

Weight Class Comparison of Physical and Physiological Parameters in Indian Female Judokas

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Abstract

This study investigates the physiological traits of Indian female judokas across weight categories, addressing a gap in research on their performance metrics and the specific demands of their sport to optimize health and competitive outcomes. Thirty-two district-level judokas, aged 12–19, participated in assessments of key fitness variables over two days. Statistical analyses, including Spearman's correlation and one-way ANOVA, revealed significant differences in physical characteristics: Extra-Lightweight judokas excelled in the Standing Broad Jump, while Half-Medium weight judokas demonstrated greater handgrip strength, and VO₂max. The study highlights notable relationships among key performance variables, suggesting that targeted training may enhance these athletes' physical fitness. The findings offer valuable insights for coaches to tailor training programs and emphasize the importance of establishing normative fitness benchmarks for judo by weight category to refine and optimize training strategies.

Keywords: Female Judokas, Weight Class, Physiological Parameters, Performance Metrics, Combat Sports.

Resumen

Introducción: El estudio investiga los rasgos fisiológicos de las judokas indias en todas las categorías de peso, abordando una brecha en la investigación sobre su entrenamiento, recuperación y salud menstrual. Métodos: Treinta y dos judokas a nivel de distrito, de 12 a 19 años, participaron en evaluaciones de variables clave de aptitud física durante dos días. Resultados: Los análisis estadísticos, incluida la correlación de Spearman y el ANOVA unidireccional, revelaron diferencias significativas en las características físicas: las judokas de peso extraligero sobresalieron en el salto de longitud desde parado, mientras que las judokas de peso medio demostraron mayor altura, fuerza de agarre y VO₂máx. Conclusiones: El estudio destaca relaciones notables entre las variables clave de rendimiento, lo que sugiere que el entrenamiento dirigido puede mejorar la aptitud física de estas atletas. Los hallazgos ofrecen información valiosa para que los entrenadores adapten el entrenamiento y subrayan la necesidad de datos normativos de aptitud física en judo por categoría de peso para refinar aún más los métodos de entrenamiento.

Palabras Clave: Judokas femeninas, Categoría de peso, Parámetros fisiológicos, Métricas de rendimiento, Deportes de combate.

Introduction

Judo is an intense form of martial art from Japan, involving high-intensity, intermittent bouts on traditional Tatami mats. Success in judo depends on mastering complex techniques and strategic thinking during 5-minute bouts (Franchini et al., 2011; White and Rollitt, 2009). Judo was included in the Olympic program for males in 1964

and in 1992 for females and has different weight categories for both the genders. For male judokas, the weight categories are <60 kg, 66 kg, 73 kg, 81 kg, 90 kg, 100 kg, and >100 kg. Female judokas participate in the weight categories, which are <48 kg, 52 kg, 57 kg, 63 kg, 70 kg, 78 kg, and >78 kg (Franchini et al., 2011). Recent Indian research highlights how weight class differences affect body composition, somatotype, physiology, and technique (Armendáriz et al., 2023). This diversity arises from the need to optimize performance according to the specific demands of each weight category. It has been found that lighter judokas often use speed-based techniques like *ashi-waza* (foot techniques) and *nage-waza* (throwing techniques), thereby requiring agility. Heavier judokas tend to use more strength-based throws like *osoto-gari* (major outer reap) and *koshi-waza* (hip techniques), leveraging their greater body mass for power (Miarka et al., 2016). Heavyweight judokas may also focus on controlling the match pace, conserving energy, and using their size to dominate opponents (Franchini et al., 2005; Stankovic et al., 2019). This diversity in tactics and physical demands emphasizes the importance of weight-specific strategies for success in judo competition (Torres-Luque et al., 2016).

Hence, measuring physiological parameters in judo is essential for optimizing performance and enhancing training outcomes for athletes of different weight categories within the same sport. Monitoring aerobic capacity, muscle strength, and anaerobic power is vital for creating a judo-specific training plan. Strength improves grip, throws, and defence (Franchini et al., 2011), while aerobic capacity sustains energy and supports recovery between matches (Franchini et al., 2012). For explosive actions and abrupt intensity surges during matches, anaerobic power is essential (Dey et al., 2018; Schoof et al., 2024). Coaches can devise well-rounded training programmes that boost endurance, explosive power, and performance to prepare athletes for the different challenges of judo competition. Identifying physiological imbalances with monitoring can prevent overtraining and injury, ensuring judokas maintain peak performance (Sterkowicz-Przybycień et al., 2014). Judo involves techniques focused on gripping and throwing, making grip strength a key indicator of physical fitness as the aim is to pin down the opponent by solely executing techniques while holding or gripping the uniform, also known as the '*Judogi*' (Franchini et al., 2011). Judokas with higher grip strength perform better in strength-related tasks such as pulling, holding, grappling, and throws (Monteiro et al., 2014). Multiple studies supported the idea that judokas with better grip endurance can maintain effective grips throughout matches thereby improving performance (Callister et al., 2002; Ren et al., 2002; Franchini et al., 2011; Chiu & Dorshimer, 2011). Bonitch-Góngora et al. (2012) also noted that judokas with stronger grips experienced fewer injuries, highlighting grip strength's role in injury prevention.

Several major judo throws, like *Osoto Gari*, *Uchi Mata*, *Harai Goshi*, *Tai Otoshi*, and *O Goshi*, depend heavily on back and leg strength. Leg strength is vital for lifting and sweeping motions, while back strength helps pull the opponent off balance and maintain control (Nadler et al., 2002; Koshida et al., 2017; Brito et al., 2020). Studies have shown a strong correlation between leg and back strength and the effectiveness of throws such as *Uchi Mata* and *Seoi Nage*. Stronger judokas perform these techniques more efficiently (Ren et al., 2002; Detanico et al., 2012; Lech et al., 2015). Elite judokas display higher leg power and back strength than non-elites which is a key for high-level competition success (Franchini et al., 2011). Additionally, judokas with better leg strength exhibit greater endurance in prolonged matches (Sterkowicz-Przybycień et al., 2014). Other performance parameters relevant for Judokas include, Explosive leg power, commonly measured through stand broad jump (SBJ) and flexibility. In judokas, both of these tests can provide important insights into their physical capabilities and potential areas for improvement. Franchini et al. (2011) highlighted that explosive leg power, as measured by the SBJ, is a key determinant of success in judo. Judokas with higher scores in the SBJ test tend to perform better in competitions, as they possess the necessary explosive strength and agility for dynamic movements and techniques. While reviewing the literature, we came across only one Indian study, Nandal and Kumar (2024) which assessed explosive strength of lower limbs using SBJ in Judokas.

Flexibility in the lower back and hamstrings is essential for executing various judo techniques, as many throws and ground techniques (*ne waza*) require a good range of motion in the spine and lower limbs (Mosler, 2014). The sit and reach test is commonly used to assess flexibility of the lower back of athletes. Tight hamstrings and lower back muscles increase the risk of injury, especially in such a dynamic sport. Jones et al. (2012) found that athletes with poor flexibility were more prone to lower back pain and hamstring injuries. Additionally, Andreato et al. (2011) noted that combat athletes with better flexibility displayed smoother and more efficient movements, enhancing both offensive and defensive maneuvers. Judo matches demand both aerobic endurance and anaerobic power due to their high-intensity, intermittent nature. VO₂ max is a key measure of cardiovascular fitness, with higher values linked to better performance in sports like Judo. Karakoç et al. (2012) suggested that the Yo-Yo intermittent test accurately reflects the aerobic capacity of athletes, correlating with match demands. Elite judokas typically have higher VO₂ max values, essential for sustaining high-intensity efforts (Franchini et al., 2011; Invernizzi et al., 2020). The Yo-Yo test also assesses recovery capacity, critical for quick recovery between intense bouts. Limited research has explored aerobic capacity in Indian female judokas. Katralli et al. (2015) evaluated both male and female judokas but had a

small female sample size. Another study reported Indian female judokas with a VO₂ max of 40.83 ± 7.81 ml/kg/min (Dey et al., 2018).

It is well known that understanding the characteristics of judokas can provide insightful information regarding what is needed for competitive success. However, research focusing on female judokas, particularly in India, is limited, making it difficult to fully understand their specific needs. Therefore, the objective of the present study was to examine the physiological characteristics of Indian female judokas across different weight categories. Expanding research in this area is crucial to optimize training and performance for female athletes in the sport.

Material and Methods

Participants

A total number of thirty two (n=32) female judokas of different weight categories, aged 12 to 19 years old, who were regularly playing, volunteered to take part in this study. Only athletes who were currently training as Judokas at a district level training institute were eligible to take part in the study. Players habitually trained six days per week, and none had a history of recent musculoskeletal injuries before participating in this study. None of the participants were taking dietary supplements or pharmaceutical drugs that could affect performance, and all were free from illness during the study. Verbal explanation of the experimental procedure was provided to everyone. The research design prioritized the safety, well-being and autonomy of all participants, adhering to standard ethical guidelines for research involving human participants. Individuals then provided written, informed consent prior to the study. The tests were conducted on two different days, on day one, all the strength based tests were conducted along with flexibility and the VO₂max test was conducted on the second day. All acquired data was classified as per the International Judo Federation (IJF) weight class criteria: Extra lightweight (-48kg); Half lightweight (-52kg) and Half Medium weight (-63, -70kg).

Procedures

Protocol: Testing Procedures

All the tests were held under standardized testing conditions. Between sessions, participants followed their usual routines but were instructed to avoid caffeinated beverages, intense exercise, and heavy physical activity for 48 hours leading up to and during the experiments. Compliance with the protocols for sleep, diet, and activity restrictions was confirmed verbally. Upon arrival, participants first underwent body composition assessments, followed by a standardized warm-up directed by their coach. After the warm-up, the players proceeded with the performance tests.

Measurement of Anthropometric Variables

Height (stature) and body mass

The height was measured by a SECA 213 Measuring Stadiometer. The distance from the standing platform, to the highest position of head (vertex) was measured with the help of a stadiometer, which indicates the subject's height. The stature was recorded in centimeters. The body mass was taken to the nearest 0.1 kg using a calibrated weighing scale (Essae DS-215, India). The subject stood at the center of the weighing machine looking straight with minimal clothing and the body mass was recorded in kilograms (Johnson BL, 1996).

Measurements of Physical Variables

Handgrip Strength Test

Hand grip strength was measured using the digital hand grip dynamometer (Baseline BIMS, USA). The subject held the dynamometer using palm and the handle rested on fingers, while being seated on a platform with feet not touching the ground. The arm was at the right angle with the elbow parallel to the ground. After taking the correct position, the athlete squeezed the dynamometer with maximum strength and maintained it for 5 seconds (Honorato et al., 2021). The best of three attempts is recorded for both hands, with adequate rest between the squeezes. The same sequence of hands was followed throughout.

Back Strength and Leg Strength Test

Back strength was measured using a digital back and leg dynamometer (Baseline, USA). To measure back strength using a back dynamometer, the participant stands on the platform of the dynamometer with their feet shoulder-width apart, ensuring even weight distribution. The handle of the dynamometer is adjusted to the appropriate height, generally at the level of the knees or just above. The participant then grasps the handle with both hands and maintains a natural posture with the knees slightly bent and the back straight. They are instructed to gradually pull upwards with maximum effort, keeping their arms extended and avoiding jerky movements. The force exerted is recorded in kilograms. Care is taken to ensure proper technique to avoid excessive strain on the lower back (Stojanovic et al., 2017).

For measuring the leg strength the participant is positioned with their feet placed flat on the platform of the digital back and leg dynamometer (Baseline, USA). Shoulder-width apart, ensuring stable footing for measurement. The dynamometer handle is adjusted to be at a height just above the knees. The participant then grips the handle firmly while maintaining a natural posture, with their knees slightly bent and back straight. They are instructed to push upwards with their legs, using maximum force while keeping the arms straight and avoiding sudden movements or jerks (Stojanovic et al., 2017).

Elastic Leg Strength Test

The subject's leg muscle strength was calculated by the standing broad jump (SBJ) test. To perform the standing broad jump, the participant stands with feet shoulder-width apart behind a marked line. With knees slightly bent, they swing their arms backward, then forward, while simultaneously jumping as far as possible horizontally. The distance is measured from the starting line to the nearest point of contact on the landing (usually the back of the heels). Ensure proper landing by bending the knees to absorb the impact. The best of three attempts is recorded, with adequate rest between jumps to prevent fatigue (Pramanick et al., 2022)

Flexibility Test

Modified Sit and Reach test was used to assess athlete's lower back flexibility. Modified sit and reach box (Baseline, USA) was used. The subject removed shoes and sat on the floor placing head and back against a wall. The subject while seated, stretched the legs ahead and kept the knees flat against the floor. The box was placed touching the subject's feet. The fingertips of both hands of the subject were placed on the ruler on the box after adjusting the zero mark on the ruler. Placing the hands, one on the top of other, the subject aim to lean forward slowly as far as possible maintaining fingertips at the same level and keeping the legs flat (Saraiva et al., 2014).

Measurements of Physiological Variables

Maximum oxygen consumption (VO₂max) Test and heart rates

The VO₂max was calculated by the YO YO IR (Intermittent Recovery) 1 test. This is the test in which the individual ran a specific distance of 20 metres. The traditional Yo-Yo test pattern consisted of a running track with a 20m run and a 5m recovery space. The athletes ran in a precise rhythm, and as the level of the test increased, so did their running speed. After the exhaustion, the specific lap and shuttle was noted, and from that specific lap and shuttle the VO₂max was calculated (Bangsbo et al., 2008). The Pre exercise heart rate was measured by heart rate monitor (Polar, Finland) (Nanchen D 2018).

Statistical Analysis

The statistical analysis was carried out using IBM SPSS Statistics 23. To present the results, descriptive statistics such as mean and standard deviation were used. The data's normality was verified using the Shapiro-Wilk normality test. Spearman's correlation was used to determine the relationships between demographic and physiological factors. Levene's test was used to assess the homogeneity of variance. For normally distributed variables, ANOVA One Way was used to compare parameters between the three weights groups, with Bonferonni's adjustment employed as a post-hoc test. The Kruskal-Wallis test was performed for variables that were not normally distributed. In all tests, a 95% confidence interval was used. Z-scores were generated for normalisations, and using Python 4.0 the Spider chart was created to visualize the physiological profile of each weight group.

Results

The average age of judokas in the three weight categories was 14.2 ± 2.0 years, with no noteworthy differences. The athletes in the three weight categories did, however, differ in their mean body height and body weight, with Half-Mediumweight judokas standing higher than their counterparts in the other two weight groups (Table 1). The body mass-height ratio as measured by BMI varied significantly between weight groups (Table 1). Pre-exercise HR did not differ significantly across groups (Table 1) and was not linked with any other parameter (Table 3).

When comparing Extra-Lightweight and Half-Mediumweight groups, significant differences were detected in both Left and Right Handgrip Strength; however, in Half-Lightweight and Half-Mediumweight judokas, only a significant difference was found in Left Handgrip Strength. Half-Mediumweight judokas exhibited significantly better absolute handgrip strength (right + left hand) than Half-Lightweight and Extra-Lightweight judokas, who had increasingly lower values (Table 1, Table 2). However, no such variations were identified when handgrip strength was examined in relation to body weight amongst the three categories (Table 1). Left and right handgrip strength were substantially linked with each other as well as the Standing Broad Jump (SBJ) (Table 3). Similar results were seen in Back and Leg Strengths, where both parameters showed significant variations across groups (Table 1). A post-hoc analysis indicated substantial differences between Extra-Lightweight and Half-Mediumweight, as well as Half-Lightweight and Half-Mediumweight (Table 2). Back and leg strength were found to be substantially related to height, weight, left handgrip strength, and right handgrip strength. Also, there was a correlation between back and leg strength (Table 3).

Table 1. Demographic and Physiological characteristics of female judokas

Variable	Mean (SD)			ANOVA or Kruskal Wallis test results	
	Weight Categories (kg)			F/H value	p
	Extra Lightweight 48 (N=11)	Half Lightweight 52-54 (N=10)	Half Mediumweight 60-68 (N=9)		
Age (yrs)	14.2 ± 2.0	15.3 ± 2.2	16 ± 2.3	1.765 ^a	0.19
Height (cm)	151.8 ± 6.6	159.9 ± 4.2	166.1 ± 7.6	13.076 ^a	0.001
Weight (cm)	47.3 ± 3.9	53.5 ± 2.9	67.4 ± 10.9	22.36 ^b	0.001
BMI (kg/m ²)	20.6 ± 1.9	20.9 ± 0.8	24.4 ± 3	10.096 ^a	0.001
Pre exercise HR (bpm)	66.1 ± 10.7	69.2 ± 5.7	65.6 ± 6.9	1.946 ^a	0.162
HGS Right (kgs)	26.4 ± 5.3	30.7 ± 4.7	37.5 ± 6.5	9.112 ^a	0.001
HGS Left (kgs)	25.5 ± 4.2	31.0 ± 4.5	36.3 ± 6.3	10.81 ^a	1
Absolute HGS (kgs)	51.94 ± 9.24	61.8 ± 9.08	71.29 ± 9.52	10.827 ^a	0.001
Relative HGS	0.56 ± 0.09	0.59 ± 0.08	0.56 ± 0.87	0.357 ^a	0.703
Back Strength(kgs)	66.7 ± 14.0	76.5 ± 5.5	86.5 ± 7.5	9.981 ^a	0.001
Leg Strength	72.7 ± 15.5	75.3 ± 7.9	100.8 ± 15.6	11.759 ^a	0.001
VO2 Max	42.6 ± 5.4	42.1 ± 5.6	47.6 ± 5.9	10.272 ^b	0.006
SBJ (m)	2.2 ± 0.3	1.9 ± 0.3	1.6 ± 0.3	6.394 ^a	0.005
Flexibility (cm)	36.3 ± 7.3	35.7 ± 7.5	44.4 ± 2.9	12.161 ^a	0.002

(a) - value of F statistic (ANOVA), (b) - value of H statistic (Kruskal-Wallis test); p - level of significance

Table 2. Post hoc test results (contains level of significance p values)

PARAMETERS	Weight Category	Extra Light	Half Light	Half Medium
Age	Extra Light		0.76	0.228
	Half Light	0.76		1
	Half Medium	0.228	1	

Height	Extra Light		0.19	0.001
	Half Light	0.19		0.121
	Half Medium	0.001	0.121	
Weight	Extra Light		0.104	0
	Half Light	0.104		0.27
	Half Medium	0	0.27	
Pre exercise HR	Extra Light		0.184	1
	Half Light	0.184		0.703
	Half Medium	1	0.703	
HGS Right	Extra Light		0.178	0.001
	Half Light	0.178		0.087
	Half Medium	0.001	0.087	
HGS Left	Extra Light		0.035	0
	Half Light	0.035		0.191
	Half Medium	0	0.191	
Absolute HGS	Extra Light		0.66	0
	Half Light	0.66		0.103
	Half Medium	0	0.103	
Leg Strength	Extra Light		1	0
	Half Light	1		0.001
	Half Medium	0	0.001	
VO2 Max	Extra Light		1	0.035
	Half Light	1		0.007
	Half Medium	0.035	0.007	
SBJ	Extra Light		0.503	0.004
	Half Light	0.503		0.124
	Half Medium	0.004	0.124	
Flexibility	Extra Light		1	0.007
	Half Light	1		0.01
	Half Medium	0.007	0.01	

Table 3. Spearman Correlation matrix between variables

Parameters	Height	Weight	Pre Exercise HR	HGS Right	HGS Left	Back Strength	Leg Strength	VO2max	SBJ
Height	—								
Weight	0.807***	—							
Pre Exercise HR	0.155	0.063	—						
HGS Right	0.549**	0.657***	0.191	—					
HGS Left	0.678***	0.645***	0.125	0.880***	—				

Back Strength	0.568**	0.634***	-0.039	0.742***	0.730***	—			
Leg Strength	0.600***	0.665***	-0.088	0.742***	0.689***	0.875***	—		
VO2max	0.113	0.164	-0.264	0.196	0.128	0.318	0.3	—	
SBJ	-0.365*	-0.344	-0.212	-0.396*	-0.389*	-0.283	-0.311	-0.462*	—
Flexibility	0.437*	0.416*	-0.162	0.117	0.174	0.206	0.276	0.493**	-0.364*

* $p < .05$, ** $p < .01$, *** $p < .001$

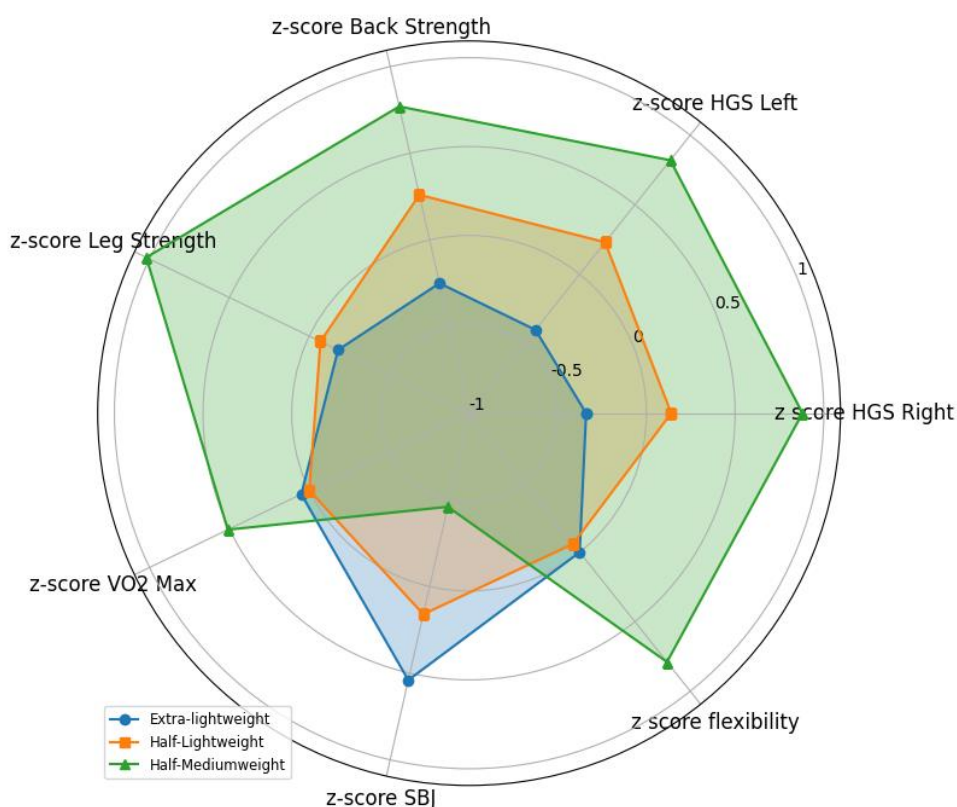


Figure 1. Spider Chart representing physiological characteristics of female judokas with respect to their weight categories.

Half-Mediumweight had the greatest VO2max, which differed significantly from Half-Lightweight and Extra-Lightweight who had similar aerobic capacity (Table 1, Table 2). Table 3 shows a substantial correlation between VO2max, SBJ, and Flexibility.

The Extra-Lightweight division had the best Standing Broad Jump and differed significantly from the Half-Mediumweight category (Tables 1 and 2). SBJ correlated significantly with height, handgrip strength, VO2max, and flexibility (Table 3). Group comparisons revealed a considerable difference in flexibility between Extra Lightweight & Half-Mediumweight as well as in Half Lightweight & Half-Mediumweight, with the Half-Mediumweight group being the most flexible (Table 1, Table 2). Flexibility was found to be strongly associated with height, weight, VO2max, and SBJ (Table 3).

Analysis using z-scores to visualize the physiological parameters (Figure 1) revealed that Half-Mediumweight judokas outperformed other groups in all strength metrics, VO2max and flexibility but exhibited significantly lower standing broad jump (SBJ) scores compared to both the Extra-Lightweight and Half-Lightweight groups.

Discussion

Although the physiological profiling of judokas has increased over time, less evidence is available in competitive Indian female judokas. Thus, the objective of the current study is to give an overview of the physiological profile based on their weight categories. The effectiveness of the throws in Judo depends on several key physical attributes, such as explosive strength of the lower body, back and core strength and flexibility. The results from this study highlight significant physiological differences between female judokas across weight categories, particularly when comparing extra-lightweight (-48 kg) and half-medium weight (>60 kg). Half-medium weight female judokas consistently demonstrated better performance in most physiological parameters compared to extra-lightweight judokas, except for the SBJ, where they clearly outperformed half-medium weight judokas. This is similar to the findings of Detanico et al. (2012) who demonstrated that the light-weight judokas presented greater performance in the jump tests than the heavyweights. This suggests that lighter-weighting judokas may have advantages in certain explosive movements, possibly due to better power-to-weight ratios, which can reflect in activities like the SBJ that require quick bursts of strength and coordination. Having good explosive power may help in techniques like *Osoto Gari* (major outer reap) and *Uchimata* (inner thigh throw), which rely largely on the ability to generate force rapidly by combining explosive strength and exact timing (Kons et al., 2018 and 2020).

In terms of the strength parameters, the findings indicated that middle-weight judokas demonstrated greater absolute strength in the handgrip strength (HGS) test. Similar results have been observed in previous studies on female judokas, where middle-weight athletes consistently exhibited superior isometric HGS (Stachoń et al., 2014 and Claessens et al., 1984). This strength advantage may be attributed to their greater muscle mass compared to lightweight judokas. Judokas in the medium to heavy weight categories may utilize their body weight as an advantage in executing techniques like *Kosoto gake*, *Kouchi gari*, and others (Franchini et al., 2011 and Chiu and Dorshimer, 2011). While grip strength is essential for controlling the opponent, techniques that involve hip engagement and body leverage allow judokas to use their body mass (Bonitch-Góngora et al., 2012). Moreover, it is important to note that judokas do not maintain maximal grip strength throughout a match. Instead, grip endurance, which plays a crucial role in maintaining control over longer periods, is equally significant (Franchini et al., 2011). On the mat, judo involves dynamic, compound movements, and pure isometric strength is rarely the determining factor during competition. Hence, the isometric HGS test merely reflects the athlete's ability to generate maximal gripping force, rather than their overall capacity to apply strength effectively during a bout. The highest relative hand grip strength has been exhibited by the half-medium weight judokas of this study, which aligns with previous publications (Francini et al., 2018). Research suggests that female judokas with lower body fat percentage tend to have higher relative handgrip strength values (Tavares Junior et al., 2023; Francini et al., 2014; Francini et al., 2018). As per the findings of other two strength tests, the half-medium weight judokas of the current study have shown superior strength in back and leg strength tests compared to half-lightweight and extra-lightweight judokas. One of the only few Indian studies examining strength and power in female judokas (Harris et al., 2020) found that medal-winning judokas had considerably superior lower-body maximum strength and peak anaerobic power in comparison to silver and bronze medalists, as well as non-medalists. However, their study did not involve the weight-category comparison.

In terms of flexibility, the half-middleweight judokas in this study appeared to be more flexible compared to the extra-lightweight and half-lightweight judokas when assessed with sit and reach test. The flexibility component of female judokas has received very little research, and existing studies have not compared flexibility performance across different weight categories. The flexibility scores of the cohort in the present study are higher than those reported by Sertić et al. (2006) and Mansilla et al. (1989), despite their participants being elite judokas from their respective countries. Meloni et al. (2006) reported that judokas they classified as light-weight exhibited greater flexibility compared to heavy-weight judokas. The extra light-weight judokas in the current study showed greater flexibility compared to the judokas in the study by Meloni et al. (2006) and (2007). Additionally, Torres-Luque (2015) and Ortega et al. (2011) reported that female combat sport athletes tend to be more flexible than their male counterparts, which may explain why the scores of the judokas in the present study are higher than those in previous studies that involved either male participants or mixed-gender cohorts. Other findings of this study involve significant differences that were observed between the weight categories: the half-mediumweight judokas showed superior aerobic capacity compared to the other two lighter categories. Previous studies have observed the role of body sizes and weight category on aerobic capacity in female judokas (Dimitrova et al., 2019). A study by Wolska-Paczoska, B. (2010) evaluated the VO₂ max scores among various weight classes in Bulgarian female judokas, revealing the following results: light-weight (41.9±4.2 ml/kg/min), middle-weight (39.6±3.2 ml/kg/min), and heavy-weight (36.1±1.9 ml/kg/min). These findings are contradictory to the findings of our study, such that the heaviest Judokas demonstrated higher aerobic capacity. This may stem from improved aerobic adaptation of the study population.

The correlation matrix reveals several important insights into the relationships between various physiological parameters of female judokas. We observed significant positive correlations ($p < 0.001$) between all strength-related parameters, including, the handgrip strength of both hands, back strength and leg strength. This suggests that judo

players are developing their strength holistically, with improvements in one strength domain likely to lead to improvements in others (Detanico et al., 2012; Barbado et al., 2016; Kons et al., 2019; Schoof et al., 2024). This finding supports the notion that judo training leads to holistic strength gains, as all these measures of strength are integral to judo performance, contributing to grappling, throwing, and resistance to opponents' moves. Interestingly, VO2 Max (an aerobic capacity metric) did not correlate with any of the strength indicators. In judo, aerobic fitness and muscular strength are considered relatively independent due to the specific demands of the sport. Aerobic capacity is crucial for recovery during the frequent high-intensity bursts in matches, while muscular strength, particularly in the upper body, is essential for executing powerful throws and maintaining grip control. Although both are essential for performance, they may be trained and improved separately to optimize both endurance and explosive strength. This has been highlighted in studies where aerobic performance and strength measures (e.g., 1RM in bench press and squat) show no significant correlation, suggesting that judokas develop these fitness attributes through distinct training methods (Monteiro et al., 2024). Judokas need endurance to last multiple fights, yet strength may always outweigh aerobic ability.

Surprisingly, in our study, standing broad jump (SBJ)—a common measure of explosive leg power, typically associated with strength—was negatively correlated ($p < 0.05$) with both hand grip strength (HGS) on the right and left, as well as VO2 Max. This suggests that Judokas with stronger grip strength or higher cardiovascular capacity may not necessarily excel in explosive, power-driven movements like the SBJ. It reinforces the idea that athletes in different weight classes may have distinct training priorities or biomechanical adaptations. This observation aligns with previous research, which highlights the emphasis on different physical attributes in judo, depending on the specific task (Callister et al., 2002; Franchini et al., 2018). While strong grips and aerobic endurance are vital for maintaining holds and enduring long matches, explosive power is a distinct skill that is trained separately and is crucial for executing fast, powerful movements like throws or jumps. This distinction stems from the different energy systems involved: explosive movements primarily use the ATP-CP system, while endurance relies on the aerobic system (Artoili et al., 2012; Julio et al., 2017). For example, grip strength is essential for controlling opponents in judo, but it does not directly contribute to success in power-based activities like the standing broad jump (SBJ), which require leg explosiveness developed through plyometrics and weightlifting. Similarly, a high VO2 max enhances endurance but is not a predictor of success in short, maximal-effort movement. Finally, we identified significant correlations ($p < 0.05$) between flexibility and other metrics such as height, weight, VO2 max, and standing broad jump (SBJ). This indicates that the half-medium weight judokas in this study have demonstrated enhanced performance in maximal aerobic capacity and explosiveness, which correlates with increased flexibility. Judo needs flexibility for intricate movements, and its correlation with other physical attributes underscores its significance in overall judo performance (Andreato et al., 2011; Franchini and Herrera-Velenzuela, 2021).

Conclusion

In conclusion, this study suggests that physiological adaptations in judo vary significantly across weight categories. Heavier female judokas tend to excel in strength, aerobic capacity, and flexibility, while lighter female judokas may perform better in explosive movements like the SBJ. These findings emphasize the complex interaction between strength, flexibility, and aerobic capacity in judokas. Strong correlations between strength measures indicate well-rounded strength development, while the lack of correlation between VO2 max and strength suggests independent development of these fitness components. Additionally, the negative correlation between SBJ and certain strength measures points to potential training adaptations based on weight class. Flexibility, strongly linked with various performance metrics, plays a key role in judo by enhancing mobility and power-based movements. Medium-weight judokas generally outperformed others in most physiological measures, benefiting from increased strength and endurance critical for heavier or higher weight categories.

Coaches can use these insights to create tailored training programs. Lighter judokas can potentially focus on explosiveness, while heavier athletes should emphasize on power and endurance. A limitation of the study is the absence of data from heavier weight categories (70kg, 78kg, >78kg), which may have affected the generalizability of the findings. While the tests were thorough, they did not include judo-specific assessments like the Special Judo Fitness Test (SJFT), limiting the study's ability to fully capture competition-specific demands. Future research should develop normative fitness data for each weight category to better guide training strategies.

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Full access to data on request.

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Conflicts of Interest

The Authors have no conflict of interest to declare

Informed Consent Statement

All the athletes included in the study provided written informed consent.

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