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Strength, Power and Anaerobic Capacities of Male Judo Athletes across Age and Competitive Levels

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ABSTRACT

Purpose: This cross-sectional study evaluated the physiological profiles of judo athletes across age and competitive levels, aiming to identify key physiological determinants of judo success.
Methods: Thirty-eight judokas from three age/competitive levels (cadet + junior, non-Olympic senior, and Olympic senior), spanning various weight classes and ages, were assessed for strength, power, and anaerobic qualities. Performance tests included countermovement jump, drop jump, maximal grip strength, and upper body Wingate anaerobic test (WIN) and results were normalized to body mass. Strength values were obtained from the athletes' self-reported training programs and normalized to competition weight class. Comparisons of the physical measures were made across age/competitive levels and a qualitative evaluation based on success in national vs. international competitions was made within the groups.
Results: Significant differences in absolute values were observed between age/competitive level groups; however, most differences disappeared after normalization. The only persistent differences were in relative WIN peak power and relative WIN mean power, which were greater for the senior athletes compared with the cadet + junior group. No significant differences were found between quality levels within the groups.
Conclusion: In the within-group analysis, it was not possible to differentiate high vs. low quality level male judo athletes in our cohort. When comparing the three groups, only relative WIN peak and relative mean power were significantly different between groups while other measures lost significance when normalized. This strengthens the notion that anaerobic power and capacity are relevant to judo success.

Keywords: Judo, martial arts, handgrip, performance, combat sports, Wingate test

INTRODUCTION

Achieving success in sports involves a combination of factors, including technical skill, tactical planning and execution, physical abilities, and psychological traits. These elements work together to shape athletes' performance in their specific sports. While some sports, like athletics and track and field, are quantifiable (i.e. through centimeters, grams, seconds) making the identification of the key factors contributing to success relatively straightforward, others, like team sports and combat sports, present more complex challenges.

Combat sports, such as judo, have their own unique physiological demands. They require short bouts of maximal effort actions combined with technical-tactical abilities, such as grappling and throwing.[1] Understanding the physiological profile and sport demands can help assess athletes and direct training in hopes to increase chances of success. However, research in judo can be challenging as multiple weight categories exist and judo style, tactics, as well as total combat time may differ between weight classes and sexes.[2–6] Additionally,

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determinants of success might be different between males and females.[7] Consequently, averaging results across weight categories may lead to inaccurate or biased conclusions. As a result, judo research often has small sample sizes, especially when dealing with elite populations.

Several studies have tried to examine the relationship between physical attributes and success in judo. For example, Kostrzewa et al.[5] found that while correlations between strength and endurance, and judo ranking varied across weight categories, lower body explosive power was identified as the most influential physiological variable. Drid et al.[8] found that elite judokas had superior muscle mass, strength, and anaerobic power, but similar grip strength to sub-elite judokas, while grip strength and anaerobic capacity were significant predictors of success for males in a study by Kons et al.[7]

Furthermore, the metabolic complexity of judo can be demonstrated by several seemingly contrasting findings. The anaerobic nature of judo is supported by high blood lactate values (>10 mmol/L) measured after fights.[9] Conversely, the oxidative contribution has been shown to be greater than the ATP-PCr and the glycolytic contribution during 1 to 5 min judo matches, representing up to 81% of total energy.[10] Considering that a judo match can last up to 15 minutes or longer with unlimited extra-time (i.e., golden score),[4] aerobic capacity also seems to be crucial for judo success. As such, judo can be considered an intermittent high-intensity anaerobic combat sport with the aerobic system functioning to support athlete recovery between efforts, much like team sports. Athletes need not only strength and power but also the ability to endure and recover quickly during the match.[1,11]

Therefore, the aim of the current study was to identify physiological characteristics of successful male judo athletes using a cross-sectional study design, comparing athletes of various success levels and ages, with a focus on anaerobic physiological indices. The results of the study could inform coaches and sport scientists and help guide the focus in training and development of elite judokas.

METHODS

Participants

Male national team and development academy judo athletes participated in the study as a part of the collaboration between the team and the Wingate Institute's sport science department. Fourteen academy athletes (cadets and juniors [CJ], age=17.04±1.4 years), 20 non-Olympic seniors (NOS, age=21.6±1.9 years) and 4 Olympic senior athletes (OLY, age=28.6±2.7 years) athletes were tested for various strength and power, and anaerobic performance as a part of their normal training and testing regimen.

The CJ athletes were under the age of 19 years old (range 14.8-18.6 years) and part of the development academy which prepares them for the national team. The NOS athletes were over the age of 18 years (with the exception of one athlete) and competing internationally, however, were yet to qualify for the Olympic games. The OLY judo athletes in our cohort were seniors who had previously competed in the Olympic games and were designated to compete in the 2024 Olympic games. Additional demographic information for each group is provided in Table 1.

All athletes were free of any physical limitations preventing them from completing the tests.

Data were collected as part of routine performance monitoring services provided to national teams and academies, and the retrospective use of anonymized data for publication was approved by the Helsinki Board at Hillel Yaffe Medical Center (Approval Numbers: 0011-20-HYCM and 0125-18-HYMC), with no requirement for individual informed consent. Individual results were shared with the athletes and coaching staff.

Table 1. Descriptive statistics of the judo athletes [displayed as mean (standard deviation)]

Parameter	CJ	NOS	OLY	Post hoc Between groups (*p*)
Age (years)	17.04 (1.41) #^	21.58 (1.90) *^	28.63 (2.75) *#	0.000
Body mass (kg)	67.32 (6.59) #^	77.39 (9.78) *^	89.93 (14.72) *#	0.000
Height (cm)	173.86 (6.57)	173.20 (5.08)	180.50 (6.66)	0.084
Judo experience (years)	10.8 (2.9) #^	16.2 (1.9) *^	21.5 (3.4) *#	0.000

*CJ= Cadets and juniors, NOS=non-Olympic seniors, OLY= Olympic seniors. Post hoc analysis: * sig diff from CJ, # sig diff from NOS, ^ sig diff from OLY.*

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Protocol

As the coaching staff was interested in understanding the contributing factors to judo success, mainly focusing on anaerobic and strength qualities, a battery of physical performance assessments was selected and employed. The selected physical performance assessments were countermovement jump (CMJ), drop jump from a 40 cm box (DJ), maximal grip strength (GRIP) and upper body Wingate anaerobic test (WIN). In addition, to assess dynamic strength, 5 repetition maximum (RM) strength measures of 3 exercises (free-weight barbell squat, hang power clean and bent-over row) were self-reported and obtained from the athletes' ongoing strength program. As data for this study was obtained from ongoing regular testing and limited time was allowed for testing (since the coaching staff was not willing to allocate time for testing on the expanse of judo training), dynamic strength was not directly tested by the researchers. Judo experience in years was self-reported by the participants. All tests were performed between 8 and 10 am, and the athletes were instructed to maintain their usual training and dietary routine.

Warm up

Prior to the physical performance assessments, athletes were weighed with minimal clothing and without shoes to the nearest 0.1 kg using a Seca mBCA 514 (Seca gmnh & co., Hamburg, Germany). Their height was measured to the nearest centimeter using a Seca model 206 (Seca gmnh & co., Hamburg, Germany). Each athlete then completed a 5-minute jog on a treadmill at a self-selected pace, followed by individual light stretching and several bodyweight squats and jumps.

Countermovement Jump

Jumping protocol was consistent with the protocol described by Warr et al.[12] The athletes stood on a dual force plate (Kistler, model 9260AA6, Winterthur, Switzerland) and were instructed to descend to a self-selected height by bending at the hips and the knees with the intention to vertically jump as high as possible, while maintaining their hands on their hips throughout the movement. Jump height was automatically calculated from take-off velocity by the analysis software (Kistler MARS, v5.2.1.237) and recorded to the nearest 0.1 cm, and peak power (W) was also noted. Both variables demonstrated high intraday and interday reliability.[13] Three attempts were given to each athlete, with at least 30 seconds rest intervals, with the greatest outcome saved for analysis.

Drop Jump

The athletes stood on a 40 cm box and dropped to the force plates with their preferred foot first, making contact with both feet simultaneously. They were instructed to keep ground contact time as short as possible, while also jumping for maximal height,[14,15] and were free to swing their arms. Reactive strength index (RSI) was automatically calculated by the software by dividing jump height (derived from flight time) with contact time. This method of calculating RSI has demonstrated high reliability with ICC>0.95.[16] After a visual demonstration and few familiarization trials, 3 attempts were given to each athlete, with the greatest RSI result saved for further analysis.

Grip Strength

The athletes sat on a chair with their elbow flexed at a 90-degree angle and the forearm in neutral position. The handle of the dynamometer was set at the second position.[17] They were instructed to squeeze the grip dynamometer (microFET Grip, Hoggan Scientific LLC., Salt Lake City, UT) as hard as they could for 3-5 seconds. This test has been demonstrated to be reliable.[18] Three attempts were given for each hand in an alternating fashion and the highest performance for the right and left hands were summed for the total score in kg.

Wingate Anaerobic Test

The athletes performed the upper body Wingate anaerobic test on a cycle ergometer (Monark Ergomedic 891E, Varberg, Sweden) with resistance equivalent to 6% of their body mass, in accordance with Franchini.[19] The athletes were sitting down on a wooden box, with their shoulders in line with the height of the crank hinge. A three-minute warm up at a slow pace (about 50 rpm) with no resistance was given, during which two 3-sec sprints against the actual test weight were performed, with 30 sec active recovery in between. After the 3 -minute warm up, a 2- minute break was given before the test started. For the test, the athlete increased the revolution speed to their maximum ability (170-200 rpm) at which point the resistance was applied and the test was simultaneously recorded using the Monark Anaerobic test software, version 3.3. The variables recorded were peak and mean power

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(W), relative peak and mean power (W/kg), and fatigue index (%), calculated as the ratio between minimum and maximum power during the test. All variables were automatically calculated by the Monark software.

Strength

Strength was indicated by the self-reported best 5 RM loads (in kg) for the following 3 exercises: barbell bent-over row (BOR), back squat and the power clean. Total strength level was the sum of load lifted in these three exercises. Because these measures were self-reported, and body mass at the time of those measurements was not recorded, total strength was normalized to competition weight class; whereas relative values for the other outcome variables were determined using body mass recorded by the researchers on the day of testing.

Judo Ranking

The world judo ranking (if the athlete was ranked) from the official International Judo Federation website (https://www.ijf.org/wrl)[20] and a coaching staff dichotomous qualitative evaluation based on success in international competitions (high vs. low quality) were used for further comparison. For the CJ group, a coach estimated their qualitative evaluation based on success in national competitions alone since these young athletes were yet to compete at the international level and most were not internationally ranked.

STATISTICAL ANALYSIS

A Pearson correlation coefficient test was performed within the combined senior group (NOS + OLY, due to the small number of Olympic athletes) to examine the association between physical qualities and world ranking and Spearman's rho test was used to assess the correlation with qualitative evaluation. Spearman's rho test was used to evaluate correlations within the academy group between physical qualities and qualitative evaluation.

An independent sample t-test was used to evaluate differences between the quality groups within each age group (CJ, combined senior group).

A between-group analysis of variance (ANOVA) was conducted to compare the three age/competitive level categories (CJ, NOS, OLY). The analyses were performed using IBM SPSS Statistics for Windows, Version 29.0.2.0 (Armonk, NY: IBM Corp), with the significance level set at 5%. Data are presented as means and standard deviations.

RESULTS

Anthropometric and judo training experience data are presented in Table 1. Weight class distribution is shown in Figure 1. When comparing the age/competitive level groups (cadet + junior [CJ], non-Olympic senior [NOS], and Olympic senior [OLY]), significant differences were found in several anthropometric and performance variables. These included age, body mass, training experience, CMJ peak power, Wingate absolute peak power (PP) and mean power (MP), total strength, and strength in the various exercises (bent-over row, squat, and power clean). A trend toward significance was noted for absolute maximal grip strength (p = 0.055) (Tables 1 and 2).

After normalization, only relative Wingate PP and MP remained significantly different between groups while relative total strength approached significance (p = 0.079) (Table 3). Post-hoc comparisons showed no significant differences between NOS and OLY; however, the small sample size in the OLY group (n = 4 for PP; n = 3 for MP) limits the interpretability of these findings. One athlete's MP data was excluded due to poor adherence to the test protocol.

Importantly, within-group analyses comparing higher- vs. lower-quality athletes (based on competition level and world ranking) performed separately in the CJ and combined senior (NOS + OLY) groups revealed no significant differences for any measured variable. Furthermore, no correlations were found with world ranking or qualitative evaluations, underscoring the limited discriminative and predictive value of these tests for athlete quality within a similar group of athletes.

DISCUSSION

The key finding of this study is that, while several variables differentiated the groups, relative upper-body anaerobic power and capacity—measured by Wingate peak and mean power, respectively, normalized to body mass—were the only variables that consistently differed between age/competitive level groups. This highlights the influence of body mass on performance outcomes and the importance of optimizing relative anaerobic

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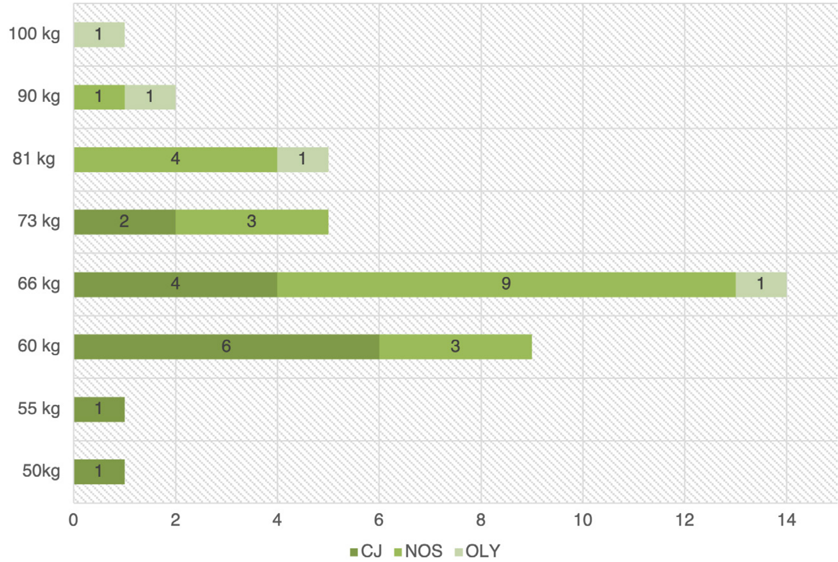

Figure 1. Distribution of judo athletes' weight categories by age/competitive level.

Table 2. Absolute values of evaluated physical performance assessments [displayed as mean (standard deviation)]

Test Name	CJ	NOS	OLY	Post hoc Between groups (*p*)
CMJ (cm)	36.51 (5.13)	38.31 (4.19)	41.05 (4.99)	0.210
CMJ Peak Power (W)	3465.14 (654.15) #^	4272.75 (611.76) *	4706.00 (447.38) *	0.000
40 cm DJ RSI	1.69 (0.41)	1.90 (0.27)	1.99 (0.42)	0.178
Grip Strength R+L Sum (kg)	98.26 (18.65)	107.13 (14.52)	121.53 (22.78)	0.055
Wingate PP (W)	512.48 (138.56) #^	695.97 (170.32) *	824.64 (161.40) *	0.002
Wingate MP (W)	338.61 (79.33) #^	455.87 (70.94) *	504.37 (78.04) *	0.000
Wingate Fatigue Index (%)	0.71 (0.08)	0.67 (0.09)	0.62 (0.16)	0.349
Total Strength (kg)	252.22 (27.63) #^	295.00 (31.44) *^	368.25 (50.94) *#	0.000
5 RM Power Clean (kg)	72.78 (8.70) #^	85.56 (11.74) *^	109.00 (18.94) *#	0.000
5 RM Bent Over Row (kg)	77.22 (7.12) #^	91.67 (12.13) *^	113.50 (13.99) *#	0.000
5 RM Squat (kg)	102.22 (18.05) #^	117.78 (12.51) *^	145.75 (18.41) *#	0.000

CJ= Cadets and juniors, NOS=non-Olympic seniors, OLY= Olympic seniors.
*CMJ= countermovement jump height, PP=peak power, MP=mean power, DJ=drop jump, RSI=reactive strength index, R=right hand; L=left hand; RM=repetition maximum. Post hoc analysis: * sig diff from CJ, # sig diff from NOS, ^ sig diff from OLY.*

Table 3. Normalized values of evaluated physical performance assessments [displayed as mean (standard deviation)]

Test Name	CJ	NOS	OLY	Post hoc Between groups (*p*)
CMJ Relative PP (W/kg)	51.26 (6.40)	55.24 (4.28)	52.96 (6.09)	0.112
Grip Strength Relative Sum (kg/BW)	1.45 (0.18)	1.41 (0.11)	1.36 (0.15)	0.432
Wingate Relative PP (W/kg)	7.58 (1.51) #	8.91 (1.26) *	9.20 (1.20)	0.022
Wingate Relative MP (W/kg)	5.01 (0.81) #^	5.88 (0.41) *	5.96 (0.05) *	0.001
Relative Total Strength (kg/BW)	3.93 (0.33)	4.16 (0.36)	4.40 (0.36)	0.079

*CJ= Cadets and juniors, NOS=non-Olympic seniors, OLY= Olympic seniors. CMJ= countermovement jump height, PP=peak power, MP=mean power, BW=body weight. Post hoc analysis: * sig diff from CJ, # sig diff from NOS, ^ sig diff from OLY.*

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qualities that may contribute to judo success. No significant differences were found between the two senior groups, although the small sample size in the Olympic-level group (n = 4) limits the strength of this comparison. Within-group comparisons based on athlete quality showed no significant differences in any variable.

Wingate Anaerobic Test

In their 2011 review, Franchini et al.[11] concluded that judo athletes present substantial power and anaerobic capacity in upper-body exercises, which could be key factors in performance. Accordingly, the upper-body Wingate test is frequently used in the assessment of judo athletes[11] and results from various studies partly support the current findings.[21,22]

Similar to our results, age-related differences were evident among cadet, junior, and senior judo athletes. Little[21] observed that cadet judo athletes exhibit lower absolute peak and mean power compared to their junior and senior counterparts, along with diminished relative peak power in comparison to senior athletes. Furthermore, a study by Franchini et al.[22] compared different competitive levels, revealing that elite athletes, characterized as national or international medalists, demonstrated higher peak and mean power values in the upper body Wingate test than their non-elite (i.e. non-medalists) counterparts. This suggests that both age and competitive level are related to variations in upper body Wingate test performance among judo athletes.

Franchini et al.[9] found that higher competitive-level athletes performed better in repeated Wingate tests when fatigued than lower competitive-level athletes. The elite athletes appear to be better at resisting fatigue and maintaining anaerobic capabilities than their lower-level counterparts, which highlights the importance of both traits. However, in their study, peak power did not differentiate between the groups, which could suggest that anaerobic capacity, or endurance, is more important than instantaneous anaerobic power. The authors concluded that performing repeated Wingate tests provides a means of evaluating judo fitness levels.

Along with data on the importance of anaerobic traits for judo, match duration data implies that a well-developed aerobic energy system might be of great value. While regulation time of a judo fight is four minutes (net combat time, as the clock is not continuous), the mean net match duration has been reported to be 3:10 ± 1:46 min,[3] with most matches ending in the final minute.[4] However, with the possibility of an unlimited golden score period (overtime when the score is tied after regulation time), net match duration in a judo match can last up to 15 minutes or more, with 20.9%-40.3% of matches entering overtime.[3,4] The total, or gross, match duration (total duration of combat plus stops) is even longer.

While data on total match duration is non-existent, video analysis of the medal rounds during the 2023 judo world championships revealed an average total time (active + pause time) of 7:17 ± 3:50 min with a range of 1:43-14:50 min and a ratio between active to pause time of 2.6:1 (Harat 2023, unpublished data). Furthermore, it was found elsewhere that work:rest ratio within the active time was approximately between 2:1 to 3:1 with 20-30 sec efforts and 5-10 sec of pauses.[1,6]

The significance of both the anaerobic and aerobic energy systems is suggested by these data, which are further supported by a study that measured energy system contribution in simulated judo fights.[10] In the study, the oxidative system contributed from 50% (with 1-min fights) up to 81% (in 5-min fights) of total energy. In other words, the longer the fights lasted, the more energy being supplied by the aerobic energy system. Accordingly, a significant positive correlation was found between performance in the specific judo fitness test (SJFT) and estimated VO_{2max} in female judokas,[23,24] suggesting that the work performed during the test was supported by aerobic metabolism. Regarding anaerobic metabolism, with efforts that last 20-30 sec at a time, it seems that anaerobic capacity (endurance) is more pertinent for judo success than instantaneous peak power. Taken together, practical applications for training competitive judo athletes should prioritize anaerobic capacity—specifically, 20–30 seconds of high-intensity general or judo-specific efforts with limited recovery, aligned with the work-to-rest ratios observed during active periods—rather than focusing solely on maximizing peak power, while also supporting a well-developed aerobic base.

Strength and Power

The results from our study demonstrated that, while absolute strength and CMJ peak power were different between the age/competitive level groups (CJ, NOS, OLY), the differences were minimized

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when results were normalized to body mass (CMJ PP) and competition weight class (strength). Relative total strength approached significance (p=0.079), while CMJ height and reactive strength (RSI) were not different between groups. These measures were also non-significant in differentiating quality levels within groups. Our results are somewhat contrasting compared to other studies which found strength and power indices to be significant predictors of success, or different depending upon athletes' competitive levels or ranking.

Kostrzewa et al.,[5] tested 16 judo athletes across four weight categories and three competitive levels, examining correlations between judo ranking and both upper-body (bench press) and lower-body (squat) explosive strength (2 reps at 50% 1RM), as well as strength endurance (30 reps in 30 seconds at 50% 1RM). Notably, the relevance of each variable varied by weight category. As is common in studies on elite athletes, the sample size was small, with only four athletes per group. When all athletes were pooled, regression analysis identified lower-body explosive strength as the most influential physiological predictor of judo ranking.

In contrast, our study found no significant between- or within-group differences in normalized lower-body power, as measured by CMJ (jump height and relative peak power) and power clean performance (a full-body movement with a strong technical component). While we observed between-group differences in absolute CMJ peak power and power clean strength, these were not associated with within-group quality level. Methodological differences between studies may explain the discrepancy—most notably, Kostrzewa et al. did not normalize strength data to body mass or weight class and employed different exercises and methods to assess lower-body power.

Drid et al.,[8] compared five elite (international medalists) to five sub-elite (national medalists) judokas in the half-heavyweight class (~100 kg) and found that the elite group exhibited superior strength and lower-body anaerobic power, assessed via an 8-second maximal cycling sprint. Specifically, elite athletes outperformed in maximal strength tests for the bench press and deadlift, but not the squat. No differences were observed in lower-body explosive strength, as measured by vertical and horizontal jump tests. The elite group also demonstrated greater muscular endurance, as well as higher aerobic and anaerobic capacities—findings that align with our practical training recommendations.

In our study, we observed no significant differences in normalized total strength across or within groups; however, a trend toward significance was noted (p = 0.079). It is possible that results may have differed with a larger sample or alternative strength assessments (e.g., different exercises or isometric testing).

Upper-body strength in our study was assessed using the bent-over row (BOR), a pulling movement pattern relevant to judo. Pulling actions are highly specific to the sport, as judokas frequently pull opponents to initiate throws or to break grips during disputes. While we examined maximal upper-body pulling strength (5RM BOR), it is possible that upper-body strength endurance or power, which were not assessed, rather than maximal strength alone, play a more decisive role in judo performance. This is supported by findings from both Drid et al.[8] and Kostrzewa et al.[5], who identified upper-body strength endurance as a significant predictor of success in certain weight classes, and also by a time-motion analysis.[1]

Grip Strength

As judo is a grappling sport, significant physiological and tactical emphasis is placed on hand grip, both in research and in practice.[25,26] In the present study, relative maximal grip strength was not a predictor of within-group quality, nor did it differentiate between groups. This aligns with several previous studies that have reported findings regarding the relevance of grip strength to judo performance. For example, relative grip strength did not vary across age groups,[27] and maximal grip strength was not associated with success in half-heavyweight adult judokas,[8] nor did it distinguish elite from non-elite judokas at the junior[28] or senior[22] levels. Moreover, grip strength was not correlated with physiological and judo-specific performance measures in elite college judokas.[29] However, contrary findings have also been reported—for instance, grip strength was associated with performance in short matches (<2 min)[7] and was sensitive to identify differences between competitive level among judo athletes in Branco et al.[30]

Given that judokas often engage in prolonged grip disputes before executing attacks,[26] maximal grip strength alone may be less critical than grip endurance, provided a minimum strength threshold is met. Rather than continuously applying maximal isometric force, athletes likely rely on maintaining submaximal force over time to sustain their grip.

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Supporting this, adolescent elite judokas were shown to have superior grip endurance compared to their non-elite counterparts.[28] Similarly, highly trained judokas did not outperform non-judokas in peak grip force but demonstrated greater resistance to fatigue.[31] The relevance of grip endurance appears to increase as the duration of a match extends.[32]

It is also important to consider the specificity of grip actions in judo, which involves multiple grip variations (e.g., collar, sleeve, belt, arm) that require different hand, finger, and arm positions.[26,33] The standard dynamometer test may not fully capture these sport-specific demands. For instance, grip strength measured using a judogi-specific test was found to be lower than that assessed with a standard dynamometer.[34] As such, judo-specific grip assessments—such as grip endurance tests involving the judogi and engaging additional joints (e.g., elbow, shoulder)—may offer better ecological validity and discriminative value. For example, performing the maximal number of pull-ups while holding a judogi sleeve discriminated between high- and low-level judokas, whereas time to grip failure (hanging from a judogi) did not.[35] These findings support the value of incorporating judo-specific grip endurance testing in performance evaluations and training programs.

LIMITATIONS

As with most studies involving competitive international athletes, we had a low number of elite Olympic athletes and a low number of athletes from each weight class. Additionally, each of these elite Olympic athletes belonged to a separate competition weight class. Since our biggest group was the non-Olympic seniors, many of them were not ranked (i.e., official IJF ranking) which reduced the power of the within-group comparison and required reliance on a different ranking system that was partly subjective. Finally, strength levels were self-reported by the athletes, rather than directly measured under controlled conditions by research staff. Beyond the general limitation of relying on self-reported data, this necessitated a methodological choice to normalize strength values to competition weight class rather than actual body mass. Since judo athletes often weigh more during training than they do during competition, this approach may have overestimated relative strength, as the reported loads lifted were divided by a body mass likely lower than the actual weight at the time of the lift. However, we assume this effect was uniform across athletes, given the common practice of weight cutting prior to competition, making this normalization approach still appropriate for comparative purposes.

CONCLUSIONS

This study found that only relative upper-body anaerobic power and capacity, measured via the Wingate test, significantly differentiated between age/competitive levels of male judo athletes. No other normalized strength or power variable, including grip strength or lower-body power, distinguished between or within groups. These findings reinforce existing literature highlighting the relevance of anaerobic qualities in judo but suggest their primary value lies in distinguishing between stages of athletic development rather than predicting individual performance quality.

Our results contribute to the growing body of evidence supporting the importance of relative anaerobic performance, particularly in the upper body, while indicating that above a certain threshold, other factors—such as technical, tactical, or psychological attributes—may play a larger role in competitive success. Coaches should emphasize anaerobic conditioning, especially upper-body anaerobic capacity relative to body mass, alongside strength endurance and aerobic development to match the duration and demands of modern judo.
Future research should aim to define minimum thresholds for key physiological qualities and explore more specific testing methods reflective of judo's unique movement patterns and match structure.

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AUTHOR CONTRIBUTIONS

Idan Harat and Rotem Kislev-Cohen contributed to the study's conception and design. Material preparation, data collection and analysis were performed by Idan Harat and Rotem Kislev-Cohen. The first draft of the manuscript was written by Idan Harat and all authors commented on previous

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versions of the manuscript. All authors read and approved the final manuscript.

CONFLICTS OF INTEREST

The authors have no relevant financial or non-financial interests to disclose.

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ETHICAL APPROVAL

Ethical approval was obtained from the Helsinki Board at Hillel Yaffe Medical Center (Approval Numbers: 0011-20-HYCM and 0125-18-HYMC).

Given that the data in this study was secondary to the routine monitoring tests integral to the scientific and medical support extended to athletes, no informed consent was sought.

DATA AVAILABILITY

The data cannot be shared as it pertains to the physical abilities of competitive national team athletes. The coaching staff has not consented to the release of this data beyond aggregate measures such as means and standard deviations.

DATES OF REFERENCE

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