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Exploring the Relationship between Anaerobic and Morphological Characteristics and Competition Success in Young Male Slovenian Judo Athletes

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Featured Application: This paper highlights the importance of young athletes' testing and comparison to correct variables of available normative values in upper body Wingate testing. Therefore, we must be careful which results (absolute or relative) we compare to the established normative values. In our case, we recommend comparing relative values of body mass to available judo upper body classificatory tables for youth judokas. Moreover, anaerobic-focused training is recommended for young athletes in judo. Additionally, these data can be used to develop young athletes' normative values for the upper body Wingate test via meta-analysis.

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Abstract: Judo elements rely on lower and upper body muscle power, supported by the ATP-PCr energy system, which is crucial in high-intensity tasks. This study aims to assess the anaerobic status of young male competitive judokas using the upper body Wingate test and explore associations with competition performance and individual morphological characteristics. A total of 29 male judokas from the U18 and U20 age categories were tested, all actively participating in top-tier national and international competitions. Anthropometric characteristics and body composition measurements were obtained for all participants through bioelectrical impedance analysis. Anaerobic testing was conducted using the upper body Wingate test with a hand ergometer. Competition performance was recorded from the final national cup ranking list. The results presented no statistically significant correlations between morphological and anaerobic variables and competitive performance among selected participants. This highlights the importance of the necessity of updated training programs to increase the anaerobic performance of young Slovenian judokas. Additionally, it shows that in these age groups, anaerobic performance is not the crucial factor but just one piece of the puzzle in young judokas' successful competition performance; therefore other variables should be further researched.

Keywords: performance; anaerobic power; combat sports; martial arts; athlete development; training

1. Introduction

Judo is a dynamic sport with a high number of interruptions and simultaneously requires complex movement skills and tactical excellence for success [1]. To be effective in judo, judo techniques must be executed precisely and in the right "window of opportunity", according to the so-called principle of the right moment with substantial power and speed [2]. The most successful judokas have excellent technique and are physically and psychologically well prepared. The latter enables them to bear the stress and pressure of fights and competitions more efficiently [3].

In judo, as a weight-restricted sport, morphological characteristics play a crucial part, with features such as the amount of body water, fat mass, and muscle mass, among others, also being important indicators of a judoka's preparation and essential feedback for the coach [4]. An appropriate training procedure can be planned based on a precise physical condition assessment, which develops the judoka's body accordingly and enables him to overcome great physical efforts. The correct identification of body characteristics also helps a judoka to lose weight more effectively to compete in the desired weight category and prevents sudden and potentially dangerous rapid weight loss [5,6]. Furthermore, good physical characteristics also help to reduce the possibility of injuries that can prevent an athlete's sports involvement and development [4]. Therefore, for a judoka to achieve top results, pass all of the psycho-physical efforts in front of him and avoid possible injuries, sports diagnostics can help them and their coaches [4]. Morphological diagnostics measures a judoka's body composition and anthropometric characteristics. It is very important to test the body composition status at the beginning of the preparatory period of the new competitive season as coaches have time to adjust the training program and make a plan with the athlete to decide in which weight category they will compete in the current year [4].

Body composition can nowadays be assessed via various methods like classical anthropometry, computed tomography (CT), underwater weighing, body impedance analysis (BIA), ultrasonography, magnetic resonance imaging (MRI), air displacement plethysmography and the dual-energy X-ray absorptiometry (DXA) [7–9]. MRI and CT have been reported to be the gold standard in measuring muscle mass [8]; however, in the last decade, DXA has become a gold standard in assessing body composition in sports [10]. However, the gold standard of DXA for measuring muscle mass has been questioned [11], and additional correction factors have been recommended [12]. DXA has some disadvantages for even broader applications, like the expensive equipment, not being portable, having a small scanning bed not suited for a larger athlete's physique, the need for trained personnel and the need for specific regression equations to compare results between different DXA machines directly [13]. However, the usage in terms of time, cost and availability varies between these methods, each with pros and cons.

Therefore, BIA has been presented as an alternative to more invasive and expensive methods [13] due to its portability, non-invasiveness, low cost, availability and ease of use [13,14]. The reliability of the BIA measurement has been reported to be influenced by factors including electrodes, the operator, the subject, the environment [13], food, alcohol, physical exercise and the time of day [15]. However, following the necessary manufacturer and laboratory testing guidelines developed over time [16,17], the measurements have been shown to be reliable [18] and valid [19,20] compared to DXA. BIA testing reports several parameters like muscle mass, fat mass and body hydration status, among others [4], and has been widely used in judo research [21–30]. Additionally, BIA research in judo has shown that elite judokas have low body fat levels [27,31,32]. Significant correlations have been shown between body composition and functional abilities in young judokas in national selections [33]. Additionally, a lower percentage of body fat was shown to be associated with higher rankings in elite judokas [34], while a higher percentage of body fat was negatively associated with the number of throws in a special judo test [35] and with lowered hand grip strength in young judokas [36]. Body composition monitoring in young judokas is also essential, as it has been highlighted that special attention should be given to heavier weight categories targeting low body fat and high muscle mass [37]. Furthermore, according to research, higher lean body mass has been shown to positively affect the anaerobic capacity of judokas [27]. Along with morphological characteristics, according to Sertić and Lindi [38], the factors influencing success in judo are coordination (15%), strength (22%), speed (12%), mobility (8%), balance (8%), personality traits (10%), mental abilities (10%) and cardiorespiratory abilities (15%). Throws in judo involve lower and upper body muscle power, supported by the ATP-PCr energy system, which is considered the most important energy system in high-intensity tasks [39]. The gold standard and most commonly used test for the indirect assessment of anaerobic power and performance is the Wingate test, which has a 30 s protocol and measures maximal power, average power, maximal power relative to body mass, power drop, etc. [40,41]. In judo, both Wingate tests for the lower body [42] and for the upper body [43] are used. However, the research on anaerobic power and capacity in young judokas is very limited [44–47], especially with the scarce use of upper body Wingate test evaluation. The lack of research on young judokas' anaerobic characteristics could also be the reason why we have only senior judokas upper body Wingate test classificatory tables. These report that the best-prepared elite male judokas reach values greater than 950 W and 11.41 W/kg [48]. However, the question arises if we should compare young athletes with seniors and their normative values. Like in the special judo fitness test (SJFT), researchers have developed separate normative values for cadet, junior and senior athletes and for both genders [49–51]. The same could be done for the upper body Wingate test; however much more research is needed on young judokas for a quality review and meta-analysis. It was reported that upper and lower body strength and power appear to be important qualities for junior competitive judokas and may contribute to competition performance [46]. However, using the upper and lower body Wingate tests in the same testing session is impractical and could impact the motor test sequence due to the impact on the energy systems and the needed time for recovery [52]. Therefore, the decision to perform an upper body Wingate test could be more practical, if the adapted ergometer is available due to several reasons. One of them is that only upper body Wingate test normative values for judo exist; therefore, the results can be quickly compared and evaluated [48]. Additionally, the upper body Wingate test variable of average power has been shown to correlate significantly with judo-specific performance [53]. Moreover, the glycolytic system in the judo Wingate test is presented the major energy contributor, being higher in the upper body than in the lower body [43].

Competitive performance can be assessed in judo through various factors (points, wins, attacks, successful attacks, efficiency index, etc.); however, it is hard to find a common denominator for participants competing in various weight categories, competitions and sometimes even in multiple age categories [54]. Therefore, the usage of national rankings lists [55–57], similar to the International Judo Federation (IJF) ranking list [58], has been shown to be a good indicator of competitive success as it is extremely hard to get all competitors into the same competition.

Therefore, this study aims to present the anaerobic status of young male competitive judokas through the usage of the upper body Wingate test and to additionally explore its association with competitive performance and individual morphological characteristics.

2. Materials and Methods

2.1. Study Design

The present study has a descriptive cross-sectional design. The participants were all categorised as athletes by the Slovenian Olympic Committee in judo. This testing was part of the categorised judo athletes' yearly scheduled screening organised by the Slovenian Judo Association. The testing was organised in the morning, where body composition was measured between 8 a.m. and 10 a.m. Afterwards, a pre-set warmup was carried out before the anaerobic testing.

2.2. Sample

The sample was comprised of 29 male judokas, all members of the youth Slovenian national team's selection. They were all categorised as athletes according to Slovenian Olympic Committee regulations and competed in the U20 and U18 age categories. The participants were regularly competing in the highest national and international competitions. All participants were free of any acute musculoskeletal injuries that could prevent their participation in testing. All assessments were completed within the physiological laboratory of the Institute of Sports at the Faculty of Sports, the University of Ljubljana. Measurements were performed during the preparatory period, and athletes were not engaged in any weight loss. This study was conducted following the Declaration of Helsinki, where each athlete or their parents–guardians signed a written informed consent form as part of the annual testing procedure of athletes in the Slovenian Judo Association. An Institutional Review Board Statement was unnecessary as the testing data were derived from the Institute of Sport's economic activities through performing testing/athlete screening for national associations and not from a research project.

2.3. Body Composition

Anthropometric measurements were performed in an air-conditioned laboratory with the room temperature held between 21 and 23 °C. The body height was measured with an anthropometer GPM (Zurich, Switzerland). Afterwards, body composition measurements were performed using bioelectrical impedance analysis (BIA), using the InBody 720 (Biospace Co., Ltd., Seoul, Republic of Korea). An experienced lab member performed measurements using the ISAK guidelines.

Body composition measurements were performed in the standing position, following all necessary accurate measurement guidelines [16]: (1) the measurements were taken in the morning (between 8 and 10 a.m.); (2) the participants were asked to abstain from large meals after 9 p.m. on the evening before the test, and on the day of the measurement, they neither ate nor drank before the end of the procedure; (3) participants were asked to refrain from extreme physical exertions 24 h prior to measuring, and the last training session should have been performed at least 12 h prior to testing; (4) the respondents did not consume alcohol 48 h before the measurement; (5) the respondents were asked to empty their bowels and bladder at least 30 min before the measurement; (6) the respondents were in the standing position for at least 5 min before the measurement to redistribute the tissue fluids; (7) the measurement was performed in the standing position according to the procedure recommended by the manufacturer (hands placed 15 cm laterally from the side of the body).

The high reliability and accuracy of InBody 720 were previously evaluated through test–retest assessments. The interclass correlation (ICC) was reported at 0.99, indicating strong reliability [59]. Additionally, significant correlations were found with the reference measure, dual-energy X-ray absorptiometry (DXA), with a correlation coefficient (r) of 0.95 and the reported standard error of estimate (SEE) of 1.8 [60]. Using the InBody 720, we measured the following body composition parameters: body mass, body mass index (BMI), skeletal muscle mass (absolute and relative) and body fat (absolute and relative).

2.4. Anaerobic Assessment

Anaerobic testing was conducted through usage of the upper body Wingate test using the hand ergometer Monark 891E (Monark Exercise AB, Vansbro, Sweden). The subjects warmed up for 5 min with a 1% load of their body mass at approximately 60 rpm [53,61], with 3 and 10 s increments at approximately 100 rpm [48] chosen by the participants at random. The test was performed after a 3 min rest [48] from zero velocity with the load set at 0.05 kg/kg of body mass [53,62]. For an in-depth analysis, we collected the following metrics: absolute peak power (W), relative peak power (W/kg), average power (W), relative average power (W/kg), power drop (W), relative power drop (W/kg), percentage of absolute power drop (%), anaerobic capacity (J) and relative anaerobic capacity (J/kg).

2.5. Competition Performance

We acquired the ranking of judokas from the freely available database (https://judoslo.si/ranking, accessed on 15 February 2022) of the Slovenian Judo Federation Cup ranking list. Competition performance (CS) was presented as using final points in standings for the particular athlete [55]. The ranking list is automatically updated after every categorised event that counts towards the Slovenian Cup.

2.6. Statistical Analysis

Data were analysed using SPSS statistical software (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY, USA). The normality of the data distribution was checked by using the Shapiro–Wilk test. The associations between variables were tested with the Spearman correlation coefficient and interpreted as follows: 0 to 0.20—negligible; 0.21 to 0.40—weak; 0.41 to 0.60—moderate; 0.61 to 0.80—strong; 0.81 to 1.00—very strong [63]. Statistical significance was set at $p \leq 0.05$.

3. Results

Table 1 presents the descriptive values of the analysed variables of body composition and anaerobic components measured by the upper body Wingate test (UbWt).

Table 1. Descriptive statistics of the sample and selected variables.

	Variables	M	SD	Min	Max
ANTHROPOMETRIC	Age (years)	16.92	1.1	14.8	20
	Height (cm)	176.5	6.6	162.3	191
	Body mass (kg)	75.45	15.76	60	132
	Body mass index (kg/m^2)	24.09	3.83	19	36.4
	Body fat percentage (%)	10.8	6.56	3.6	33.9
	Body fat (kg)	8.89	8.59	2.6	45.1
	Skeletal muscle mass percentage (%)	51	3.71	38	55
	Skeletal muscle mass (kg)	38	5.68	31.1	53.6
ANAEROBIC	Absolute peak power (W)	552	136	346	852
	Relative peak power (W/kg)	7.43	1.75	3.91	11.32
	Mean power (W)	324	58	225	472
	Relative average power (W/kg)	4.33	0.51	2.51	5.26
	Absolute power drop (W)	396	127	185	698
	Relative power drop (W/kg)	5.33	1.7	2.77	9.3
	Percentage of absolute power drop (%)	71	8	53	82
	Anaerobic capacity (J)	9708	1731	6751	14151
	Relative anaerobic capacity (J/kg)	130.01	15.4	75.43	157.83
	Competition performance (points)	456	339	107	1533

M—mean. SD—standard deviation. Min—minimum. Max—maximum.

Descriptive results divided by weight categories for selected anaerobic variables from the UbWt are presented in Table 2.

Table 2. Descriptive statistics (mean ± standard deviation) for upper body Wingate test (UbWt) per weight categories.

WC	APP (W)	RPP (W/kg)	AP (W)	RAP (W/kg)	PD (W)	RPD (W/kg)	PD (%)	AAC (J)	RAC (J/kg)
−60 kg (n = 5)	433 ± 57	7.14 ± 0.89	257 ± 20	4.24 ± 0.29	299 ± 54	4.93 ± 0.87	69 ± 4	7721 ± 586	127 ± 9
−66 kg (n = 5)	455 ± 101	6.91 ± 1.46	278 ± 29	4.22 ± 0.39	322 ± 115	4.87 ± 1.71	69 ± 11	8339 ± 860	127 ± 12
−73 kg (n = 10)	611 ± 141	8.45 ± 2.04	334 ± 29	4.62 ± 0.40	456 ± 135	6.32 ± 1.95	74 ± 7	10029 ± 855	139 ± 12
−81 kg (n = 5)	557 ± 67	6.93 ± 0.85	341 ± 28	4.25 ± 0.36	376 ± 52	4.68 ± 0.64	67 ± 2	10240 ± 835	128 ± 11
−90 kg (n = 1)	852	9.73	417	4.76	698	7.97	82	12518	143
−100 kg (n = 1)	596	6.00	435	4.38	345	3.47	58	13049	131
+100 kg (n = 2)	615 ± 135	5.22 ± 1.85	402 ± 97	3.42 ± 1.28	448 ± 60	3.78 ± 1.03	74 ± 6	12088 ± 2917	103 ± 39

WC—weight category; APP—absolute peak power; RPP—relative peak power; AP—average power; RAP—relative average power; PD—power drop; RPD—relative power drop; AAC—absolute anaerobic capacity; RAC—relative anaerobic capacity.

The results in Table 3 revealed no significant correlation between body composition variables and competition performance.

Table 3. Correlation between competition performance and body composition.

Variable	MALE	
	Ranking	
	Spearman Coefficient	
	r	*p*
Age (years)	0.26	0.18
Height (cm)	−0.3	0.12
Body mass (kg)	0.03	0.86
Body mass index (kg/m^2)	0.26	0.18
Body fat percentage (%)	0.28	0.15
Body fat (kg)	0.26	0.17
Skeletal muscle mass percentage (%)	−0.29	0.13
Skeletal muscle mass (kg)	−0.07	0.71

r—Spearman correlation coefficient; *p*—significance value.

Furthermore, no significant correlation between UbWt and competition performance for males under the age of 20 years was noted in Table 4.

Table 4. Correlation between UbWt results and competition performance.

Variable	MALE	
	Ranking	
	Spearman Coefficient	
	r	*p*
Absolute peak power (W)	−0.05	0.79
Relative peak power (W/kg)	−0.17	0.37
Average power (W)	−0.01	0.96
Relative average power (W/kg)	0.01	0.97
Power drop (W)	−0.07	0.71
Relative power drop (W/kg)	−0.2	0.3
Power drop (%)	0.04	0.84
Absolute anaerobic capacity (J)	−0.01	0.96
Relative anaerobic capacity (J/kg)	0.02	0.96

r—Spearman correlation coefficient; *p*—significance value.

Table 5 presents the correlations between the UbWt results and anthropometrical variables. The age variable has several significant moderate correlations with anaerobic variables (absolute peak power, average power, relative average power, power drop, absolute anaerobic capacity and relative anaerobic capacity). Body height correlates significantly on a moderate level with average power and absolute anaerobic capacity. Body mass correlates significantly on a weak level with power drop and on a moderate level with absolute peak power, but strongly with average power and absolute anaerobic capacity. Body mass index correlates significantly on a moderate level with absolute peak power, but strongly with average power and absolute anaerobic capacity. Body fat percentage does not show any correlations with anaerobic variables. However, absolute body fat shows significant correlations on a moderate level with average power and absolute anaerobic capacity. Skeletal muscle mass percentage does not show any correlations with anaerobic variables. However, absolute values of skeletal muscle mass show significant correlations on a moderate level with absolute average power and power drop, while on a very strong level with average power and absolute anaerobic capacity. The overall variable age presented significant positive correlations with six out of nine anaerobic variables, while absolute skeletal muscle mass was correlated with five out of nine variables.

Table 5. Correlations between UbWt results and anthropometrical variables.

Variable	Age (years)		Height (cm)		BM (kg)		BMI (kg/m^2)		BF% (%)		BF (kg)		SMM% (%)		SMM (kg)	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
APP (W)	0.487 **	0.007	0.263	0.168	0.530 **	0.003	0.466 *	0.011	0.228	0.235	0.342	0.069	−0.057	0.768	0.551 **	0.002
RPP (W/kg)	0.355	0.058	−0.170	0.379	−0.105	0.586	−0.113	0.558	−0.031	0.872	−0.070	0.717	0.090	0.644	−0.028	0.885
AP (W)	0.475 **	0.009	0.440 *	0.017	0.798 **	0.001	0.703 **	0.001	0.272	0.154	0.473 **	0.010	−0.059	0.763	0.815 **	0.001
RAP (W/kg)	0.572 **	0.001	−0.135	0.486	0.072	0.711	0.099	0.610	−0.002	0.993	0.031	0.872	0.111	0.565	0.161	0.404
PD (W)	0.421 *	0.023	0.197	0.305	0.391 *	0.036	0.320	0.091	0.257	0.179	0.291	0.126	−0.124	0.523	0.418 *	0.024
RPD (W/kg)	0.315	0.096	−0.166	0.389	−0.150	0.439	−0.163	0.397	−0.026	0.893	−0.092	0.634	0.062	0.751	−0.074	0.704
PD (%)	0.281	0.140	0.007	0.970	0.041	0.834	0.033	0.866	0.143	0.458	0.065	0.738	−0.118	0.543	0.095	0.624
AAC (J)	0.475 **	0.009	0.440 *	0.017	0.798 **	0.001	0.703 **	0.001	0.272	0.154	0.473 **	0.010	−0.059	0.763	0.815 **	0.001
RAC (J/kg)	0.572 **	0.001	−0.135	0.486	0.072	0.711	0.099	0.610	−0.002	0.993	0.031	0.872	0.111	0.565	0.161	0.404

Significance *—$p \leq 0.05$; **—$p \leq 0.001$; AAC—absolute anaerobic capacity; AP—average power; APP—absolute peak power; BF—body fat; BM—body mass; BMI—body mass index; *p*—significance value; PD—power drop; *r*—Spearman correlation coefficient; RAC—relative anaerobic capacity; RAP—relative average power; RPP—relative peak power; RPD—relative power drop; SMM—skeletal muscle mass; %—percentage.

4. Discussion

This study aimed to assess the anaerobic status of young male competitive judokas using the upper body Wingate test and explore associations with competition performance and individual morphological characteristics. However, no significant associations were found between competition performance and young male judokas' morphological or anaerobic characteristics. At the same time, several significant correlations were observed between morphological and anaerobic variables, with variables age and absolute skeletal muscle mass having the most significant associations with each other.

These outcomes highlight that body composition and anaerobic performance are not key factors in young male judokas for success. According to the morphological data from Table 1, the height of Slovenian judokas in our sample shows similar height values compared to other studies on Slovenian judokas in the youth categories (176.5 ± 6.6 cm vs. 176.5 ± 9.7 cm). Similarity is also seen in body mass (75.5 ± 15.8 kg vs. 72.0 ± 7.3 kg) [64]. Compared to Spanish judokas in the same age categories, Slovenian judokas have similar physical characteristics: body mass (74.4 ± 9.7 kg vs. 75.5 ± 15.8 kg); body height (174.0 ± 5.0 cm vs. 176.5 ± 6.6 cm); body mass index (24.4 ± 2.9 kg/m^2 vs. 24.1 ± 3.8 kg/m^2); body fat (10.3 ± 6.6 kg vs. 8.9 ± 8.6 kg); skeletal muscle mass (38.0 ± 5.7 kg vs. 40.8 ± 2.2 kg) [22]. Slovenian judokas also have similar physical characteristics compared to Slovakian judokas, with a body mass of 75.5 ± 15.8 kg vs. 76.2 ± 8.4 kg and a body height of 176.5 ± 6.6 cm vs. 177.00 ± 6.2 cm [65]. Research comparing the present study's data to Polish judokas has also shown similar physical characteristics: body mass (75 ± 9.4 kg vs. 75.5 ± 15.8 kg); body height (178.6 ± 6.3 cm vs. 176.5 ± 6.6 cm); body fat (7.4 ± 2.8 kg vs. 8.9 ± 8.6 kg); skeletal muscle mass (38.4 ± 4.9 kg vs. 40.8 ± 2.2 kg) [66]. From this, we could conclude that young Slovenian male judokas have similar physical characteristics as their peers from other countries who are competing in national and international competitions. From the body composition data, we can still see that there is room for body composition transformation via muscular hypertrophy without increasing body weight, while lowering adipose tissue [66]. The overall data in Table 5 show that the age variable is significantly positively correlated with six out of nine anaerobic variables. The research on 14–16-year-old boys training in judo has shown that this is the age of rapid anaerobic capacity development [67]. However, the data presented that the anaerobic features of young judokas are still developing in the U18 and U20 age competition categories. Additionally, absolute skeletal muscle mass correlated with five out of nine variables. This highlights the importance of increased muscle mass for young judokas' anaerobic development. Body height showed significant positive correlations with average power (AP; $p = 0.02$) and absolute anaerobic capacity (AAC; $p = 0.02$). This is in line with previous research on young judokas [68]. This could be explained by taller athletes being connected to higher body mass, which is related to increased skeletal muscle mass. It was reported that SMM increases linearly up to 120 kg in athletes and then reaches a plateau [69]. Additionally, body height has shown significant correlations in judokas with explosive power tests [70] which are predetermined with anaerobic power and capacity, as already shown in current data. The same could be said for the significant correlations noted between body mass and APP ($p = 0.003$), AP ($p = 0.001$) and AAC ($p = 0.001$) as for the significant correlations noted between BMI (APP, $p = 0.011$; AP, $p = 0.001$ in AAC $p = 0.001$) and anaerobic variables. Power drop (PD) also showed significant correlations with BM and SMM. The following variables are directly connected to the load applied in the Wingate test—a higher BM leads to a higher load. Also, as already presented, higher body mass is connected to higher SMM.

Additionally, previous research has highlighted that body composition measurements in judo performed with BIA technology should be conducted with the eight polar systems due to the accuracy of measurements [66,71], which Inbody 720 uses and has been used in the present research. Therefore, future studies in judo should strive to have a common denominator in these eight polar (electrodes) BIA systems despite the various models available. This would be even more important if we take into account that various manufacturers use different algorithms to calculate the total water content, which is one of the foundational variables in the calculation of other body mass composition components [71].

Compared to published UbWt normative values for male competitors [48], Slovenian judokas scored 3 out of 5. A score of 3 or good includes the results of absolute maximum power between 486 and 764 W or relative maximum power between 6.56 and 9.45 W/kg. With a score of 7.43 W, Slovenian judokas are placed in the lower part of the third class. For judokas to achieve a score of 5 or excellent, they would have to achieve values greater than 950 W or 11.41 W/kg, which indicates that our judokas still have much room for improvement. We came to similar conclusions when comparing the relative maximal power between our judo players and judo players from other national teams. Compared to British seniors (8.50 ± 0.50 W/kg vs. 7.43 ± 1.75 W/kg), Canadian seniors (8.70 ± 1.20 W/kg vs. 7.43 ± 1.75 W/kg) and Polish junior judokas (8.80 ± 0.80 W/kg vs. 7.43 ± 1.75 W/kg), we can see that Slovenian judokas, as far as relative maximum power is concerned, are below the compared values [72]. However, we have to acknowledge a small methodological difference between our studies, as the normative values developed in 2018 for senior judokas for the UbWt were obtained by using a higher load at 0.06 W/Kg [48] compared to our study, which used 0.05 W/kg. A study by the same author showed no differences in loads of 0.04, 0.05, 0.06 or even 0.065 W/kg of body mass in judokas undertaking the UbWt [73]. This means that we can directly compare our values to these normative tables. However, whether we can use these tables to compare our young judokas to seniors is still questionable. Research comparing the UbWt performance between juvenile, junior and senior judoists has shown that there were significant differences ($p < 0.05$) in mean absolute power and peak absolute power between juvenile and senior groups [74]; however, no differences were noted when the results were relativised to body mass. The main study outcome reported that athletes above seventeen display anaerobic power similar to junior and senior athletes with regard to body mass [74]. Therefore, we must be careful which results (absolute or relative) we compare to the established normative values. In our case, we recommend comparing relative values to body mass.

Power drop in UbWt (Table 1) shows a substantial drop in absolute maximal power (70.63 ± 7.64%) and in relative peak power (5.33 ± 1.70 W/kg). From a practical/coaching point of view, young Slovenian judokas might have a greater chance of ending/winning the fight in the opening minutes, while the energy systems can still support high anaerobic loads. If the fight goes into the second half of full competition time or overtime, the judoka's chances of ending the fight with a victory could be drastically reduced. During a judo fight, maintenance of high-intensity actions derives from the PCr system and the anaerobic lactic system, which is activated during repetitive periods of high-intensity activity [41]. However, not only the anaerobic but also the aerobic system plays a significant role in supporting judokas' sustained efforts, as oxidative metabolism presents the main metabolic pathway for providing energy during the rest periods between high-intensity actions—like referee interruptions [41]. The following also shows that for good anaerobic development, very good aerobic foundations need to be built to help deal with the side products formed by intensive anaerobic actions and the energy systems supporting them. All of the above also gives essential feedback to coaches so they can update their periodisation and implement training that increases anaerobic capacity, power and other connected systems [75].

That the results of anaerobic strength and anaerobic capacity were not significantly related to competitive performance (Table 4) only confirms the complexity of judokas' broad movement and functional requirements for ultimate competitive success. The research by Sertić and Lindi (2003) [38] predicted a theoretical model of factors influencing success in judo: coordination (15%), strength (22%), speed (12%), mobility (8%), balance (8%), personality traits (10%), mental abilities (10%) and cardiorespiratory abilities (15%). Therefore, anaerobic components are just a small portion of a well-rounded judoka. Additionally, the competitive performance in judo could be measured via different variables like the result in a particular competition [76–78] or even be more subdivided into the number of attacks, number of successful attacks, number of unsuccessful attacks, number of used techniques, etc [79]. However, these have an important limitation as it is very hard to get all participants in the same competitions. Therefore, the IJF and/or national ranking lists present an objective common denominator of competitions for athletes.

The data suggest that Slovenian judokas have appropriate body composition from a morphological standpoint. However, they display a deficiency in anaerobic power and capacity, which have been reported to be vital during the tsukuri (positioning) and kake (execution) phases of judo throws [27]. With the information obtained in this study, we can conclude that there is an urge to adapt the training process of Slovenian judokas. Training should emphasise maximal strength and anaerobic capacity development, both of which are needed to develop the required energy systems. Additionally, it would be beneficial or even a necessity to upgrade the content of the education curriculum for judo coaches by integrating additional material on periodisation and the planning of strength and conditioning training, emphasising the development of anaerobic characteristics. Improvements in educational content for Slovenian judo trainers could help young Slovenian judokas with physical fitness and competition success rates.

The current study needs to acknowledge some limitations. Firstly, the sample size overall and in some weight categories is small; however, this is the realistic nature of judo and a smaller national team like Slovenia. Unfortunately, a small national team and its pool of athletes does not allow for the existence a national team A, B or even C in respective age categories like some larger nations [35,80]. However, the sample tested was 100% of the national team in the respective age groups. Additionally, in heavier weight categories, the number of participants are usually smaller than in the light or middle weight categories at various levels of competitions; therefore, the numbers align with the realistic setting of judo. Also, it has been highlighted that research with elite athletes (regardless of the age group) faces a small sample dilemma, as the sample should not be extended to lower level participants due to the transferability of findings back to the elite level [81]. Competition success in judo could be measured differently; however, it is very hard to observe all participants in the same competition. Therefore, the IJF and/or national ranking lists present an objective common denominator of competitions for athletes in judo.

Body composition was not assessed via the DXA method due to a lack of availability [66] and funding. However, BIA has been showed to be a reliable [18] and valid [19,20] method if the specific testing guidelines [16,17] are followed. Moreover, in BIA measurements, it was reported that water content impacts the reactance and resistance of these measurements [82–84]. Therefore, athletes should not be in any weight loss period to ensure an accurate body composition assessment is conducted in judo research. The present study accounted for specific testing guidelines and weight loss, which adds to its credibility. Judo is an acyclic sport and the UbWt, as a general test, does not present a sport-specific evaluation. An additional combination with the special judo fitness test (SJFT) might give a better overview of the anaerobic variables in young judokas. The analysis has been performed only on male judokas, so further research should also focus on young female participants. Finally, the lack of studies on anaerobic variables in young judo athletes hinders a more comprehensive discussion.

5. Conclusions

The present study aimed to present the anaerobic status of Slovenian young male competitive judokas through the usage of the upper body Wingate test and its associations between morphological characteristics and competitive performance. Data analysis shows that Slovenian young male competitive judokas exhibit suitable morphological characteristics and body composition compared to their peers. However, they are deficient in anaerobic characteristics when compared to the literature. It is evident that young Slovenian judokas could benefit from a reconstruction of strength and conditioning plans, focusing on the development of maximal strength production with anaerobic power and capacity, which are pivotal in judo. An update to the testing procedure to include SJFT would also be recommended to give a better overview of specific anaerobic judo performance. We showed that anaerobic power and capacity are still developing in these age groups. Additionally, the present research suggests that in these age groups, anaerobic performance is not the crucial factor but just one piece of the puzzle in the successful competition performance of young judokas. Therefore, other variables should be further researched. Moreover, we must be careful which results (absolute or relative) we compare to the established normative values available in the literature. We recommend comparing relative values of body mass to available judo upper body classificatory tables for young judokas. However, these data might also be used to create new normative values for the UbWt focused just on the young judokas via future meta-analysis.

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