developed and based on the formulas used for judo, ju-jitsu and kickboxing(Adam et al., 2012; Ambroży et al., 2021b; Rydzik & Ambroży, 2021).

The technical and tactical profile in Ju-jitsu allows coaches to develop a training plan and an appropriate strategy for the athlete. The indicators of technical and tactical training were computed using the following formulas.

1. Effectiveness of the attack in the first part of the fight.

$$\mathbf{EaF1} = \frac{(n1x1) + (n2x2)}{N}$$

n1 – number of attacks assessed with *waza-ari* points (1 point)
n2 - number of attacks assessed with *ippon* points (2 points)
1, 2 – point values of successful attacks
N – total number of observed fights

2. Effectiveness of attack in the second part of the fight.
   $$\mathbf{EaF2} = \frac{(n1x1)+(n2x2)}{N}$$
   n1 – number of attacks assessed with *waza-ari* points (1 point)
   n2 - number of attacks assessed with *ippon* points (2 points)
   1, 2 – point values of successful attacks
   N – total number of observed fights
3. Effectiveness of attack in the third part of the fight.
   $$\mathbf{EaF3} = \frac{(n1x1)+(n2x2)+(n3x3)}{N}$$
   n1 – number of attacks assessed with *waza-ari* points (1 point)
   n2 - number of attacks assessed with *ippon* points (2 points)
   n3 – number of attacks assessed with *ippon* points (3 points)
   1, 2, 3 – point values of successful attacks
   N – total number of observed fights
4. Attack efficiency in the first part of the fight.
   $$\mathbf{AeF1} = \frac{\textit{Number of successful attacks}}{\textit{The total number of attacks}} \mathbf{x\ 100}$$
5. Attack efficiency in the second part of the fight.
   $$\mathbf{AeF2} = \frac{\textit{Number of successful attacks}}{\textit{The total number of attacks}} \mathbf{x\ 100}$$
6. Attack efficiency in the third part of the fight.
   $$\mathbf{AeF3} = \frac{\textit{Number of successful attacks}}{\textit{The total number of attacks}} \mathbf{x\ 100}$$
7. Attack activity in the first part of the fight**.**
   $$\mathbf{A_a^{F1}} = \frac{\sum a}{n}$$
   $\sum a$ – sum of attacks
   n – – total number of fights by the athlete
8. Attack activity in the second part of the fight**.**
   $$\mathbf{A_a^{F2}} = \frac{\sum a}{n}$$
   $\sum a$ – sum of attacks
   n – – total number of fights by the athlete
9. Attack activity in the third part of the fight**.**
   $$\mathbf{A_a^{F3}} = \frac{\sum a}{n}$$
   $\sum a$ – sum of attacks
   n – – total number of fights by the athlete

Bioethics Committee and Funding

Prior to participation in the tests, the participants were informed about the research procedures, which were in accordance with the ethical principles of the Declaration of Helsinki WMADH (2000). The participant's written consent was the inclusion criterion. The research was approved by the Bioethics Committee at the Regional Medical Chamber (No. 42/ KBL/OIL/2015 dated April 15, 2015).

The implementation and analysis of the research, as well as the publication fee, were carried out as part of the project "The impact of plyometric training on the level of physical fitness, physiological indicators, and muscle damage in basketball players," No. 362/BS/INoS/2024. The study was also funded under the Ministry of Science and Higher Education's "Regional Excellence Initiative" program for 2024-2027 (project no. RID/SP/0027/2024/01) in the amount of PLN 4 053 904,00.

Statistical Analysis

The statistical analysis of the collected data was conducted using the Statistica v.13.1 software from Statsoft (Tibco). Basic descriptive statistics were calculated, including the mean, median, minimum and maximum values, the first and third quartiles, standard deviation, and coefficient of variation. Spearman's Rank correlation was employed to assess relationships, and the choice of the test was made after checking the distribution of variables with the Shapiro-Wilk test. A significance level of $p<0.05$ was adopted for statistically significant differences.

Results

Table 2 presents the descriptive statistics of the body composition of the athletes from the Polish National Team.

Table 2. Basic descriptive statistics of the body composition of the athletes from the Polish National Team

	$\bar{x}$	Me	Min	Max	Q_1	Q_3	SD	V_z
Body mass - kg	83.5	84.1	61.6	109.4	74	93.4	14.3	17.2
Percentage of body fat - %	9.8	9.4	5.6	16.4	5.9	11.5	3.8	38.7
Muscle mass - kg	72.1	71.9	60.1	87	66.3	77.7	8.4	11.7
Bone mass - kg	3.8	3.8	3.2	4.4	3.5	4	0.4	9.5
Body Mass Index - BMI	25.0	25.2	21.4	29.1	22.6	27	2.7	10.8
Daily Caloric Intake - DCI (kcal)	4661.6	4625.0	3800.0	5788	4284	5122	608.0	13.0
Metabolic age in years	16.2	14.0	12.0	25	12	22	5.3	32.9
Body water percentage - %	66.6	67.7	61.9	69.4	65.3	68.2	2.6	3.8
Abdominal fat level	2.5	2.5	1.0	4	1	4	1.4	57.3

$\bar{x}$-Arithmetic mean, Me- Median, Min-Minimum value, Max- Maximum value, Q1- Lower quartile, Q3-Upper quartile, SD-Standard deviation, Vz- Coefficient of variation

The study results indicate that the average muscle strength level of the lower limbs, verified through a squat with a barbell, was estimated at 147 kg. Meanwhile, muscular endurance, measured by the number of classic squats with a barbell with an external resistance equal to the exerciser's body weight, averaged 21.5 repetitions. The chest muscle strength was at a level of 116.5 kg, while the shoulder girdle and back muscle strength was at 14.8 pull-ups with an overhand grip on a bar (Table 3).

Table 3. Basic Descriptive Statistics of Strength Tests of the Polish National Team

	$\bar{x}$	Me	Min	Max	Q_1	Q_3	SD	V_z
Classic squat with maximum external load (squat record) - kg	147	150	100	180	120	180	30.93	21.04
Classic squat with external load equal to body weight - n	21.5	21.5	18	26	20	23	2.42	11.23
Bench press with maximum external load (bench press record) - kg	116.5	110	90	145	105	140	18.72	16.06
Bench press with external load equal to body weight - n	9.3	9.5	7	12	8	10	1.57	16.85
Pull-ups with overhand grip - n	14.8	15.5	10	18	13	17	2.66	17.96

The number of throws performed in the Special Throwing Skill Test (TSSR) was 6.4±0.52 in the first series, 10.1±0.74 in the second series, and 8.9±0.32 in the third series. The total number of throws performed in the test ranged from 24 to 27 (Table 4, Figure.3).

Table 4. Basic Descriptive Statistics of the Number of Throws in the TSSR Test

	$\bar{x}$	Me	Min	Max	Q_1	Q_3	SD	V_z
Number of throws in series A (15s) - n	6.4	6	6	7	6	7	0.52	8.07
Number of throws in series B (30s) - n	10.1	10	9	11	10	11	0.74	7.31
Number of throws in series C (30s) - n	8.9	9	8	9	9	9	0.32	3.55
TOTAL number of throws for each athlete - n	25.4	25	24	27	24	27	1.26	4.98

As shown in Table 5, the arithmetic mean of the resting heart rate for the Polish National Team athletes was 100.1 bpm. After completing the task, it was 190.6 bpm, and after one minute of rest, it was 153.8 bpm. Additionally, using the Kruskal-Wallis ANOVA test, it was examined whether there were statistically significant differences in the heart rate levels at rest, immediately after completing the task, and after one minute of rest following the task. The study indicated that the differences in heart rate levels were statistically significant $p<\alpha$ ($p=0.0000$). The highest values were observed in the heart rate immediately after completing the task, 190.6 bpm, and the lowest in the resting heart rate before the task, 100.1 bpm.

Table 5. Basic Descriptive Statistics of Heart Rate Values in the TSSR Test

	$\bar{x}$	Me	Min	Max	Q_1	Q_3	SD	V_z
Resting heart rate before the test - beats·min^{-1}	100.1	99.5	95	106	97	104	4.01	4.01
Heart rate immediately after the test - beats·min^{-1}	190.6	191	185	195	187	194	3.41	1.79
Heart rate after 1 minute of rest following the test - beats·min^{-1}	153.8	154	151	156	152	155	1.75	1.14

Statistical analysis shows that the differences in the number of throws in the examined series are statistically significant, $p<\alpha$ ($p=0.0000$). The highest average number of throws is in series B (10.1), and the lowest is in series A (6.4); this is because the trial time in series A is 15 seconds, while in series B, it is 30 seconds (Figure 3).

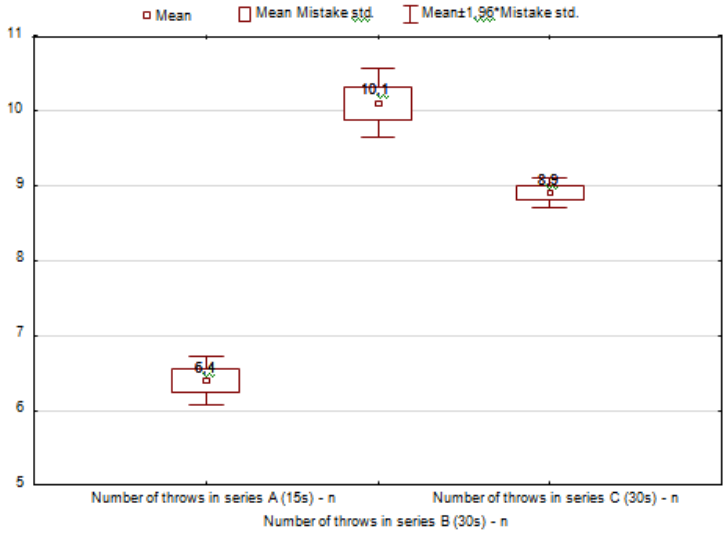

Figure 3. Average Number of Throws in Series A, B, and C

Using the correlation coefficient, it was checked whether there are relationships between body composition and the efficiency of athletes in combat. The research shows that body composition does not affect efficiency in phases I and II, as well as the average efficiency throughout the fight. Dependencies are present only in phase III. All significant dependencies are positive, meaning directly proportional; as the analyzed indicator increases, the attack efficiency in phase III also increases (Table 6).

Table 6. Correlation and test probability between body composition and efficiency in phases I, II, and III, as well as the average efficiency across the three phases

Body Composition of the Polish National Team Members	Ae PHASE I	Ae PHASE II	Ae PHASE III	Average Ae
Body Mass	0.216	-0.0662	0.6579	0.4522
	p=.549	p=.856	p=.039	p=.189
Body Fat Percentage	0.2472	0.0389	0.6046	0.4678
	p=.491	p=.915	p=.064	p=.173
Muscle Tissue Level	0.2042	-0.1471	0.6068	0.3803
	p=.571	p=.685	p=.063	p=.278
Bone Mass	0.2511	-0.1484	0.5478	0.3482
	p=.484	p=.682	p=.101	p=.324
BMI	0.2359	-0.1004	0.6504	0.4357
	p=.512	p=.783	p=.042	p=.208
DCI (Daily Caloric Intake)	0.2096	-0.1496	0.57	0.3554
	p=.561	p=.680	p=.085	p=.314
Metabolic Age	0.0909	0.1708	0.6246	0.5114
	p=.803	p=.637	p=.054	p=.131
Percentage of Water in the Body	-0.2079	-0.0359	-0.4763	-0.3731
	p=.564	p=.922	p=.164	p=.288
Abdominal Fat Level in the Abdominal Cavity	0.1061	0.187	0.7297	0.5920
	p=.771	p=.605	p=.017	p=.071
Muscle Tissue Mass	0.2339	0.0933	0.605	0.4895
	p=.515	p=.798	p=.064	p=.151
Percentage of Fat Tissue	-0.0571	0.3961	0.6885	0.6269
	p=.875	p=.257	p=.028	p=.052

*** *p< 0,001 There is a very high statistically significant correlation*
** *p< 0,01 There is a high statistically significant correlation*
* *p< 0,05 There is a statistically significant correlation*
Ae I - Efficiency of the attack in the first part of the fight. Ae II - Efficiency of the attack in the second part of the fight.. Ae III - Efficiency of the attack in the third part of the fight. Average Ae – Average efficiency of the attack

Using correlation analysis, it was examined whether there are relationships between body structure and composition and the activity levels of the athletes. The research indicates that there are no relationships between the studied indicators (Table 7).

Table 7. Correlation and test probability between body composition and athletes' activity in phases I, II, and III, as well as the average activity across the three phases

Body Composition of the Polish National Team Members	Aa PHASE I	Aa PHASE II	Aa PHASE III	Average Aa
Body Mass	0.0502	-0.2013	0.3788	0.0456
	p=.890	p=.577	p=.280	p=.900
Body Fat Percentage	-0.3039	-0.3426	0.3409	-0.3106
	p=.393	p=.332	p=.335	p=.382
Muscle Tissue Level	0.1339	-0.0246	0.356	0.1487
	p=.712	p=.946	p=.313	p=.682
Bone Mass	0.0532	0.1376	0.2456	0.0887
	p=.884	p=.705	p=.494	p=.807
BMI	-0.0563	-0.169	0.316	-0.0545
	p=.877	p=.641	p=.374	p=.881
DCI (Daily Caloric Intake)	0.1209	-0.0861	0.4107	0.1316
	p=.739	p=.813	p=.238	p=.717
Metabolic Age	0.0093	0.0475	-0.0903	0.0085
	p=.980	p=.896	p=.804	p=.981
Percentage of Water in the Body	0.3762	0.3682	-0.3207	0.3837
	p=.284	p=.295	p=.366	p=.274
Abdominal Fat Level in the Abdominal Cavity	-0.2214	-0.1923	0.1488	-0.2252
	p=.539	p=.595	p=.682	p=.532
Muscle Tissue Mass	-0.3521	-0.4039	0.3176	-0.3667
	p=.318	p=.247	p=.371	p=.297
Percentage of Fat Tissue	-0.3791	-0.5228	0.1229	-0.4243
	p=.280	p=.121	p=.735	p=.222

Aa I - Activity of the attack in the first part of the fight. Aa II - Activity of the attack in the second part of the fight.. Aa III - Activity of the attack in the third part of the fight. Average Aa – Average Activity of the attack

The study indicates that body composition does not affect effectiveness in phases I and II, nor the average effectiveness throughout the entire fight. Significant relationships were found between specific body composition parameters and phase III of the fight. Most of these relationships are positive and directly proportional; as the analyzed indicator increases, the effectiveness of the attack in phase III also increases. These are significant relationships when correlation coefficients range from 0.64 to 0.75. Only in the case of the percentage of body water is the relationship negative. The relationship is inversely proportional, meaning that as body water increases, effectiveness in phase III decreases. This relationship is significant (Table 8).

Table 8. Correlation between body composition and attack effectiveness in phases I, II, and III, as well as the average effectiveness across the three phases

Body Composition of the Polish National Team Members	Ea PHASE I	Ea PHASE II	Ea PHASE III	Average Ea
Body Mass	0.3271	0.0492	0.7346	0.475
	p=.356	p=.893	p=.016	p=.165
Body Fat Percentage	0.0417	-0.0161	0.7146	0.2129
	p=.909	p=.965	p=.020	p=.555
Muscle Tissue Level	0.4069	0.0587	0.6846	0.5322
	p=.243	p=.872	p=.029	p=.113
Bone Mass	0.3969	0.1092	0.6573	0.5286
	p=.256	p=.764	p=.039	p=.116
BMI	0.2355	-0.0246	0.6401	0.3564
	p=.512	p=.946	p=.046	p=.312
DCI (Daily Caloric Intake)	0.4031	0.0385	0.6925	0.5262
	p=.248	p=.916	p=.026	p=.118

Body Composition of the Polish National Team Members	Ea PHASE I	Ea PHASE II	Ea PHASE III	Average Ea
Metabolic Age	-0.0145	0.1751	0.2032	0.0806
	p=.968	p=.629	p=.573	p=.825
Percentage of Water in the Body	0.0249	0.0514	-0.7036	-0.1453
	p=.946	p=.888	p=.023	p=.689
Abdominal Fat Level in the Abdominal Cavity	-0.126	0.1081	0.5802	0.0658
	p=.729	p=.766	p=.079	p=.857
Muscle Tissue Mass	-0.0149	-0.0024	0.7397	0.1745
	p=.968	p=.995	p=.014	p=.630
Percentage of Fat Tissue	-0.3428	0.0162	0.4607	-0.1702
	p=.332	p=.965	p=.180	p=.638

Ea I - Effectiveness of the attack in the first part of the fight. Ea II - Effectiveness of the attack in the second part of the fight.. Ea III - Effectiveness of the attack in the third part of the fight. Average Ea – Average effectiveness of the attack

Discussion

This analysis focused on the physical fitness levels of the Polish National Team athletes, as well as their body composition and structure, in relation to the course of ju-jitsu fighting. A fight in this formula consists of three stages: the first stage where athletes start with kicks and punches, the second stage which begins after a capture and includes throws and takedowns to the ground, and the third and final stage where athletes on the ground use joint locks on the arms and legs, or holds and chokes(Ambroży et al., 2017).

The analysis shows that the general physical fitness (mainly assessed through strength tests) of elite ju-jitsu athletes, in terms of leg strength (squats), is lower than that of Muay Thai and Brazilian Jiu-Jitsu athletes(Wąsacz et al., 2022) and comparable to other ju-jitsu athletes(Ambroży T et al., 2014). In terms of shoulder girdle strength (pull-ups), the tested athletes achieved better results than Muay Thai representatives but significantly worse than Brazilian Jiu-Jitsu athletes(Wąsacz et al., 2022). In the bench press test (chest muscle strength), they scored lower than representatives of both Muay Thai and Brazilian Jiu-Jitsu (Wąsacz et al., 2022). Compared to non-national team ju-jitsu athletes, the tested athletes scored better in both shoulder girdle and chest strength(Ambroży T et al., 2014). These results may indicate significant deficiencies in strength training among the tested athletes, suggesting that improvements in this type of training could enhance the performance capabilities of the Polish National Team in ju-jitsu.

The TSSR test conducted during the research allows for determining the proficiency level of the *ippon seoi nage* throw technique (which is the most popular and effective throw in ju-jitsu (Chwała W. et al., 2013)), as well as the specific fitness in terms of speed and endurance required in the second phase of the fight(Sterkowicz, 1995; Sterkowicz, S.; Zuchowicz, A.; Kubica, 1999).

Comparing the results of the tested athletes to judo athletes indicates that in terms of the number of throws performed, with a result of 25.4±1.26, they were weaker than the tested adult judo athletes, who scored 27.0±2.0 – 28.4±2.0(Drid et al., 2012). Additionally, in terms of fatigue level (heart rate after the test 190.6±3.4) and speed of recovery (heart rate after one minute of rest 153.8±1.75), they also performed worse (heart rate ranging from 180.1±10.0 to 186±11.0 and from 151.9±18.1 to 165±13)(Drid et al., 2012). Although, in terms of recovery level, they achieved average values compared to the tested judokas. These results indicate room for improvement in the specialized training of throws as well as in the levels of specific endurance and speed within the Polish National Team in sport ju-jitsu. Focusing on these parameters during training could further enhance their proficiency, which should translate into better competition results.

Investigating the relationships between body composition and technical-tactical training indicators, it was observed that there were no significant relationships in most cases. Significant relationships were found only between specific parameters of body composition, efficiency, and effectiveness of the attack in the third phase of the fight. This indicates that body composition may be important during ground fighting. Similar conclusions are also presented by other authors(Almeda et al., 2023; Evans et al., 2022).

Limitations of the Study

As with most studies, the design of the present work is subject to certain limitations. The analysis included only athletes competing at the elite level of sports competitions. In the future, comparing athletes with different levels of advancement may lead to more comprehensive comparisons. Another limitation was the lack of current data on the specificity and sensitivity of the fitness tests used. To take into account the multidimensional context, it is recommended to conduct evaluation studies for specific motor tests in the field of ju-jitsu.

Conclusions

Our research indicates areas for improvement in the training of the Polish National Ju-Jitsu Team, specifically in the realm of special fitness and strength preparation.

No correlations were found between body composition and athlete activity, nor between efficiency and attack effectiveness in the first and second phases of the fight. However, correlations were identified between certain body composition parameters and efficiency and attack effectiveness in the third phase of the fight.

The analyses conducted suggest the need for further research in this area to better understand the relationships between various body composition parameters and the performance outcomes achieved by ju-jitsu athletes. Ultimately, the knowledge gained could help optimize training programs, thereby enhancing the efficiency, activity, and effectiveness of athletes during matches.

Practical Implication

In sports training, particular attention should be paid to developing special fitness, especially in relation to the second phase of the fight, as well as comprehensive strength preparation.

Funding: The study was funded under the Ministry of Science and Higher Education's "Regional 430 Excellence Initiative" program for 2024-2027 (project no. RID/SP/0027/2024/01) in the amount of 431 PLN 4 053 904,00 and the project "The impact of plyometric training on the level of physical fitness, physiological indicators, and muscle damage in basketball players," No. 362/BS/INoS/2024

Institutional Review Board Statement: The research was approved by the Bioethics Committee at the Regional Medical Chamber (No. 42/ KBL/OIL/2015 dated April 15, 2015)

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available upon request from the

Conflicts of Interest: The authors declare no conflict of interest

References

Adam, M., Smaruj, M., & Pujszo, R. (2012). Charakterystyka indywidualnego przygotowania techniczno-taktycznego zawodników judo, zwycięzców Mistrzostw Świata z Paryża w 2011 oraz z Tokio w 2010 roku. *IDO MOVEMENT FOR CULTURE. Journal of Martial Arts Anthropology*, *12*(2), 60–69.

Adam M., Tabakov S., Blach L., Smaruj, M. (2013). Characteristics of the technical-tactical preparation of male and female judo competitors participating in the Olympic Games-London 2012. *Ido Movement for Culture*, *13(2)*, 75–88.

Almeda, C. G., Mangine, G. T., Green, Z. H., Feito, Y., & French, D. N. (2023). Experience, Training Preferences, and Fighting Style Are Differentially Related to Measures of Body Composition, Strength, and Power in Male Brazilian Jiu Jitsu Athletes—A Pilot Study. *Sports*, *11*(1), 13. https://doi.org/10.3390/sports11010013

Ambroży T. (2008). *Struktura treningu ju-jitsu*. Biblioteka Trenera. Centralny Ośrodek Sportu.

Ambroży T., Klimek A.T., & Pilch W. (2007). Wydolność anaerobowa reprezentantów Polski w Ju-Jitsu. *Medicina Sportiva Practica*, *8, no 1*, 5–7.

Ambroży T, Nowak M, Mucha, D., Chwała W., Piwowarski J, & Sieber L. (2014). The influence of an original training programme on the general physical fitness of ju-jitsu trainees. *Ido Movement for Culture. Journal of Martial Arts Anthropology*, *14 No4*, 69–76.

Ambroży, T., Rydzik, Ł., Spieszny, M., Chwała, W., Jaszczur-Nowicki, J., Jekiełek, M., Görner, K., Ostrowski, A., & Cynarski, W. J. (2021a). Evaluation of the Level of Technical and Tactical Skills and Its Relationships with Aerobic Capacity and Special Fitness in Elite Ju-Jitsu Athletes. *International Journal of Environmental Research and Public Health*, *18*(23), 12286. https://doi.org/10.3390/ijerph182312286

Ambroży, T., Rydzik, Ł., Spieszny, M., Chwała, W., Jaszczur-Nowicki, J., Jekiełek, M., Görner, K., Ostrowski, A., & Cynarski, W. J. (2021b). Evaluation of the Level of Technical and Tactical Skills and Its Relationships with Aerobic Capacity and Special Fitness in Elite Ju-Jitsu Athletes. *International Journal of Environmental Research and Public Health*, *18*(23), 12286. https://doi.org/10.3390/ijerph182312286

Ambroży, T., Rydzik, Ł., Wąsacz, W., Małodobry, Z., Cynarski, W. J., Ambroży, D., & Kędra, A. (2023). Analysis of Combat in Sport JU-JITSU during the World Championships in Fighting Formula. *Applied Sciences*, *13*(20), 11417. https://doi.org/10.3390/app132011417

Ambroży, T., Sterkowicz-Przybycień, K., Sterkowicz, S., Kędra, A., Mucha, D., Ozimek, M., & Mucha, D. (2017). Differentiation of Physical Fitness in Polish Elite Sports Ju-Jitsu Athletes Physical Fitness in Elite Ju-Jitsu Athletes. *Journal of Kinesiology and Exercise Sciences*, *27*(79), 57–70. https://doi.org/10.5604/01.3001.0012.1430

Andrade, A., Flores, M. A., Andreato, L. V., & Coimbra, D. R. (2019). Physical and Training Characteristics of Mixed Martial Arts Athletes: Systematic Review. *Strength & Conditioning Journal*, *41*(1), 51–63. https://doi.org/10.1519/SSC.0000000000000410

Blagrove, R. C. (2022). Understanding and developing aerobic fitness. In *Advanced Strength and Conditioning* (pp. 55–78). Routledge. https://doi.org/10.4324/9781003044734-6

Brooks, J. H. M., Fuller, C. W., Kemp, S. P. T., & Reddin, D. B. (2005). A prospective study of injuries and training amongst the England 2003 Rugby World Cup squad. *British Journal of Sports Medicine*, *39*(5), 288–293. https://doi.org/10.1136/bjsm.2004.013391

Brown, M., Buchheit, M., Lacome, M., Hader, K., & Guilhem, G. (2023). Correlations Between Hamstring Muscle Architecture, Maturation, and Anthropometric Measures in Academy Soccer Players. *International Journal of Sports Physiology and Performance*, *18*(6), 615–624. https://doi.org/10.1123/ijspp.2022-0031

Chwała W., Ambroży T., & Sterkowicz, S. (2013). Three-dimensional analysis of the ju-jitsu competitors' motion during the performance of the ippon-seoi-nage throw. *Arch Budo Sci Martial Art Extreme Sport*, *9*, 41–53.

Dos'Santos, T., Thomas, C., Comfort, P., & Jones, P. A. (2019). The Effect of Training Interventions on Change of Direction Biomechanics Associated with Increased Anterior Cruciate Ligament Loading: A Scoping Review. *Sports Medicine*, *49*(12), 1837–1859. https://doi.org/10.1007/s40279-019-01171-0

Drid, P., Trivić, T., & Tabakov, S. (2012). Special Judo Fitness Test - a Review. *Serbian Journal of Sports Sciences*, *6*(4), 117–125.

Evans, C., Kaminski, J., Peacock, C., Algieri, C., Rojas, J., Santana, J. C., Ricci, A., & Antonio, J. (2022). Between- and Within-Sex Differences in Body Composition Variables in Professional MMA Fighters and Boxers. *Journal of Exercise and Nutrition*, *5*(3). https://doi.org/10.53520/jen2022.103130

Ferreira Marinho, B., Vidal Andreato, L., Follmer, B., & Franchini, E. (2016). Comparison of body composition and physical fitness in elite and non-elite Brazilian jiu-jitsu athletes. *Science & Sports*, *31*(3), 129–134. https://doi.org/10.1016/j.scispo.2015.12.001

Galan D., & Rata G. (2016). Study of the frequency of fighting system techniques in Ju-jitsu. *Discobolul – Physical Education. Sport and Kinetotherapy Journal*, *12(1)*, 42–47.

Halson, S. L. (2014). Monitoring Training Load to Understand Fatigue in Athletes. *Sports Medicine*, *44*(S2), 139–147. https://doi.org/10.1007/s40279-014-0253-z

Heydenreich, J., Kayser, B., Schutz, Y., & Melzer, K. (2017). Total Energy Expenditure, Energy Intake, and Body Composition in Endurance Athletes Across the Training Season: A Systematic Review. *Sports Medicine - Open*, *3*(1), 8. https://doi.org/10.1186/s40798-017-0076-1

James, L. P. (2014). An Evidenced-Based Training Plan for Brazilian Jiu-Jitsu. *Strength & Conditioning Journal*, *36*(4), 14–22. https://doi.org/10.1519/SSC.0000000000000053

Kędra, A., Kasicki, K., & Ambroży, T. (2023). Analysis of physical fitness level and its relationship with the level of Technical-Tactical Preparedness of Ju-Jitsu Athletes. *Archives of Tourism, Hospitality and Sport Science*, *8*(1), 39–47. https://doi.org/10.5604/01.3001.0054.2846

Mala, L., Maly, T., Cabell, L., Cech, P., Hank, M., Coufalova, K., & Zahalka, F. (2019). Body composition and morphological limbs asymmetry in competitors in six martial arts. *International Journal of Morphology*, *37*(2), 568–575. https://doi.org/10.4067/S0717-95022019000200568

Manolachi, V., Chernozub, A., Tsos, A., Potop, V., Kozina, Z., Zoriy, Y., & Shtefiuk, I. (2023). Integral method for improving precompetition training of athletes in Mixed Martial Arts. *Journal of Physical Education and Sport*, *23*(6), 1359–1366. https://doi.org/10.7752/jpes.2023.06166

Marques Junior, N. K. (2020). Periodization models used in the current sport. *MOJ Sports Medicine*, *4*(2), 27–34. https://doi.org/10.15406/mojsm.2020.04.00090

Nowak M, & Ambroży T. (2015). *Współczesny trening obwodowy w teorii i praktyce*. Fall.

Podstawski, R., Markowski, P., Choszcz, D., Lipiński, A., & Borysławski, K. (2017). Effectiveness of martial arts training vs. Other types of physical activity: Differences in body height, body mass, bmi and motor abilities. *South African Journal for Research in Sport, Physical Education and Recreation*, *39*(1), 111–133.

Ronikier A. (2001). *Fizjologia sportu*. Biblioteka Trenera COS.

Rydzik, Ł., & Ambroży, T. (2021). Physical fitness and the level of technical and tactical training of kickboxers. *International Journal of Environmental Research and Public Health*, *18*(6), 1–9. https://doi.org/10.3390/ijerph18063088

Sidney, K., Shephard, R., & Harrison, J. (1977). Endurance training and body composition of the elderly. *The American Journal of Clinical Nutrition*, *30*(3), 326–333. https://doi.org/10.1093/ajcn/30.3.326

Sozański, H. (1999). *Podstawy teorii treningu sportowego*. Biblioteka Trenera COS.

Staller, M. (2013). The analysis of successfully applied techniques in part 1 in ju-jitsu fighting. *LASE J. Sport Sci, 4.*, 14–20.

Sterkowicz, S. (1995). Test specjalnej sprawnosci ruchowej w judo. Special Judo Fitness Test. *Antropomotoryka*, *12,13*(29–44).

Sterkowicz, S., & Ambroży T. (1992). The fitness profile of the men who train's ju-jitsu. *Antropomotoryka*, *7*, 135–141.

Sterkowicz, S.; Zuchowicz, A.; Kubica, R. (1999). Levels of anaerobic and aerobic capacity indices and results for the special fitness test in judo competitors. *J. Hum. Kinet.*, *2*, 115–135.

Sterkowicz-Przybycień K, Ambroży T, Jasiński M, A. K. (2014). Body build, body composition and special fitness of female top ju-jitsu contestants. *Arch Budo*, *10*, 117–125.

Sterkowicz-Przybycień, K., Ambrozy, T., Jasiński, M., & Kędra, A. (2014). Body build, body composition and special fitness of female top ju-jitsu contestants. *Archives of Budo*, *10*(1), 117–125.

Szopa J., Mleczko E., & Żak S. (2000). *Podstawy antropomotoryki*. Wydawnictwo Naukowe PWN.

Terry, C. M. (2006). The Martial Arts. *Physical Medicine and Rehabilitation Clinics of North America*, *17*(3), 645–676. https://doi.org/10.1016/j.pmr.2006.05.001

Thornton, H. R., Delaney, J. A., Duthie, G. M., & Dascombe, B. J. (2019). Developing Athlete Monitoring Systems in Team Sports: Data Analysis and Visualization. *International Journal of Sports Physiology and Performance*, *14*(6), 698–705. https://doi.org/10.1123/ijspp.2018-0169

Wąsacz, W., & Pociecha, M. (2021). Differentiation of the somatic structure and the level of motor potential of athletes in mixed martial arts (MMA) and Brazilian jiu-jitsu (BJJ) sections. *Health Promotion & Physical Activity*, *14*(1), 38–46. https://doi.org/10.5604/01.3001.0014.8182

Wąsacz, W., Rydzik, Ł., Ouergui, I., Koteja, A., Ambroży, D., Ambroży, T., Ruzbarsky, P., & Rzepko, M. (2022). Comparison of the Physical Fitness Profile of Muay Thai and Brazilian Jiu-Jitsu Athletes with Reference to Training Experience. *International Journal of Environmental Research and Public Health*, *19*(14), 8451. https://doi.org/10.3390/ijerph19148451

Zaggelidis, G., Zaggelidis, C., & Malkogeorgos, A. (2019). Evaluation of Elite Ju-Jitsu Athletes' Physical Fitness Using the JMG Test. *Studia Universitatis Babeş-Bolyai Educatio Artis Gymnasticae*, *64*(3), 17–22. https://doi.org/10.24193/subbeag.64(3).18