Comparative analysis of physical and physiological performance in professional tennis, table tennis, and badminton athletes

Análisis comparativo del rendimiento físico y fisiológico en atletas profesionales de tenis, tenis de mesa y bádminton

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Abstract

Introduction: Racket sports such as tennis, table tennis, and badminton exhibit distinct physical and physiological demands shaped by differences in match intensity, duration, and technical characteristics.
Objective: This study aimed to compare the physical performance profiles and physiological responses of elite athletes from the three sports to identify sport-specific adaptations and performance determinants.
Methodology: Thirty provincial gold-medalist athletes (10 tennis, 10 table tennis, 10 badminton) underwent a comprehensive assessment comprising anthropometric measurements, core rotational strength, upper- and lower-body performance metrics, muscular endurance, agility-based footwork coordination, as well as physiological biomarkers including heart rate response, VO_2max, hemoglobin concentration, and fasting blood glucose.
Results: Significant differences were observed across sports. Tennis players demonstrated superior core rotational strength, upper-body power, lower back endurance, and aerobic capacity. Badminton athletes showed higher agility, abdominal endurance, footwork coordination, upper- and lower-body power, speed, flexibility, hemoglobin levels, and lower resting heart rate, aligned with the sport's high-intensity and rapid directional changes. In contrast, table tennis athletes exhibited comparatively lower physical and physiological outcomes, consistent with the sport's shorter rallies and restricted playing space.
Conclusions: These findings underscore distinct performance profiles across racket sports and highlight the necessity of tailored training interventions to optimize the physical and physiological capacities of elite athletes.

Keywords

Racquet sports; physical performance; physiological performance; athletic conditioning; game-specific demands.

Resumen

Introducción: Los deportes de raqueta como el tenis, el tenis de mesa y el bádminton presentan exigencias físicas y fisiológicas distintas, determinadas por las diferencias en la intensidad, la duración y las características técnicas de los partidos.
Objetivo: Este estudio tuvo como objetivo comparar los perfiles de rendimiento físico y las respuestas fisiológicas de atletas de élite de los tres deportes para identificar adaptaciones específicas de cada deporte y determinantes del rendimiento.
Metodología: Treinta atletas medallistas de oro provinciales (10 de tenis, 10 de tenis de mesa y 10 de bádminton) se sometieron a una evaluación integral que incluyó mediciones antropométricas, fuerza rotacional del tronco, métricas de rendimiento de la parte superior e inferior del cuerpo, resistencia muscular, coordinación de pies basada en la agilidad, así como biomarcadores fisiológicos como la respuesta de la frecuencia cardíaca, el VO_2máx, la concentración de hemoglobina y la glucosa en sangre en ayunas.
Resultados: Se observaron diferencias significativas entre los deportes. Los tenistas demostraron mayor fuerza rotacional del tronco, potencia de la parte superior del cuerpo, resistencia lumbar y capacidad aeróbica. Los jugadores de bádminton mostraron mayor agilidad, resistencia abdominal, coordinación de pies, potencia de la parte superior e inferior del cuerpo, velocidad, flexibilidad, niveles de hemoglobina y menor frecuencia cardíaca en reposo, en consonancia con la alta intensidad y los rápidos cambios de dirección propios de este deporte. En contraste, los jugadores de tenis de mesa exhibieron resultados físicos y fisiológicos comparativamente inferiores, acordes con los intercambios más cortos y el espacio de juego limitado de este deporte.
Conclusiones: Estos hallazgos subrayan los distintos perfiles de rendimiento en los deportes de raqueta y resaltan la necesidad de intervenciones de entrenamiento personalizadas para optimizar las capacidades físicas y fisiológicas de los atletas de élite.

Palabras clave

Deportes de raqueta; rendimiento físico; rendimiento fisiológico; acondicionamiento atlético; exigencias específicas del juego.

Introduction

Racket sports such as tennis, table tennis, and badminton are widely recognized as high-intensity intermittent activities that impose complex physical and physiological demands on athletes (Liu et al., 2024). Although these sports share the use of a racket and ball or shuttlecock, their performance requirements differ substantially due to variations in court size, rally duration, movement patterns, and technical–tactical characteristics (Cádiz Gallardo et al., 2023). These differences influence the relative contribution of aerobic and anaerobic energy systems, as well as cardiovascular, metabolic, and neuromuscular responses during competition (Pluim et al., 2023). Empirical evidence indicates that tennis predominantly relies on aerobic capacity and muscular endurance, badminton emphasizes explosive actions and rapid recovery, and table tennis prioritizes reaction speed and fine motor control under time pressure (Lambrich & Muehlbauer, 2022; Pradas et al., 2022; Cheng, 2025). Despite their apparent similarities, these sport-specific demands suggest that professional athletes engaged in different racket sports may develop distinct physical and physiological characteristics, raising important questions regarding how such demands translate into measurable performance-related attributes.

Previous research has extensively investigated performance determinants within individual racket sports; however, most studies have addressed these disciplines in isolation, limiting direct cross-sport comparisons. In tennis, investigations have primarily focused on associations between physical fitness components and stroke performance across competitive levels (Lambrich & Muehlbauer, 2022). Table tennis research has emphasized physiological responses, neuromuscular performance, and sex-related differences influencing match outcomes (Pradas et al., 2021; Shahidi & Bilal, 2024), whereas badminton studies have largely explored metabolic and mechanical demands arising from repeated high-intensity rallies (Ooi et al., 2009; Yaprak, 2020). Although these sport-specific approaches have generated valuable insights, the lack of integrated comparative analyses across racket sports restricts a comprehensive understanding of how differing physical demands correspond to physiological adaptations. Consequently, the current state of the literature does not yet provide a unified framework for comparing physical and physiological characteristics among professional athletes from different racket sport disciplines (Zeng, 2023).

In addition to physiological aspects, anthropometric characteristics play a relevant role in shaping performance potential in racket sports, reflecting biomechanical and functional adaptations to sport-specific demands. Previous studies have reported variations in body size, body mass distribution, and structural characteristics among tennis, badminton, and table tennis athletes (Yasin et al., 2010; Yadav, 2011; Pradas et al., 2021). However, anthropometric indicators are rarely examined alongside physiological variables within a single comparative framework involving multiple racket sports. Therefore, the present study aims to analyze and compare the physical and physiological characteristics of professional tennis, table tennis, and badminton athletes. By providing an integrated comparison across disciplines, this study seeks to offer novel empirical evidence that may support evidence-based training design, performance optimization, and athlete development strategies aligned with the specific demands of each racket sport (Cádiz Gallardo et al., 2023; Romero-Morales et al., 2024).

Method

Study Design and Participants

A cross-sectional comparative design was employed to assess the physical and physiological performance characteristics of athletes from three racket sports. The study recruited 30 professional athletes who had won gold medals at the 2025 East Java Provincial Sports Week (Porprov IX), consisting of 10 tennis, 10 table tennis, and 10 badminton players. All participants were female, aged 17–22 years, and had a minimum of five years of competitive experience. Written informed consent was obtained from each participant before inclusion in the study. All measurements were conducted over two consecutive days under standardized conditions to minimize fatigue and external variability.

Physical and Physiological Performance Assessments

A comprehensive set of physical and physiological parameters was measured to evaluate sport-specific performance characteristics. The complete list of assessments, units, and instruments used is presented in Table 1.

Table 1. Comparative Physical and Physiological Profiles of Tennis, Table Tennis, and Badminton Athletes

Assessments	Units	Instruments
Abdominal muscle endurance	reps	60 Second Sit Up Test
Lower back muscle endurance	s	Superman Back Hold 5 Kg test
Agility coordination-reactive-footwork	s	30 Second Square Jump Test
Core rotational strength	s	5 kg Russian Twist Test
Upper body strength	reps	Chin Up Test
Lower body power	cm	Vertical Jump Test
Upper body power	cm	Medicine Ball Throw 5Kg
Speed	s	20 m Sprint Test
Agility	s	Illinois Agility Test
VO_2max	mL/kg/min	Multistage Fitness Test
Flexibility	cm	Sit and Reach Test
Resting HR	bpm	Polar heart rate monitor h10
Hemoglobin	g/dL	Easy Touch GCHb
Fasting blood glucose	mg/dL	Accu-Chek® Performa

Data analysis

Data were analyzed using SPSS version 21.0 (SPSS Inc., Chicago, IL, USA). Descriptive statistics were reported as mean ± standard deviation. Between-group comparisons were performed using a one-way ANOVA followed by Tukey's post-hoc test. Statistical significance was set at $p < 0.05$.

Results

An analysis of the anthropometric characteristics and age of tennis, table tennis, and badminton athletes revealed no significant differences among the groups in body weight, height, body mass index, or age ($p > 0.05$) (Table 2). These findings indicate that the three groups had comparable baseline anthropometric characteristics, suggesting that subsequent differences observed in physical and physiological performance variables were not influenced by body size or general physical attributes, but rather reflected sport-specific functional demands.

Comparative analysis of physical and physiological performance variables demonstrated several significant between-group differences (Table 3; Figure 1). Badminton athletes showed superior performance in abdominal muscle endurance, upper- and lower-body power, speed, agility, flexibility, hemoglobin concentration, and lower resting heart rate. Tennis players exhibited significantly higher core rotational strength, upper-body power, and lower-back muscle endurance. In contrast, table tennis athletes demonstrated comparatively lower values across most physical and physiological performance measures, although several variables remained statistically comparable among groups. Overall, these findings indicate sport-specific differences in physical and physiological performance characteristics, rather than differences in anthropometric or body composition–based profiles.

Table 2. Physical and Age Profile of Tennis, Table Tennis, and Badminton Athletes

Characteristics	Tennis (n=10)	Table Tennis (n=10)	Badminton (n=10)	p-value
Weight (kg)	58.35 ± 3.13	57.20 ± 4.59	55.30 ± 4.97	0.295
Height (m)	1.65 ± 0.05	1.63 ± 0.06	1.59 ± 0.06	0.105
Body mass index (kg/m^2)	21.41 ± 0.71	21.49 ± 1.02	21.95 ± 0.86	0.347
Age (yrs)	18.10 ± 2.43	19.10 ± 1.79	18.50 ± 2.17	0.583

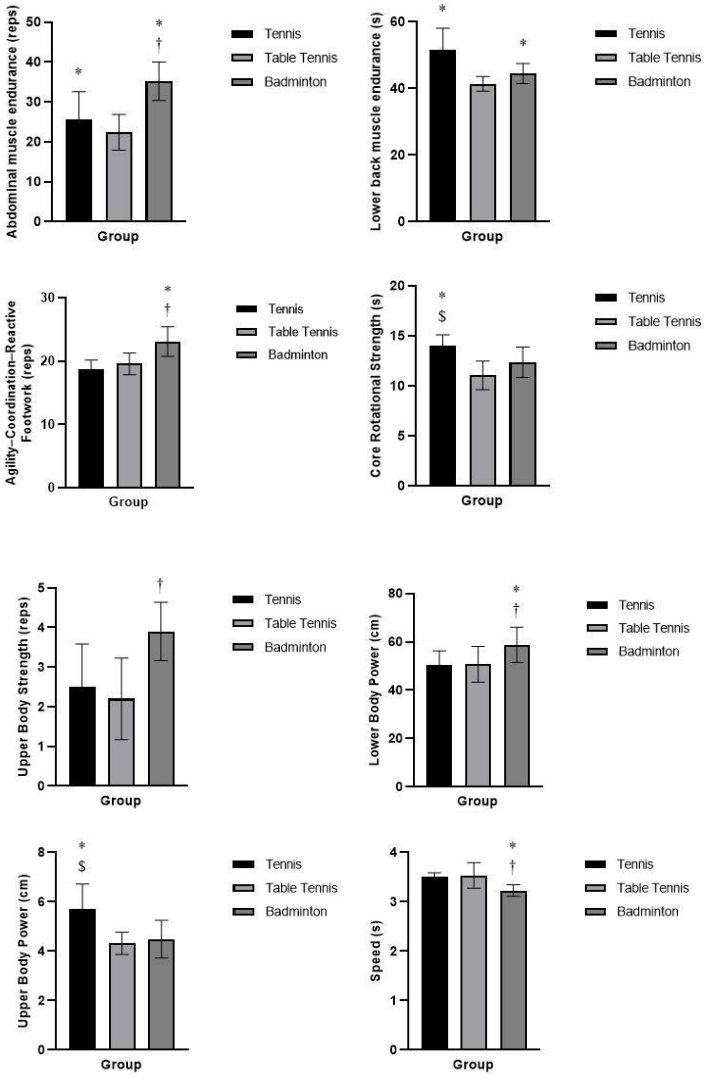
Note: The p-value was obtained using a one-way ANOVA test. Data are presented as mean ± SD.

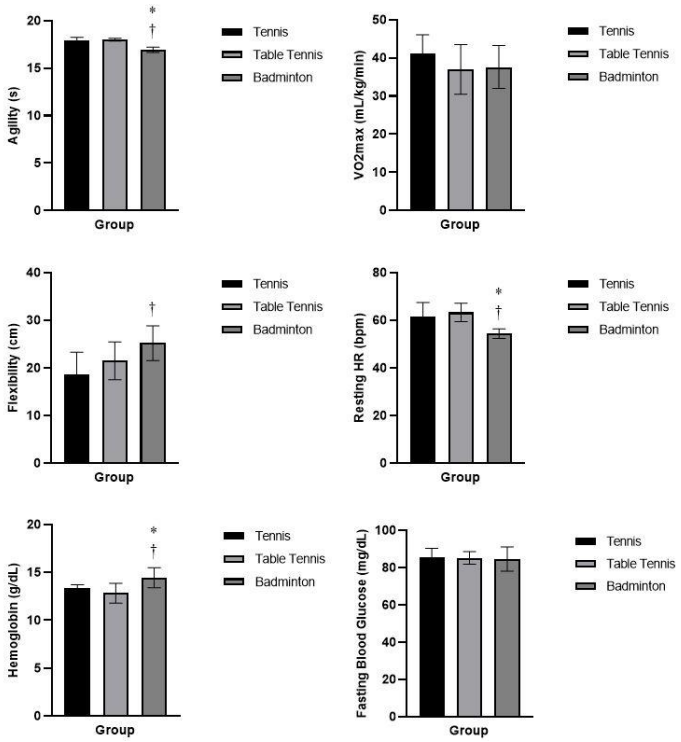
Table 3. Comparative Analysis of Physical and Physiological Performance of Professional Racquet Athletes

Parameters	Tennis (n=10)	Table Tennis (n=10)	Badminton (n=10)	p-value
Abdominal muscle endurance (reps)	25.50±7.06*	22.40±4.50	35.20±4.83*†	0.000
Lower back muscle endurance (s)	51.50±6.64*	41.40±2.17	44.50±3.03*	0.000
Agility coordination-reactive-footwork (s)	18.70±1.49	19.60±1.71	23.10±2.33*†	0.000
Core rotational strength (s)	13.97±1.12*$	11.06±1.43	12.37±1.52	0.000
Upper body strength (reps)	2.50±1.08	2.20±1.03	3.90±0.74*†	0.001
Lower body power (cm)	50.20±6.11	50.70±7.39	58.80±7.27*†	0.016
Upper body power (cm)	5.71±1.01*$	4.32±0.45	4.49±0.76	0.001
Speed (s)	3.51±0.08	3.53±0.26	3.23±0.12*†	0.001
Agility (s)	17.89±0.36	18.01±0.14	16.93±0.28*†	0.000
VO_2max (mL/kg/min)	41.16±4.89	36.99±6.53	37.62±5.65	0.233
Flexibility (cm)	18.73±4.58	21.50±3.95	25.20±3.65*†	0.006
Resting HR (bpm)	61.60±5.89	63.30±3.89	54.40±1.96*†	0.000
Hemoglobin (g/dL)	13.39±0.31	12.84±1.04	14.46±1.05*†	0.001
Fasting blood glucose (mg/dL)	85.50±4.93	85.30±3.37	84.70±6.49	0.936

Note: Note: (*) Significant at Table Tennis ($p < 0.05$). (†) Significant at Tennis ($p < 0.05$). ($) Significant at Badminton ($p < 0.05$). The p-value was obtained using the one-way ANOVA test followed by Tukey's HSD post-hoc test. Data are presented as mean ± standard deviation (SD).

Figure 1. Comparative Physical and Physiological Performance of Professional Racquet Athletes





Note: (*) Significant at Table Tennis ($p < 0.05$). (†) Significant at Tennis ($p < 0.05$). ($) Significant at Badminton ($p < 0.05$). The p-value was obtained using the one-way ANOVA test followed by Tukey's HSD post-hoc test. Data are presented as mean ± standard deviation (SD).

Discussion

The comparative analysis in the present study indicates that although tennis, table tennis, and badminton are all classified as intermittent high-intensity racket sports, the observed differences among these disciplines are variable-specific rather than reflective of comprehensive physical and physiological profiles. The results revealed no significant between-group differences in anthropometric characteristics, VO_2max, or fasting blood glucose, suggesting relatively comparable baseline physiological capacity across sports. Nevertheless, several performance-related variables differed in accordance with sport-specific technical demands and movement patterns. Tennis players demonstrated superior core rotational strength, upper-body power, and lower-back muscle endurance, which are closely associated with repetitive trunk rotation and force transmission during serves and groundstrokes (Ulbricht et al., 2016; Fett et al., 2018). Badminton athletes exhibited higher agility, speed, abdominal muscle endurance, upper- and lower-body power, flexibility, hemoglobin concentration, and lower resting heart rate, reflecting the sport's rapid directional changes, frequent jumping actions, and high-intensity rally structure with limited recovery periods (Ooi et al., 2009; Robertson et al., 2022), in line with findings by Cheng (2025) highlighting the impact of repeated high-intensity movements on acceleration and neuromuscular response. In contrast, table tennis athletes showed comparatively lower values across several physical and physiological variables, consistent with the sport's shorter rally durations, restricted playing area, and greater emphasis on reaction speed, coordination, and movement precision rather than sustained power output (Zagatto et al., 2010; Pradas de la Fuente et al., 2023; Xiong et al., 2022; Zhao et al., 2020). Taken together, these findings suggest that performance differences among racket sports are best interpreted as sport-specific adaptations expressed through selected performance variables, rather than as uniform distinctions in overall physiological capacity, supporting the energy system dominance framework in which the relative contribution of aerobic and anaerobic pathways varies according to the temporal and tactical structure of each sport without necessarily producing significant differences in global aerobic fitness (Pluim et al., 2023; Lambrich & Muehlbauer, 2022).

From an applied perspective, these findings reinforce the importance of sport-specific conditioning in designing training programs for high-performance athletes. In tennis, targeted development of endurance and lower-limb strength is essential to maintain optimal performance during long rallies (Lambrich & Muehlbauer, 2022; Pluim et al., 2023). For table tennis players, neuromuscular coordination, visual reaction speed, and upper-limb quickness represent priority training components due to the sport's explosive and precision-oriented nature (Pradas et al., 2021; Pradas de la Fuente et al., 2023). In badminton, improvements in anaerobic capacity, agility, and rapid recovery through high-intensity interval training have shown substantial benefits for enhancing competitive performance (Ooi et al., 2009; Robertson et al., 2021). These outcomes also have theoretical implications for the development of performance optimization frameworks that emphasize sport-specific physiological adaptation (Romero-Morales, 2024). Moreover, technological advancements such as wearable tracking and machine-learning–based analytics now allow for real-time monitoring of physiological variables, providing opportunities for more precise and individualized training program design (Zeng, 2023; Stepper, 2025). Accordingly, the present study contributes to contemporary approaches in evidence-based training and talent development pathways within professional racket sports.

Despite offering new insights into the physiological and physical profiles of racket sport athletes, this study acknowledges several limitations. First, methodological variations among reference studies—such as differences in VO_2max protocols, lactate sampling techniques, and agility test procedures—may influence cross-study comparisons and the interpretation of results (Brechbuhl et al., 2018; Cheng, 2025). Second, the cross-sectional nature of the present investigation limits its ability to capture long-term adaptations to sport-specific training. Future research should incorporate longitudinal designs and wearable physiological sensors to monitor fatigue, recovery, and performance dynamics in real time (Zeng, 2023). Artificial intelligence–based analytical approaches also show promise for predicting performance trajectories and injury risk through more accurate biometric modeling (Stepper, 2025). Despite these limitations, the study provides an important contribution to the understanding of differential physiological adaptations and physical demands across tennis, table tennis, and badminton. These findings have both academic and practical relevance for coaches, practitioners, and policymakers in designing targeted, efficient, and evidence-based training interventions (Romero-Morales, 2024; Gallardo et al., 2023).

Conclusions

This study demonstrates that each racket sport presents distinct physical and physiological performance profiles that reflect the specific demands of gameplay. Tennis athletes exhibited superior core rotational strength, upper-body power, lower-back muscular endurance, and aerobic capacity. Badminton players showed dominant fitness characteristics in agility, abdominal muscle endurance, coordination, and agility–footwork performance, limb strength and power, speed, flexibility, and more favorable physiological indicators, including higher hemoglobin levels and lower resting heart rate. Conversely, table tennis athletes displayed comparatively lower values across most performance components, consistent with the sport's short rally duration and confined playing area. Overall, these findings highlight the presence of sport-specific performance signatures and emphasize the need for tailored training programs that align with the unique physiological requirements of each discipline to optimize performance at the professional level.

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