RESEARCH ARTICLE

Anaerobic power output and its relationship with the physical fitness indices among combat sports athletes

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ABSTRACT

Background: Combat sports have attained significant global popularity. In addition to the requisite physical, technical, and tactical skills, physiological characteristics like anaerobic power are crucial for executing short, high-intensity combative activities. *Objectives*: The objectives of the study were to investigate the relationship of anaerobic power output with the selected physical fitness indices among combat sports athletes. *Methods*: A total of forty (n=40) well-trained combat sports athletes (Judo and Wushu-Sanda) volunteered to participate in the study. A 30-second Wingate test (WAnT) was administered to determine the lower body anaerobic power (Watts). The significance level was set at $p < 0.05$. *Results*: Fatigue index scores were significantly higher in Judokas compared to Wushu-Sanda athletes. However, no significant differences were observed in other physical and physiological characteristics. Sex-specific differences existed, with female judokas exhibiting significantly greater flexibility and a lower fatigue index compared to Wushu Sanda athletes. In contrast, there were no such sport-specific differences observed among male athletes. Across the 25th and 75th percentiles of anaerobic power cut-points, there were significant differences observed among height, aerobic power, back strength, and handgrip strength. *Conclusions*: Sex and body weight exhibited the strongest association and emerged as the best predictors of maximum anaerobic power using multiple stepwise regression analyses. Even though other variables, such as height, handgrip strength (right), back strength, aerobic power, and recovery heart rate, exhibited significant correlations. The study offers practitioners valuable guidance on tailoring training regimens to meet the demands of both anaerobic and aerobic power in combat sports athletes, taking into account both sex and sport.

Keywords: Combat sports, Physical fitness indices, Anaerobic power, VO_{2Max}, sports performance.

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INTRODUCTION

Combat sports have gained immense popularity in recent years and have been growing increasingly interesting. At the Tokyo 2020 Olympics, combat sports accounted for 26% of all the medals. [1] The growing participation in combat sports is becoming increasingly significant, encompassing striking, grappling, mixed martial arts, and weapon-based disciplines.[2] Competitive combat sports depend on a distinctive amalgamation of physical strength, speed, endurance, and tactical acumen to succeed at various levels.[3] Physical fitness is essential for evaluating an athlete's ability to perform effectively in the high-intensity activities typical of combat sports. Anaerobic power output is a crucial component of physical fitness for combat athletes, as it directly impacts their ability to produce force and maintain power during rapid and intense actions.[4] This is evident in certain combat sports, such as wrestling, boxing, Judo, and Taekwondo, where rapid surges of energy are often required to outmaneuver an opponent. Recent years have witnessed an increasing interest among Sports science researchers and practitioners in exploring the correlation between anaerobic power output and various physical fitness indices among combat sports athletes. That would lead to optimizing the sports-specific training protocols and enhancing athletic performance.[5,6]

Anaerobic power output refers to the body's ability to perform high-intensity tasks for brief periods without primarily relying on oxygen. This function is facilitated by the ATP-PCr (adenosine triphosphate-phosphocreatine) and glycolytic energy systems, which deliver immediate energy but are not sustainable over extended durations. Anaerobic power is crucial in combat sports, as athletes must generate explosive force for actions such as punches, throws, kicks, and defensive techniques.[7] Rapid recovery between exertions is crucial, enabling athletes to sustain their performance throughout a competition. The frequent and intense bursts of exertion in combat sports make strong anaerobic power production a crucial factor for competitive success.[8]

Although studies have shown a correlation between the physical characteristics and physiological parameters among combat sports.[9,10] Even the influence of the participant's sex on physiological and performance-oriented indices, as well as

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sex-specific variances, has been studied and established.[11,12] Previous researchers have explored the physiological characteristics of athletes participating in popular combat sports, such as judoka, wrestling, and boxing, at various levels.[13-15] However, a comparative study of physiological parameters and physical fitness indices to combat sports like Judo and Wushu-Sand, particularly anaerobic power (peak power), has not been extensively explored. Wushu-Sanda is a combat sport that involves athletes in offensive and defensive techniques, including barehanded confrontations, and has become very popular, growing notably worldwide.[16]

Nevertheless, there is a paucity of studies regarding lower-body anaerobic power cut-points and their correlation with physical fitness indices, particularly among Indian combat sports players in Judo and Wushu-Sanda. [9] Therefore, the present study aimed to determine and investigate anaerobic power and its relationship with various physical fitness indicators, including isometric strength, aerobic endurance, back strength, and flexibility of the back and hamstrings. [7,17]

MATERIALS AND METHODS

Participants

A total of forty (n=40) male and female Indian combat sports athletes participated in this study, comprising Judo (n=20: Male-10, Female-10) and Wushu-Sanda (n=20: Male-10, Female-10). The participants were from the north-eastern part of India. They possess a sport-specific training experience spanning four to five years. The selected judokas and wushu-sanda athletes met the inclusion criteria by having the necessary sport-specific training experience and being free from any injuries or illnesses. And no known mental health concerns, and had never smoked.

Ethical Considerations

All participants received detailed information regarding the study's objectives, procedures, potential discomforts and advantages, as well as other relevant factors, before giving their consent to participate. Informed consent was obtained from the subjects. The research was performed in compliance with the most recent Declaration of Helsinki. The research received approval (Ref: SSU/IEC-FHW/2023/05) from the Institutional Human Ethics Committee of Sri Sri University, Cuttack, Odisha.

Experimental procedures

The current study utilized a cross-sectional design and was conducted across three distinct visits during the pre-competition phase. During the initial appointment, age, height, and weight were measured following the sensitization process. Subsequently, isometric handgrip strength, back strength, and flexibility of the back and leg hamstrings were assessed during the morning session. During the second visit, the lower-body anaerobic power assessment was performed using the Wingate 30-second all-out test methodology on a cycle ergometer. This evaluation occurred during both the morning and afternoon sessions on the same day. During the last visit, participants' aerobic endurance was assessed in the morning session using the 20-meter Multistage Shuttle Run Test protocol. The athletes were afforded one day of respite between the consecutive evaluation days.

Anthropometric measurement

Demographic information, such as decimal age in years, and anthropometric measures, including height (in cm) and weight (in kg), were measured according to the guidelines of the International Society for the Advancement of Kinanthropometry (ISAK). The height was measured using a stadiometer (model 284; Seca) to the nearest 0.1 cm, and the weight was measured using a weighing scale (model 707; Seca Corporation, Columbia, MD, USA) to the nearest 0.1 kg.

Measurement of physiological variables

Wingate 30-second test

The assessment of anaerobic power was carried out in a mechanically braked cycle ergometer (884E, peak bike, Monark, Sweden). The 30-second Wingate's all-out test protocol was employed.[4] The participants underwent a standardized warm-up before the actual test. The flywheel resistance was set, corresponding to 7.5% of everyone's body weight.[18] The anaerobic parameters, such as peak power, average power, and fatigue, were determined.[9]

The peak power, average power, and fatigue were calculated automatically by the ATS (Anaerobic test software) using the following formula.

Peak Power = Work (kg-m/min) / Time (minutes)

Work = [Force x Distance (# of revolutions x distance per revolution)]

Average Power = Force x Total distance in 30 seconds

Rate of Fatigue = [(Peak Power – Minimum Power)/Peak Power] x 100

Measurement of physical fitness indices

Measurement of aerobic endurance quality

On the third day of visits, a 20-m multistage fitness test (MSFT), also known as the "beep test," was employed to assess aerobic performance in terms of maximum oxygen uptake capacity, expressed as VO_{2Max}.[19] In a non-slippery track, the 20-m distance was marked, and cones were placed on both sides. Before the test, participants were instructed to perform a standardized warm-up. The participants performed the running task following a pre-recorded standard "bleep-test" audio signal, which involved running back and forth between the markers.[20] The number of completed shuttles was recorded, along with the distance covered by an individual. VO_{2Max} was predicted based on the standard formula.[21]

$VO_{2Max} = 31.025 + (3.238 \times \text{velocity}) - (3.248 \times \text{age}) + (0.1536 \times \text{age} \times \text{velocity})$.

Measurement of isometric handgrip strength

Isometric strength, specifically handgrip strength (HGS) for both hands, was assessed using the handgrip strength dynamometer (Grip-D, T.K.K 5401 Takei, Japan). The dynamometer was calibrated before the assessments according to the manufacturer's instructions. The participants were told to engage in a general warm-up for a minimum of 5 to 10 minutes. Subsequently, three further tests were conducted, with an interval of 2 to 3 minutes between each test for both the right and left hands. Participants were told to exert maximum force and to maintain the grip for a duration of 3 to 5 seconds. The mean values of the three trials for each hand were recorded in kilograms (kg).[22, 23]

Measurement of back strength

Back strength was assessed utilizing a back strength dynamometer (Back-D, T.K.K 5402, Takei, Japan). The participants were directed to engage in a general warm-up, including back and hamstring stretches, for a minimum duration of 5 to 10 minutes. Subsequently, each subject was evaluated individually. During the back strength evaluation, the leg was extended, and the back was bent to around a 130-degree angle, with the subject instructed to hoist as much weight as possible. Three consecutive measurements were conducted, and the average lift was recorded in kilograms (kg) for each participant.[24]

Measurement of back and hamstring flexibility

Flexibility of the lower back and hamstrings was assessed using the conventional sit-and-reach test methodology. Sit-and-reach box (Baseline-Fabrication Enterprises Inc, New York) was utilized for the evaluation. The participants were told to engage in a general warm-up for a minimum of 5 to 10 minutes. Subsequently, they were examined individually. The palms of both hands were positioned together and instructed to press the ruler forward, maintaining the position for 3 to 5 seconds. Three times, measurements were taken, and the best one was calculated for the final flexibility results in centimeters (cm).[25,26]

Statistical analysis

All data were expressed as mean and standard deviation (SD), and statistical analyses were performed using IBM SPSS (version 26.0, Inc., Chicago, IL, USA). The normality of the data was checked using the Shapiro-Wilk test. Pearson's correlation coefficient (r) was used to check the relationship among the variables. An independent sample t-test was utilized to assess the physical and physiological attributes. The stepwise multiple linear regression was employed to determine the prediction models of the independent physiological variables. One-way analysis of variance (ANOVA) was utilized to ascertain variations in physical and physiological (anaerobic power cut-points) parameters. The level of significance was set at $p < 0.05$.

RESULTS

The primary outcome of the study, peak anaerobic power, was normally distributed ($p = 0.213$). The results depicted in Table 1 showed that the majority of physical fitness and physiological variables did not exhibit significant differences across types of sports (Judo versus Wushu-Sanda), except for the fatigue index. Judokas exhibited a lower fatigue index compared to Wushu-Sanda athletes ($p = 0.001$, Mean Difference: 2.40 ± 0.685, 95% CI: -3.78, -1.00). However, gender-specific comparison across sports depicted no significant differences in physical and physiological parameters among males (Table 1) as opposed to significant differences in flexibility and fatigue index. The flexibility was higher ($p = 0.047$, Mean Difference: 3.35 ± 1.57, 95% CI: 0.05,

Table 1: Physical fitness indices and physiological characteristics of combat sports athletes

Parameters	*Judo*			*Wushu-Sanda*		
	Male (n = 10)	*Female (n = 10)*	*Overall (n = 20)*	*Male (n = 10)*	*Female (n = 10)*	*Overall (n = 20)*
Age (Year)	17.20 ± 1.81	18.10 ± 1.52	17.70 ± 1.69	17.20 ± 0.79	17.80 ± 2.1	17.50 ± 1.57
Height (cm)	166.50 ± 4.17	157.60 ± 4.80	162.00 ± 6.32	165.50 ± 3.31	158.50 ± 6.63	162.00 ± 6.22
Weight (kg)	63.70 ± 7.47	59.00 ± 12.70	61.40 ± 10.41	59.10 ± 5.24	53.10 ± 6.24	56.10 ± 6.39
HGS Right (kg)	41.90 ± 7.77	30.90 ± 3.89	36.40 ± 8.22	44.10 ± 4.39	29.70 ± 2.77	36.90 ± 8.22
HGS Left (kg)	41.00 ± 3.69	30.00 ± 3.61	35.50 ± 6.66	42.90 ± 3.23	28.20 ± 2.67	35.50 ± 8.07
Back strength (kg)	131.20 ± 20.80	92.50 ± 13.76	111.80 ± 26.27	129.10 ± 12.85	84.10 ± 4.26	106.60 ± 24.89
Flexibility (cm)	42.90 ± 6.04	46.80 ± 3.59	44.80 ± 5.22	45.10 ± 2.66	43.40 ± 3.43	44.30 ± 3.11
VO_{2Max} (mL/kg/min)	55.00 ± 4.16	44.00 ± 4.76	49.50 ± 7.11	52.00 ± 3.86	43.20 ± 3.19	47.60 ± 5.69
Peak AP (watt.)	11.30 ± 1.39	7.90 ± 1.17	9.60 ± 2.16	11.00 ± 0.8	8.50 ± 1.11	9.70 ± 1.62
Avg. AP (watt.)	7.80 ± 0.53	5.90 ± 0.84	6.90 ± 1.22	7.90 ± 0.38	6.40 ± 0.66	7.10 ± 0.95
Fatigue Index	6.90 ± 1.80	4.60 ± 1.56	5.80 ± 2.04	8.10 ± 2.35	8.30 ± 2.35*	8.20 ± 2.29*

AP= Anaerobic power; HGS = Handgrip strength; Data are presented as mean ± SD. * indicates a significant difference with the male counterpart.

Table 2: Differences in physical fitness indices across peak anaerobic power cut points categories

Parameters	*Male*		*Female*		*Overall*		
	8.0–10.9 (n=09)	*≥11 (n=11)*	*≤8.0 (n=10)*	*8.0–10.9 (n=10)*	*≤8.0 (n= 10)*	*8.1–10.9 (n=19)*	*≥11 (n=11)*
Age (year)	17.60 ± 1.24	16.90 ± 1.45	18.00 ± 2.11	17.90 ± 1.52	18.00 ± 2.11	17.70 ± 1.37	16.90 ± 1.45
Height (cm)	166.30 ± 3.94	165.70 ± 3.65	158.10 ± 7.25	158.00 ± 3.86	158.10 ± 7.25	162.00 ± 5.71*	165.70 ± 3.65*
Weight (kg)	64.60 ± 7.3	58.80 ± 5.11	59.90 ± 13.11	52.20 ± 3.84	59.90 ± 13.11	58.10 ± 8.44	58.80 ± 5.11
HGS Right (kg)	45.40 ± 6.44	41.00 ± 5.59	30.60 ± 3.25	29.90 ± 3.57	30.60 ± 3.25	37.20 ± 9.39	41.00 ± 5.59[b]
HGS Left (kg)	43.20 ± 3.08	40.80 ± 3.61	29.80 ± 3.61	28.40 ± 2.8	29.80 ± 3.61	35.40 ± 8.14*	40.80 ± 3.61*@
Back strength (kg)	130.80 ± 19.23	129.60 ± 15.61	89.10 ± 12.28	87.50 ± 9.69	89.10 ± 12.28	108.00 ± 26.56*	129.60 ± 15.61*@
Flexibility (cm)	45.40 ± 3.70	42.80 ± 5.22	45.50 ± 3.27	44.70 ± 4.46	45.50 ± 3.27	45.10 ± 4.02	42.80 ± 5.22
VO_{2Max} (mL/kg/min)	54.40 ± 5.40	52.70 ± 2.94	42.70 ± 3.87	44.50 ± 4.04	42.70 ± 3.87	49.20 ± 6.86*	52.70 ± 2.94*
Fatigue Index	6.60 ± 2.28	*8.20* ± 1.76	5.90 ± 2.82	7.00 ± 2.61	5.90 ± 2.82	6.80 ± 2.4*	8.20 ± 1.76*

HGS = Handgrip strength; Data are presented as mean ± SD. * and @ indicate significant differences with ≤8.0 group and @ 8.1-10.9, respectively.

6.65), and the fatigue index ($p = 0.001$, Mean Difference: 3.67 ± 0.89, 95% CI: -5.55, -1.75) was lower among female Judokas compared to Wushu-Sanda athletes.

Maximum anaerobic power was positively correlated ($p < 0.05$) with height (r = 0.488), handgrip strength (right; r = 0.584, left; r = 0.629), back strength (r = 0.669), and aerobic power (r = 0.590), and negatively correlated with gender (r = -0.806). The single best predictor of anaerobic power (Watt/kg) was gender [Max. AP = 14.166 – 3.007 × Gender (Male = 1 and Female = 2); $r^2 = 0.649$, SEE = 1.133]. Whereas gender combined with weight (Max. AP = 17.825 — 3.298 × Gender — 0.055 × Body Weight (kg); $r^2 = 0.711$, SEE = 1.043) showed a higher association with anaerobic power. Among other physical fitness and physiological variables, the back strength (Peak AP = 4.218 + 0.050 × Back strength (kg); $r^2 = 0.448$, SEE = 1.422) was a better predictor of anaerobic power in this study. The physical fitness variables, such as height, handgrip strength, and back strength, exhibited a significant difference across anaerobic power cut points, combining both genders. The height was lower in the lowest anaerobic power category, and it was highest in the higher AP category ($p < 0.05$). The handgrip strength (both left and right) and back strength were higher with the highest anaerobic power output (Table 2). Further, $\dot{V}O_{2Max}$ also showed significant differences across AP categories, with higher AP values indicating higher $\dot{V}O_{2Max.}$ However, there were no significant gender-specific differences in physical fitness and physiological variables across AP categories.

DISCUSSION

The study aimed to investigate the relationship between physiological parameters (peak power, average power, and fatigue) and physical fitness parameters among the selected combat sport groups. The main finding of the study was that the sports-specific differences associated with the physical and physiological characteristics were not observed in male athletes. In contrast, female judokas exhibited a lower fatigue index compared to wushu-sanda players.

Physical and physiological characteristics are unique and specific to the type of sports.[27,28] Even within combat sports, body fat percentage varied from almost 4 to 9% in boxing,[29] and 16% in wrestling. The physiological indices, like aerobic power, reported in different studies ranged from 48 to 61 ml/kg/min, with the lowest reported in Taekwondo and the highest in boxing.[30] Further, the peak anaerobic power for the lower body ranged from 9 to 16 watts/kg across the literature in combat sports. [7] The Brazilian Jiu-Jitsu athletes reported a peak power of 11.9 ± 1.4 watt/kg.[31] The highest is noted in Turkish national boxers and kickboxers, reaching up to 18.8 watt/kg.[32] In contrast, our study observed no differences in physical and physiological characteristics, except for fatigue, between Judo and Wushu-Sanda. Similarly, a research study has reported no significant differences in physical metrics, such as height, weight, and muscle mass, among combat sports athletes.[33] However, the lower-body anaerobic power in our study was similar to that reported in previous studies by other combat sports athletes.[17, 9] Combat athletes in this study, though belonging to two different sporting groups, exhibited similar physical and physiological characteristics. Although their sport-specific skills, techniques, and tactics vary in nature, they share a similar training environment, including basic strength and conditioning strategies, which may have influenced the results.

The fatigue index (FI) is typically estimated to determine the rate of decline in power, particularly in sports that involve anaerobic performance. A lower FI value supports sustaining an anaerobic effort, whereas a value greater than 10 has been reported to influence limited lactate tolerance. These cut-offs were generated based on field-based anaerobic tests (Running-Based Anaerobic Sprint Test (RAST)).[34] However, the Fatigue Index obtained using laboratory-based direct measurement (30 sec. WAnT) in the present study showed that the greater the peak power, the higher the fatigue index value.

Peak power is a valuable indicator for monitoring training adaptation and sports performance outcomes in combat sport athletes.[35] Among combat sports, the peak power output in the lower body plays a major role in grappling (judo, wrestling) and kicking (taekwondo and Wushu-Sanda) performance.[36] The peak power (PP) for the Judo (9.6 ± 2.16 watt/kg) and Wushu-Sanda athletes (9.7 ± 1.62 watt/kg) in the present study was found to be similar.[37] However, to the best of our knowledge, there were no standard cut-offs or classification of anaerobic peak power among combat sports, making it difficult to compare or monitor a specific combat sport across different levels of performance. Thus, on categorizing the peak power based on interquartile ranges for this study, it was observed that height, handgrip strength (both left and right), back strength, and aerobic power were higher in the 75^{th} percentile peak power (≥11 watt/kg) group compared to the 25^{th} percentile peak power (≤8.0 watt/kg). However, these differences appeared to be influenced by the sex of the participant, as sex-specific comparisons did not reveal differences in height, handgrip, back strength, or aerobic power.

The present study has provided valuable insights into physical fitness and physiological variables among Indian combat sport athletes, capturing a first-of-its-kind dataset on the physical and physiological demands of athletes participating in Wushu-Sanda. However, the study is limited by its small sample size, which affects generalizability, and other factors that may have influenced the anaerobic peak power, such as weight category, training history, body composition, sleep patterns, and diet, were not explored. To understand the lower body's power, other factors, such as biomechanical analysis, were not investigated. The physiological and fitness indices were measured only at a single point in time, which may be a limitation of the study. Future research should be conducted across larger cohorts to establish reference values for anaerobic power across combat sports disciplines. This study highlights the complex interplay between anaerobic power, fatigue resistance, and physical fitness in combat sports. It provides valuable directions for practitioners to tailor training programs based on sport-specific and gender-specific needs, ensuring athletes perform optimally during competition.

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CONFLICT OF INTEREST

The author declares no conflict of interest.

REFERENCES

1. Franchini E, Sterkowicz S, Szmatlan-Gabrys U, Gabrys T, Garnys M. Energy system contributions to the special judo fitness test. *Int J Sports Physiol Perform*. 2011;6(3):334-343. doi:10.1123/ijspp.6.3.334.
2. Dmitry Andreevich S. Genetic Prerequisites of Sports Success of Sportsmen Going in for Combat Sports. *J. Pharm. Sci. & Res.* 2017; 9(9):1569-1572.
3. Valdes-Badilla P, Perez-Gutierrez M. Physical Conditioning for Combat Sports: Book review. *Ido Movement for Culture*. 2018;18(1):45-48. doi:10.14589/ido.18.1.7.
4. Ouergui I, Hssin N, Haddad M, et al. The Effects of Five Weeks of Kickboxing Training on Physical Fitness. *Muscles, Ligaments and Tendons Journal*. 2014; 4(2): 106-113.
5. Franchini E. Energy System Contributions during Olympic Combat Sports: A Narrative Review. *Metabolites*. 2023;13(2). doi:10.3390/metabo13020297.
6. Sandford GN, Laursen PB, Buchheit M. Anaerobic Speed/Power Reserve and Sport Performance: Scientific Basis, Current Applications and Future Directions. *Sports Medicine*. 2021;51(10):2017-2028. doi:10.1007/s40279-021-01523-9.
7. Tortu E, Ouergui I, Ulupinar S, Özbay S, Gençoğlu C, Ardigò LP. The contribution of energy systems during 30-second lower body Wingate anaerobic test in combat sports athletes: Intermittent versus single forms and gender comparison. *PLoS One*. 2024;19 doi:10.1371/journal.pone.0303888.
8. James LP, Beckman EM, Kelly VG, Haff GG. The neuromuscular qualities of higher- and lower-level mixed-martial-arts competitors. *Int J Sports Physiol Perform*. 2017;12(5):612-620. doi:10.1123/ijspp.2016-0373.
9. Čular D, Ivančev V, Zagatto AM, et al. Validity and reliability of the 30-s continuous jump for anaerobic power and capacity assessment in combat sport. *Front Physiol*. 2018; 9:543. doi:10.3389/fphys.2018.00543.
10. Tabben M, Chaouachi A, Mahfoudhi M, et al. Physical and physiological characteristics of high-level combat sport athletes. *Journal of Combat Sports and Martial Arts*. 2014;5(1):1-5. doi:10.5604/20815735.1127445.
11. Hunter SK. Sex differences in human fatigability: Mechanisms and insight to physiological responses. *Acta Physiologica*. 2014;210(4):768-789. doi:10.1111/apha.12234.
12. Franchini E, Cormack S, Takito MY. Effects of high-intensity interval training on olympic combat sports athletes' performance and physiological adaptation: a systematic review. *J Strength Cond Res*. 2019; 33(1)/242–252. www.nsca.com
13. Pérez Armendáriz ML, Adhikari R, Bawari B, Varamenti E, Pullinger SA. Anthropometric characteristic, somatotype, and body composition of Indian Female Combat Sport Athletes: A comparison between Boxers, Judokas, and Wrestlers. *International Journal of Kinanthropometry*. 2023;3(1):109-117. doi:10.34256/ijk23112.
14. Franchini E, Del Vecchio FB, Matsushigue KA, Artioli GG. Physiological Profiles of Elite Judo Athletes. *Sports Med*. 2011; 41(2): 147-166.
15. Polak E, Seredynski A, Przednowek K. Physical fitness profiles of junior athletes practicing selected combat sports. *Revista de Artes Marciales Asiáticas*. 2016;11(2s):28. doi:10.18002/rama.

v11i2s.4156.
16. Liu Y, Zhang Y, Qin Y, Hou X, Zhao Q, Li J. The Inhibition of Return of Sanda Athletes in Three Dimensional Static and Dynamic Scenes. *Percept Mot Skills*. 2023;130(1):520-538. doi:10.1177/00315125221139001.
17. Gacesa JZP, Barak OF, Grujic NG. Maximal anaerobic power test in athletes of different sport disciplines. *J Strength Cond Res*. 2009; 23(3)/751–755. www.nsca-jscr.org
18. Dey S, Adhikari S, Ghosh T. Association between special judo fitness test index and physiological variables among Indian judokas. *African Journal of Biomedical Research*. 2024. 27(4S), 3101-3108. doi:10.53555/AJBR.v27i4S.4156.
19. Leger LA, Lambert J. A Maximal.Multistage 20-m Shuttle Run Test to Predict VO2 Max. *Eur J Appl Physiol Springer-Verlag*. 1982 49:1-12.
20. Boraczyński M, Boraczyński T, Podstawski R, Wójcik Z, Gronek P. Relationships between Measures of Functional and Isometric Lower Body Strength, Aerobic Capacity, Anaerobic Power, Sprint and Countermovement Jump Performance in Professional Soccer Players. *J Hum Kinet*. 2020;75(1):161-175. doi:10.2478/hukin-2020-0045.
21. Validity of the 20 m shuttle run test with 1 min stages to predict VO2max in adults - PubMed. Accessed December 11, 2024. https://pubmed.ncbi.nlm.nih.gov/2924218/.
22. Trajković N, Rančić D, Ilić T, Herodek R, Korobeynikov G, Pekas D. Measuring handgrip strength in school children: inter-instrument reliability between Takei and Jamar. *Sci Rep*. 2024;14(1). doi:10.1038/s41598-024-51368-1.
23. Castañeda-Camarena JJ, Martínez-Cervantes TJ, Navarrete-Juárez ME, et al. Body composition and handgrip strength in Brazilian Jiu-Jitsu athletes: a systematic review. *Revista Medicina Universitaria*. 2023;25(2). doi:10.24875/rmu.22000089.
24. Shahidi SH, Özkaya İ, Karakaş ÇS, Taşkıran Y, Esformes JI. Validity and Reliability of Isometric Muscle Strength using the Powrlink Portable Device. *International Journal of Strength and Conditioning*. 2023;3(1). doi:10.47206/ijsc.v3i1.237.
25. Franchini E, Herrera-Valenzuela T. Developing flexibility for combat sports athletes. *Revista de Artes Marciales Asiaticas*. 2021;16(1s):192-203. doi:10.18002/rama.v16i1s.7005.
26. Wells KF, Dillon EK. The sit and reach—a test of back and leg flexibility. *Research Quarterly of the American Association for Health, Physical Education and Recreation*. 1952; 23(1):115-118. doi:10.1080/10671188.1952.10761965.
27. Khayyat HN, Sağlr SG, Hataş Ö, Smolarczyk M, Akalan C. Physical, physiological and psychological profiles of elite Turkish taekwondo athletes. *Biomed Hum Kinet*. 2020;12(1):187-196. doi:10.2478/bhk-2020-0024.
28. Torres-Luque G, Hernández-García R, Escobar-Molina R, Garatachea N, Nikolaidis PT. Physical and physiological characteristics of judo athletes: An update. *Sports*. 2016;4(1). doi:10.3390/sports4010020.
29. Hausen M, Taylor L, Bachini F, Freire R, Pereira G, Itaborahy A. Physical Capacities and Combat Performance Characteristics of Male and Female Olympic Boxers. *Res Q Exerc Sport*. Published online 2024. doi:10.1080/02701367.2024.2325683.
30. Durkalec-Michalski K, Podgórski T, Sokołowski M et al. Relationship between body composition indicators and physical capacity of the combat sports athletes. *Arch Budo*. 2016; 12: 247-256. https://www.researchgate.net/publication/309571117.
31. Andreato L V., Leite AE, Ladeia GF, et al. Aerobic and anaerobic performance of lower- and upper-body in Brazilian jiu-jitsu athletes. *Sci Sports*. 2022;37(2):145.e1-145.e8. doi:10.1016/J.SCISPO.2021.03.006.
32. Bayrakdaroğlu S, Can I. Anaerobic power, lower-body strength characteristic and some kinetics and kinematics during loaded-squat jump movement in Turkish national boxers and kickboxers. *Arch Budo Sci Martial Art Extreme Sport*. 2018; 14: 153-159.
33. Sukamti ER, Budiarti R, Nugroho W, Miftachurochmah Y, Azeem K. A study of physical fitness characteristics of junior wushu players depend on sex difference. *Jurnal Keolahragaan*. 2022;10(1):31-39. doi:10.21831/jk.v10i1.44068.
34. Zagatto AM, Beck WR, Gobatto CA. Validity of the running anaerobic sprint test for assessing anaerobic power and predicting short-distance performances. *J Strength Cond Res*. 2009;23(6):1820-1827. doi:10.1519/JSC.0b013e3181b3df32.
35. Julio UF, Franchini E. Developing aerobic power and capacity for combat sports athletes. *Revista de Artes Marciales Asiáticas*. 2021;16(1s):10-59. doi:10.18002/rama.v16i1s.7000.
36. Huang HC, Wu WL, Chang YK, Chu IH. Physical fitness characteristics of adolescent wushu athletes. *Journal of Sports Medicine and Physical Fitness*. 2018;58(4):399-406. doi:10.23736/S0022-4707.16.06748-7.
37. Zari S, Fatemeh A G, Zeinab A G, Sahar A . Determining Physiological Profile of National Iranian Wushu Team. *Bull. Env. Pharmacol. Life Sci*. 2014; 3 (8): 69-72.

PEER-REVIEWED CERTIFICATION

During the review of this manuscript, a double-blind peer-review policy has been followed. The author(s) of this manuscript received review comments from a minimum of two peer-reviewers. Author(s) submitted revised manuscript as per the comments of the assigned reviewers. On the basis of revision(s) done by the author(s) and compliance to the Reviewers' comments on the manuscript, Editor(s) has approved the revised manuscript for final publication.