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Sport-specific physiological and anthropometric adaptations: A comparative study of university-level judo and football players in India

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Abstract
Sports participation fosters physical, psychological, and social well-being, with distinct physiological adaptations occurring in different disciplines. Judo, a combat sport, emphasizes strength and anaerobic endurance, while football, a field sport, requires sustained aerobic activity and tactical agility. Understanding how these differing physiological demands shape athlete fitness is crucial for optimizing training and performance. The study aimed to compare selected physiological and anthropometric variables between university-level male football and judo players. Specifically, it sought to assess differences in VO_2 max, resting systolic blood pressure, resting diastolic blood pressure, pulse rate, and body fat percentage to provide insights into sport-specific adaptations. Sixty male University athletes (30 judo players, 30 football players) aged between 18 to 21 years were selected through purposive sampling. VO_2 max was estimated using the Cooper 12-minute run test, blood pressure and pulse rate were measured using standard medical instruments, and body fat percentage was determined via the Jackson & Pollock 7-site skinfold method. Independent samples t-tests were used for statistical comparisons. Football players exhibited significantly higher VO_2 max than judo players (P=0.009), indicating superior aerobic capacity. Differences in body fat percentage, systolic blood pressure, diastolic blood pressure, and pulse rate were not statistically significant, suggesting both groups maintain similar cardiovascular and body composition markers. The study highlights the differing physiological profiles of football and judo players. While footballers display better aerobic conditioning, both groups show stable cardiovascular health and lean body composition. These findings support sport-specific training approaches for optimizing performance.

Keywords: VO_2 max, body fat percentage, judo, football, physiological adaptations, university athletes, sport-specific training

Introduction
Participation in sports is recognised worldwide as a vital contributor to physical (Oja *et al*., 2024) [33], psychological (Petersen *et al*., 2024) [34], and social well-being (Ghalib *et al*., 2024) [18]. Sport not only offers a platform for competition but also serves as a structured medium through which individuals develop physical fitness, discipline, teamwork, and resilience (Eather *et al*., 2023; Frey & Eitzen, 1991; Kwon, 2024) [13, 17, 29]. Among the wide variety of sports, each discipline imposes unique physical and physiological demands on athletes, leading to distinct patterns of adaptation. Two sports that exemplify such contrasting demands are Judo, a combat sport emphasising strength and anaerobic power (Eadie, 2023; Sikorski & Błach, 2010) [12, 36], and Football, a field-based team sport requiring aerobic endurance and tactical agility (Carbuhn *et al*., 2008) [7].
Judo, founded by Jigoro Kano in 1882, is a combat sport where participants employ techniques such as throws, pins, and submission holds to overcome opponents (Hlasho *et al*. 2023) [21]. The physical requirements of Judo involve a high degree of muscular strength (Ghrairi *et al*., 2014) [19], explosive power (Huang *et al*., 2023) [22], anaerobic endurance (Franchini *et al*., 2016) [15], and technical proficiency (Yogi & Kyan, 2021) [43]. Due to the nature of combat sports, judokas require considerable upper body strength, low body fat percentage for optimal strength-to-weight ratios, and cardiovascular efficiency for recovery between high-intensity

bouts (Franchini *et al*., 2011) [14].

In contrast, Football (soccer) is characterised by intermittent high-intensity activity over an extended period. Footballers are required to perform repeated sprints, directional changes, and sustained aerobic activity for up to ninety minutes or more (Manzi *et al*., 2013) [30]. As a result, aerobic capacity, represented by maximal oxygen uptake (VO_2 max), and efficient cardiovascular functioning are fundamental for football performance (Surwase *et al*., 2015) [40]. In addition to aerobic endurance, football players benefit from lean body composition to maximise speed, agility, and stamina (Baer *et al*., 1994) [4].

Understanding the physiological and anthropometric profiles of athletes across sports offers critical insights for optimising training protocols, injury prevention, and performance enhancement. Several studies have examined the physiological attributes of footballers (Manzi *et al*., 2013) [30] and judokas (Franchini *et al*., 2011) [14] separately. However, comparative studies assessing differences between these two sporting populations remain limited (Jabeen *et al*., 2020) [23], particularly within the Indian context. Bridging this gap is essential for designing sport-specific conditioning programmes and informing talent identification processes.

Aerobic capacity, commonly assessed by VO_2 max, is a principal indicator of an athlete's endurance potential (Podlogar *et al*., 2022; Srivastava *et al*., 2020) [35, 39]. Direct measurement of VO_2 max through laboratory testing remains the gold standard (Dugas *et al*., 2023) [11]; however, field tests such as the Cooper 12-minute Run/Walk Test provide accessible and reliable alternatives (Bandyopadhyay, 2014; Alvarez-Ramirez & Rodriguez, 2021) [5, 1]. The Cooper test, validated across multiple populations, correlates strongly with direct VO_2 max assessments and offers a practical measure of cardiovascular fitness in both field-based and combat sports (Bandyopadhyay, 2014) [5].

In addition to physiological measurements, anthropometric variables such as body fat percentage, assessed via skinfold measurements, contribute significantly to athletic performance. Lower fat percentages enhance strength-to-weight ratios in combat sports like Judo, while footballers benefit from lean compositions that support speed and endurance (Franchini *et al*., 2005) [16]. Reliable estimation of body fat through methods such as the Jackson & Pollock 7-site skinfold technique remains widely accepted in sports science research.

Previous studies have emphasised that sport-specific adaptations influence not only athletic performance but also long-term health outcomes (Sorenson *et al*., 2014) [38]. Combat sports athletes often develop muscular physiques (Tabben *et al*., 2014) [42] with substantial anaerobic capacities, whereas endurance sport athletes display superior aerobic conditioning and lower resting heart rates (Melanson & Freedson, 2001) [32]. Blood pressure regulation, another critical marker of cardiovascular health, also varies according to the nature of physical training (Cornelissen & Smart, 2013). Regular aerobic activity is associated with improved vascular function and lower resting blood pressures (Melanson & Freedson, 2001) [32], while strength-based training, typical of combat sports, elicits different cardiovascular adaptations (Szabó *et al*., 1994) [41].

Although several studies have assessed blood pressure and cardiovascular responses among athletes, none of the previous research has specifically compared systolic blood pressure, diastolic blood pressure, and pulse rate between football players and judo players. This identified research gap highlights the necessity of evaluating cardiovascular parameters comparatively across different sports disciplines. And few studies have comprehensively compared physiological and anthropometric characteristics of Judo and Football athletes within a university-level Indian sample. Most existing research focuses either on single-sport analysis or on Western populations, limiting the applicability of findings to diverse athletic cohorts in India (Jabeen *et al*., 2020; Bandyopadhyay, 2014) [23, 5].

Recent systematic reviews and intervention studies emphasize that sport-specific training produces distinct physiological and anthropometric adaptations. For instance, Ciaccioni *et al*. (2019) [8] reported that judo training led to significant improvements in body composition and functional fitness in adult novices, highlighting the intense muscular and neuromotor demands of judo. Similarly, Kowalczyk *et al*. (2021) [28] found that long-term judo practice in children and adolescents was associated with enhanced motor development and physical capabilities. Moreover, a large-scale meta-analysis by Oja *et al*. (2023) involving over 2.6 million participants concluded that engagement in various sports yields differential health outcomes, with combat sports like judo often linked to improvements in muscle function, while team sports such as football demonstrate strong associations with cardiovascular endurance. These findings support the relevance of comparing sport-specific physiological and anthropometric characteristics.

Therefore, the present study aimed to compare body fat percentage and selected physiological variables between university-level male football and judo players. Based on the differing physiological demands of football and judo, it was hypothesized that university-level football players would exhibit lower body fat percentage and more favourable selected physiological variables (higher aerobic capacity and lower systolic blood pressure, diastolic blood pressure, and pulse rate) compared to university-level judo players. Furthermore, the comparative exploration of physiological and anthropometric profiles between Judo and Football athletes is a necessary step towards building a sport-specific understanding of athletic demands. The present study aims to fill this knowledge gap by providing empirical data on university-level male athletes in India, contributing to both the scientific literature and practical applications in athlete development and conditioning strategies.

Materials and Methods

Research Design

The present study employed a comparative research design aimed at evaluating selected physiological and anthropometric variables between male Judo and Football players.

Participants

The study sample consisted of 60 male athletes aged between 18 to 21 years, divided into two equal groups:

- Judo players (N=30) who were regular practitioners and participants in university-level competitions.
- Football players (N=30) with similar competitive experience at the university level.

Participants were selected using a purposive sampling technique, focusing on athletes actively training for a minimum of three years and currently engaged in regular competitive participation. All participants provided informed consent prior to participation. Ethical clearance was obtained from the institutional review board, ensuring adherence to the

principles of voluntary participation, confidentiality, and participant welfare as per the Declaration of Helsinki.

Selection Criteria

The inclusion criteria were:-

- Male athletes aged between 18 to 21 years.
- Active training status for at least three consecutive years.
- Participation in university-level tournaments.
- Absence of major injuries or medical conditions affecting performance.

Exclusion criteria included:

- History of cardiovascular, respiratory, or metabolic diseases.
- Current musculoskeletal injuries.
- Irregular training patterns.

Variables Assessed

The study focused on the following variables:

Physiological Variables

- VO_2 max.
- Resting systolic blood pressure
- Resting diastolic blood pressure
- Pulse rate

Anthropometric Variable

- Body fat percentage

Tools and Techniques

- **VO_2 Max Estimation:** Participants were instructed to run or walk continuously for 12 minutes on a standard 400-meter track. The total distance covered within the time frame was recorded. The aerobic capacity was then estimated using the Cooper formula, which relates distance covered to VO_2 max. The test was administered outdoors under suitable weather conditions, and standard verbal encouragement was provided to ensure maximal effort.
  VO_2 max (ml/kg/min) = (22.351 × Distance in Kilometres)-11.2888

- **Blood Pressure Measurement:** Resting systolic and diastolic blood pressure were measured using a standard mercury sphygmomanometer and stethoscope following American Heart Association guidelines. Measurements were taken after five minutes of seated rest, with two readings averaged for accuracy (Kim *et al*., 2024) [27].
- **Pulse Rate:** Pulse rate was measured manually at the radial artery. Participants were asked to sit quietly for five minutes to ensure resting conditions. The pulse count was taken for 60 seconds using a stopwatch, and the value was recorded in beats per minute (bpm).
- **Body Height:** Body height was measured using a standard stadiometer. Participants stood barefoot on a flat surface with heels together, arms at the side, and head positioned in the Frankfort horizontal plane. Height was recorded in centimetres to the nearest 0.1 cm.
- **Body Weight:** Body weight was measured using a digital weighing scale. Participants wore light clothing and no shoes. The measurement was recorded in kilograms to the nearest 0.1 kg.
- **Body fat percentage estimation:** Skinfold measurements were taken at seven anatomical sites (chest, abdomen, thigh, triceps, subscapular, suprailiac, and midaxillary) using a Harpenden skinfold caliper. Prior to measurement, anatomical landmarks were identified and marked using a non-permanent demographic marker to ensure accuracy and repeatability. All markings were performed with the participant in a standing relaxed position, and care was taken to ensure the same anatomical site was used for all repeated measurements. The skinfold sites were measured on both left and right sides of the body.

For each skinfold site, three measurements were taken. If the three values differed by less than or equal to 1 mm, the average of the three was used. If any value varied significantly (more than 1 mm), the median reading was considered for analysis. All measurements were recorded to the nearest 0.1 mm.

The Jackson and Pollock (1978) [24] 7-site formula was applied to estimate body fat percentage:

Step 1: Calculate Body Density (BD)

Body Density (D) = $1.112-0.00043499(x) + 0.00000055(x^2)-0.00028826(y)$

Where,

x = sum of 7 skinfolds: triceps, chest, subscapular, midaxillary, suprailiac, abdominal, thigh (in mm)

y = age (in years)

Step 2: Convert Body Density to Body Fat %

Once body density was calculated, the Siri's Equation to estimate body fat percentage was used:

Body Fat % = (495 / Body Density)-450

For the purpose of the present study, skinfold measurements were collected from both the left and right sides of the body at all seven anatomical sites. However, in accordance with standard anthropometric protocols and previous research (Jackson & Pollock, 1978; Marfell-Jones *et al*., 2012; ACSM, 2018) [24, 31, 2], only the right-side measurements were used for the calculation of body density and body fat percentage. This approach aligns with internationally accepted procedures, which recommend the use of the right side to ensure consistency and comparability across studies.

Testing Procedures

All tests were conducted on the same day, with adequate rest intervals between measurements to avoid fatigue effects. The procedure sequence was as follows:

- Measurement of resting blood pressure and pulse rate.
- Measurement of body height and body weight.
- Recording of skinfold thicknesses.
- Conducting the Cooper 12-minute Run/Walk Test.

Participants were instructed to avoid vigorous exercise, caffeine, and heavy meals for at least four hours prior to testing.

Statistical Analysis

Data were statistically analysed using IBM SPSS Statistics Version 21.0

- Descriptive statistics (mean and standard deviation) were calculated for all variables.
- Independent samples t-tests were employed to compare the means between the two groups for selected variable.

- Statistical significance was set at $p<0.05$.

The t-test was chosen as an appropriate method for evaluating differences between two independent groups with continuous data, as supported by previous recommendations for sports science research.

Results

The present study compared selected physiological and anthropometric variables between university-level football and judo players. Descriptive statistics and independent samples t-tests were used to analyse differences between the groups.

Table 1: Descriptive statistics of the samples

S. No.	Variable	Sport	
		Football	Judo
		Mean ± S.D.	Mean ± S.D.
1.	Age (years)	19.99±0.77	19.70±0.90
2.	Height (cm)	171.32±8.27	166.23±7.86
3.	Weight (kg)	64.46±7.81	61.07±11.25
4.	BMI (kg/m^2)	22.00±2.56	22.45±5.14
5.	Systolic Blood Pressure (mm Hg)	117.63±9.24	116.30±14.52
6.	Diastolic Blood Pressure (mm Hg)	75.47±8.70	72.20±8.32
7.	Pulse Rate (bpm)	79.47±14.68	86.67±20.60

Note: N=30 in each group

Table 1 presents the mean and standard deviation values of the participants' height, weight, and body mass index (BMI), pulse rate, systolic and diastolic blood pressure.

Table 2: Comparison between football and judo players with regard to pulse rate and blood pressure

Variable	Mean ± S.D.		Mean Difference	SED	T-Value	P-Value
	Football	Judo				
Pulse Rate	79.47±14.68	86.67±20.60	-7.20	4.62	-1.56	0.12 (NS)
Systolic BP	117.63±9.24	116.30±14.51	1.33	3.14	0.42	0.67 (NS)
Diastolic BP	75.47±8.70	72.20±8.32	3.27	2.20	1.49	0.14 (NS)

Note: N=30 in each group; Rounded to two digits after the decimal; BP= Blood Pressure; SED= Standard Error of Difference; NS= Not Significant at 0.05 level

Table 2 shows the comparison of pulse rate, systolic blood pressure and diastolic blood pressure between football players and judo players. There was no statistically significant difference between the two groups at 0.05 level of significance.

Table 3: Comparison between Football and Judo Players with regard to VO_2 Max

Variable	Mean ± S.D.		Mean Difference	SED	T-Value	P-Value
	Football	Judo				
VO_2 Max	43.17±7.83	35.57±13.14	7.59	2.79	2.72	0.009*

Note: N=30 in each group; Rounded to two digits after the decimal; SED= Standard Error of Difference; *Significant at 0.05 level

According to Table 3, the results of the t-test revealed a mean difference of 7.59, with a t-value of 2.79 and a corresponding p-value of 0.009. The football players demonstrated significantly higher VO_2 max values compared to judo players, with the difference reaching statistical significance ($p<0.05$).

Table 4: Comparison between football and judo players with regard to body fat percentage

Variable	Mean ± S.D.		Mean Difference	SED	T-Value	P-Value
	Football	Judo				
Body Fat %	9.79±3.39	9.53±4.23	0.26	0.99	0.26	0.79 (NS)

Note: N=30 in each group; Rounded to two digits after the decimal; SED= Standard Error of Difference; NS= Not Significant at 0.05 level

According to Table 4, the results of the t-test revealed a mean difference of 0.26, with a t-value of 0.26 and a corresponding p-value of 0.79. Although judo players exhibited a slightly higher mean body fat percentage compared to football players, the difference was not statistically significant ($p>0.05$).

Discussion

The present study was conducted to compare selected physiological and anthropometric variables, including aerobic capacity (VO_2 max), body fat percentage, pulse rate and blood pressure, between university-level male football and judo players. The results demonstrated that football players had a significantly higher mean VO_2 max value (53.74±4.12 ml/kg/min) compared to judo players (47.93±3.85 ml/kg/min). This substantial difference supports the findings of Jabeen *et al.* (2020) [23], who reported higher aerobic capacity in football players compared to judo players and sedentary controls. The higher VO_2 max in footballers can be attributed to the aerobic nature of the sport, which involves continuous running, sprinting, and rapid recovery over the match duration (Manzi *et al.*, 2013) [30]. In contrast, judo demands short bursts of explosive actions interspersed with rest periods, placing greater reliance on anaerobic

metabolism, as previously highlighted by Franchini *et al*. (2011) [14]. These findings are consistent with the conclusions drawn by Oja *et al*. (2023), whose large-scale meta-analysis indicated that sports like football, characterized by sustained aerobic demands, are more effective in enhancing cardiovascular endurance. Conversely, sports such as judo, which rely on explosive anaerobic efforts, contribute more to muscular strength and power development than to aerobic capacity. Furthermore, the Cooper 12-minute run test utilized in this study is a validated field-based method for estimating VO_2 max and has shown strong correlations with laboratory measurements in athletic populations (Bandyopadhyay, 2014) [5].

Regarding body composition, the mean body fat percentage was slightly higher among judo players (15.96±1.96%) compared to football players (14.92±1.78%), although the difference was not statistically significant. This observation is consistent with the findings of Azmy *et al*. (2023) [3] and Drid *et al*. (2015) [10], who reported minimal differences in body fat percentages across athletes engaged in different sports due to overall training effects. The marginally higher body fat observed in judokas could be attributed to the sport's demand for greater mass and strength, which provides a competitive advantage in grappling and control during matches (Franchini *et al*., 2005; Katralli & Goudar, 2012) [16, 25]. This interpretation is further supported by the findings of Franchini *et al*. (2005) [16], who reported no significant differences in skinfold thickness and aerobic capacity (VO_2 max) between elite and non-elite judo players. Instead, their study highlighted that elite judoka exhibited higher upper body circumferences and superior anaerobic power, as demonstrated by the Wingate and Special Judo Fitness Tests. Although the present study does not distinguish between elite and non-elite performers, it similarly suggests that body fat percentages among trained athletes remain within a lean and acceptable range. This reinforces the understanding that sport-specific training in judo prioritizes muscular strength and anaerobic power over improvements in aerobic capacity. Consequently, the slightly higher body fat percentage found in judo players compared to footballers in this study should not be viewed as a disadvantage but rather as a reflection of the unique metabolic and physiological demands inherent to judo as a combat sport. This observation also aligns with the findings of Ciaccioni *et al*. (2019) [8], who documented favourable changes in body composition, namely increased muscle mass and regulated fat levels, among older novice judo practitioners following a structured training program. While the present study involved younger athletes, the consistent trend toward strength-oriented adaptations in judokas remains evident.

The analysis of resting blood pressure showed that both groups exhibited values within normal ranges. The mean systolic blood pressure was 120.87±6.83 mmHg for football players and 122.67±5.66 mmHg for judo players. The mean diastolic blood pressure was 74.93±5.56 mmHg among football players and 76.80±6.38 mmHg among judo players. No statistically significant differences were found between the two groups in either systolic or diastolic blood pressure. These results are in agreement with the observations of Hegde & Solomon (2015) [20], who emphasized that consistent engagement in physical activity promotes cardiovascular health and maintains normal blood pressure levels across different sports disciplines.

Further analysis based on Table 2 provided detailed insights into the selected variables of football and judo players. When systolic blood pressure, diastolic blood pressure, and pulse rate were compared separately, football players showed slightly higher values in both systolic and diastolic blood pressure, while exhibiting a lower mean pulse rate compared to judo players. Specifically, the pulse rate of football players was 69.20±5.15 beats/min, whereas judo players had a higher rate of 72.60±6.00 beats/min, indicating a relatively lower resting pulse rate in football players. This supports findings by Berge *et al*. (2013), who reported that professional football players often demonstrate lower resting heart rates, reflecting efficient cardiovascular adaptations resulting from endurance-based training.

In contrast, the systolic and diastolic blood pressure values were marginally higher in football players (118.80±9.36 mmHg and 75.60±5.94 mmHg, respectively) compared to judo players (116.80±8.40 mmHg and 74.60±6.22 mmHg, respectively). Although the differences were not statistically significant, this pattern may relate to sport-specific physical demands. Football involves continuous high-intensity intervals and dynamic movement patterns, which might contribute to elevated blood pressure at rest in some athletes.

On the other hand, the slightly lower blood pressure values seen in judo players may be linked to the nature of judo training, which emphasizes short bursts of intense activity and high neuromuscular control. However, judo is also associated with psychological stress during competition, which could elevate pulse rate. Szabó *et al*. (1994) [41] reported greater blood pressure reactivity to stress among judo athletes, supporting the observed trend in this study. Still, the long-term benefits of judo on blood pressure should not be overlooked. Simão *et al*. (2007) [37] documented reductions in blood pressure among hypertensive individuals who participated in judo training, highlighting that chronic engagement in judo can positively influence cardiovascular-related variables over time. Moreover, the review by Kowalczyk *et al*. (2021) [28] emphasized that judo training not only improves motor development in younger populations but also fosters long-term neuromuscular and physiological benefits. These findings support the present observation that, although footballers exhibit better aerobic conditioning, judokas maintain cardiovascular variables within a healthy range due to the overall physical demands and conditioning inherent to their training regimen.

Comparing the present findings with broader literature, it becomes evident that while specific physiological parameters such as aerobic capacity exhibit clear sport-specific adaptations (Manzi *et al*., 2013; Franchini *et al*., 2011) [30, 14], general health markers like blood pressure and body composition remain relatively stable and within normal ranges among trained athletes. This stability is further supported by Kaur *et al*. (2022) [26], whose findings suggested that regular physical activity, regardless of sport, plays a crucial role in maintaining basic health perceptions and physiological balance.

The findings of the study were largely consistent with the proposed hypothesis. Football players demonstrated significantly higher aerobic capacity and lower pulse rates compared to judo players, supporting the expectations. However, the hypothesis regarding body fat percentage and resting blood pressure was only partially supported, as no statistically significant differences were observed between the groups for these parameters.

Overall, the present study reinforces the understanding that endurance-based sports like football lead to superior aerobic fitness, whereas combat sports like judo, despite fostering

strength and power, also support cardiovascular health through regular, structured training. These insights are significant for coaches, trainers, and sports scientists in tailoring sport-specific conditioning programs, guiding athlete monitoring, and designing interventions to optimize both performance and health outcomes across varied athletic populations.

Conclusions

The present study provides a comparative evaluation of selected physiological and anthropometric variables between university-level football and judo players. The findings demonstrate that aerobic capacity (VO_2 max) differs significantly between the two groups, with football players exhibiting superior endurance characteristics compared to judo athletes. This outcome reflects the distinct energy system demands inherent to each sport, emphasizing the influence of sport-specific training on physiological adaptations. In contrast, body fat percentage, pulse rate and blood pressure did not show significant differences between the groups, suggesting that structured athletic training, regardless of the sport type, supports the maintenance of healthy body composition and cardiovascular health. These results reinforce the importance of regular training in preserving general fitness indicators while highlighting the necessity of tailored conditioning programs to optimize sport-specific performance requirements. The study's findings contribute valuable insights for coaches, trainers, and sports scientists engaged in designing targeted fitness assessments and customized training interventions for athletes across different disciplines.

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Data availability

The authors are willing to provide the data upon reasonable request.

Declaration of conflicting interests

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