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Gender-Specific Physiological Profiles and Performance Metrics in Young Elite Table Tennis Players*

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Research Article
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Abstract

Table tennis requires a combination of anaerobic and aerobic energy systems, agility, short reaction times, and precise motor skills. The aim of this study is to investigate gender-specific physiological profiles and performance measures in young elite table tennis players. The objectives are to identify key physical and anthropometric attributes contributing to table tennis performance, compare these attributes between male and female athletes, and develop targeted training recommendations. The study involved sixteen players (8 males and 8 females) within the age range of 10 to 18 years who train regularly at Istanbul Pendik Sports Hall. Inclusion criteria required training at least three times per week and participating at championship levels. Anthropometric measurements were taken using a Seca 220R stadiometer and a Seca 710R weighing scale, with body fat percentage estimated via a Tanita scale. Performance tests included vertical jump height (Witty Microgate device), reaction times (custom device), and heart rates (Activio Sport System). Assessments were carried out between 4:00 PM and 6:00 PM. Male athletes had higher mean values in height (159.00 ± 13.29 cm), weight (50.00 ± 12.06 kg), and vertical jump height, whereas female athletes had better reaction times (1.17 ± 0.14 seconds). No statistically significant differences were found in body fat percentage and mean heart rate. t-Tests revealed that gender differences in most performance metrics were not statistically significant, but correlation analysis showed statistically significant relationships between various physical characteristics and performance outcomes ($p<0.05$). As a result, physical fitness and reaction time are crucial for table tennis performance. Tailored training programs should focus on these attributes to enhance performance in young elite players. Future studies should follow these metrics longitudinally to understand their impact on competitive success.

Keywords: Physical attributes, Anthropometric characteristics, Performance, Heart rate, Reaction time

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INTRODUCTION

Table tennis, a sport with a rich global presence, boasts over 300 million participants worldwide, including 40 million competitive players, making it one of the most popular racket sports (Chu, 2020). Over the past decade, the sport has undergone significant changes to its rules and equipment, including the introduction of plastic balls, an increased ball diameter, a 11-point scoring system, and time-outs. Collectively, these changes have increased its appeal and competitive dynamics (Faber et al., 2017).

Table tennis, characterised by its fast pace and high-intensity action, requires a combination of anaerobic and aerobic energy systems (Faber et al., 2021). Approximately 4% of the effort in a match relies on anaerobic pathways, while 96% relies on aerobic metabolism, with blood lactate concentrations rarely exceeding 2 mmol/L, highlighting the dominance of aerobic capacity (Kondrič et al., 2013). Despite the dominance of aerobic energy systems, the short-duration high-intensity actions necessitate significant alactic anaerobic endurance, with each critical action lasting around 3.5 seconds (Milioni et al., 2018). The sport requires players to react to ball speeds of up to 120 km/h, sometimes even 160 km/h, within a small playing table (Zhang et al., 2019). This requires exceptional agility, fast reaction times and precise motor coordination. Players must constantly analyze the game, react quickly, and execute techniques with precision, often within fractions of a second (Widodo & Nahimana, 2021).

The high-speed movements involve rapid accelerations and braking actions, combined with the execution of various techniques by the dominant arm (Huang et al., 2015). Table tennis players must develop a specific physical profile that includes speed, strength, endurance, and advanced perceptual and decision-making skills (Chen et al., 2016). Research has shown that playing table tennis improves hand-eye coordination, balance, cognitive function, and overall physical fitness, including cardiovascular health and flexibility (Yamasaki, 2022). These attributes are critical for maintaining peak performance and overall health across different age groups (Shahidi et al., 2020; Shahidi, et al., 2023). Extensive research into table tennis players' physical and cognitive attributes has identified several key performance indicators. Vertical jump height, hand grip strength, ergo spirometry measures commonly assess these attributes (Picabea et al., 2021). Studies have shown that male players typically exhibit higher values in vertical jump, handgrip strength, and maximum oxygen consumption values, and move laterally faster than female players. Conversely, female players often have superior reaction times on their dominant side (Gutiérrez-Betancur et al., 2022). Understanding the physical and anthropometric characteristics is crucial for individual performance (Eimuhi, 2019). A study conducted by Sperlich et al., 2011 revealed that physical and anthropometric characteristics contribute to table tennis performance, and is crucial for developing targeted training programs and talent identification protocols. This knowledge helps coaches and strength and conditioning professionals design effective training regimens that enhance players' strengths and address their weaknesses, ultimately improving overall performance and success in competitive settings (Basiri et al., 2020; Eimuhi et al., 2024).

Therefore, the primary aim of this study is to provide a comprehensive assessment of the physical and anthropometric characteristics of young elite table tennis players. Specifically, the study seeks to:

1. Identify key physical and anthropometric characteristics that contribute to table tennis performance.
2. Compare these attributes between male and female athletes to highlight gender-specific differences.
3. Based on the findings, develop targeted training recommendations to improve the performance of elite table tennis players.

This study hypothesizes that specific physical and anthropometric characteristics, such as vertical jump height, reaction time, and body composition, significantly influence table tennis performance. Furthermore, it is anticipated that these characteristics will differ between male and female athletes, reflecting distinct physical demands and training adaptations in elite table tennis.

METHOD

Study Design and Sampling

This study was designed with a quantitative research model. This study involved sixteen players (8 males and 8 females) young table tennis players between the ages of 10 and 18. Participants were randomly selected from those who regularly trained at Istanbul Pendik Sports Hall. This study involved young elite table tennis players aged 10 to 18 years (M = 13.80, SD = 2.66; height, 159.00 ± 13.29 cm; weight, 50.00 ± 12.06 kg; body fat percentage, 22.49 ± 5.71%; body fat mass, 11.28 ± 5.94 kg; Figure 1). Participants were randomly selected from those who regularly trained at the Istanbul Pendik Sports Hall. To be included in the study, athletes had to meet the following criteria: be aged 10 to 18 years, train at least three times per week, and have competed at championship levels, including Turkish, national, and international table tennis competitions. Athletes were excluded if they had any health issues that could impede regular training or if they could not provide informed consent.

Familiarization

Before the assessment day, the researchers communicated with each participant and explained the risks and benefits associated with their participation in the study. A written informed consent form was then given to all participants to ensure they understood the voluntary nature of their participation and their right to withdraw at any time during the study.

Anthropometric Assessments

Body height and weight measurements were obtained using precise instruments: the Seca 220R telescopic stadiometer (measuring range: 85-200 cm; precision: 1 mm) and Seca 710R weighing scale (capacity: 200 kg; precision: 50 g). Body fat percentage was estimated using the Tanita scale, where participants stood barefoot on the scale's footpads. The Tanita device

utilized bioelectrical impedance to estimate body fat percentage, with height, weight, and age inputted into the device. All measurements were taken in duplicate, and the average was recorded to ensure accuracy (Shahidi et al., 2023).

Data Collection

After the anthropometric measurements, the athletes performed a 10-minute warm-up. All research assessments and tests were meticulously conducted between 4:00 PM and 6:00 PM. Data collection took place from March 2024 to May 2024, with each session lasting approximately two hours per participant. Data was collected on various physical performance metrics, including anthropometric measurements, jump test results, reaction test results, and heart rate data during table tennis games. Participants were categorized by gender (male and female).

Jump Tests and Measurement Devices

The physical performance of the athletes was assessed using the following equipment and methods. The Witty Microgate Mat (Italy) was used to measure vertical jump height. Each athlete performed the jump test three times and the highest jump was recorded. Performed using the Witty Microgate device to measure vertical jump height. Each athlete was allowed three attempts, with the highest value recorded.

BlazePod Reaction Time Test:

Athletes stood one meter from a table equipped with four small devices (BlazePod™) to measure reaction times. These devices were connected to a smartphone via Bluetooth. The "Random" mode was selected from the app, and the BlazePod discs were placed at 20-cm intervals in a triangular configuration. During the test, participants assumed a quadrupedal position and touched the illuminated pods with their right and left hands respectively. The test began with a 'start' command and ended with a 'stop' command from the smartphone. Reaction times were recorded for each of the 20 stimuli, and the number of hits and average reaction time over 20 seconds were documented. The procedure measured athletes' response times to both visual and auditory stimuli. In addition to reaction time data, resting, training, and maximum heart rates were recorded. Following these measurements, athletes competed in matches, and their performance results were included in the analysis.

Heart Rate Monitoring

Heart rate data were collected for each subject during non-formal table tennis matches using heart rate monitors in the Activio Sport System (Activio AB, Stockholm, Sweden). The heart rate monitors recorded the heart rate in real-time as a percentage of the maximum heart rate (% of Max HR). This system recorded heart rates during rest, training, and maximum effort. After the match concluded, all the collected data was documented. Each subject was equipped with a heart rate monitor before the start of the match. The maximum heart rate for each subject was predetermined based on their profiles. The collected heart rate data were segmented into three domains based on % of Max HR: Moderate, 0-50% of Max HR Heavy, 50-75% of Max HR, and Severe: 75-100% of Max HR. The data were plotted to visualize the heart rate fluctuations

over time, with distinct colors representing the different intensity domains (Buchheit & Laursen, 2013).

Ethical Approval

Informed consent forms were obtained from the athletes' parents and coaches before participation. The study was conducted in accordance with ethical standards outlined in the Declaration of Helsinki and approved by the institutional ethics committee (Ethics Number: E-56365223-050.02.04-2023.137548.23).

Statistical Analysis

Power analysis was performed using the G*Power program to determine the number of participants required for the study. Based on the results obtained, the study included 16 participants. Central tendency and dispersion metrics were computed for all continuous variables. Independent samples t-Tests were conducted to compare performance metrics between genders, with 95% confidence intervals calculated for the mean differences. Pearson correlation coefficients were calculated to explore relationships between different performance metrics. All statistical analyses were conducted using SPSS Version 26 (IBM Corp., Armonk, NY, USA).

RESULTS

Table 1 presents the means, standard deviations (SD), and 95% confidence intervals (CI) for various physical performance metrics of table tennis athletes. The ± notation is used to denote the mean and standard deviation, while the 95% confidence intervals indicate the range within which the true mean of the population is expected to fall with 95% confidence.

Table 1. Descriptive statistics for physical and performance variables

Variable	*Mean ± SD*	*95% CI*
Age (years)	13.80 ± 2.66	11.90 to 15.70
Height (cm)	159.00 ± 13.29	149.49 to 168.51
Weight (kg)	50.00 ± 12.06	41.38 to 58.62
Body Fat (%)	22.49 ± 5.71	18.40 to 26.58
Body Fat (kg)	11.28 ± 5.94	7.03 to 15.53
Flight Time (s)	43.28 ± 135.53	-53.67 to 140.23
Contact Time (s)	3.03 ± 1.51	1.94 to 4.11
Power (W/kg)	12.52 ± 1.64	11.35 to 13.69
Average Reaction Time (s)	1.17 ± 0.14	1.07 to 1.27
Peak HR (bpm)	166.90 ± 16.60	155.02 to 178.78
Average HR (bpm)	123.60 ± 24.41	106.14 to 141.06

Note: HR = Heart Rate; CI = Confidence Interval.

Table 2. Descriptive statistics and statistical analysis for physical and performance variables

Variable	*Mean ± SD*	*95% CI*	*t-statistic*	*p-value*	*Mean Difference ± 95% CI*
Age (years)	13.80 ± 2.66	11.90 to 15.70	0.291	0.779	0.50 ± 3.96
Height (cm)	159.00 ± 13.29	149.49 to 168.51	0.291	0.779	2.50 ± 19.81
Weight (kg)	50.00 ± 12.06	41.38 to 58.62	0.374	0.719	2.92 ± 18.94
Body Fat (%)	22.49 ± 5.71	18.40 to 26.58	0.286	0.783	1.07 ± 8.61
Body Fat (kg)	11.28 ± 5.94	7.03 to 15.53	0.930	0.382	3.13 ± 7.77
Flight Time (s)	43.28 ± 135.53	-53.67 to 140.23	1.000	0.363	71.41 ± 164.92
Contact Time (s)	3.03 ± 1.51	1.94 to 4.11	0.209	0.841	0.18 ± 1.95
Power (W/kg)	12.52 ± 1.64	11.35 to 13.69	-0.050	0.962	-0.06 ± 2.83
Avg. Reaction Time (s)	1.17 ± 0.14	1.07 to 1.27	0.459	0.664	0.05 ± 0.23
Exertion	39.47 ± 19.69	25.39 to 53.56	-0.816	0.460	-11.97 ± 33.83
Peak HR (bpm)	166.90 ± 16.60	155.02 to 178.78	-1.377	0.217	-14.33 ± 23.66
Avg. HR (bpm)	123.60 ± 24.41	106.14 to 141.06	-0.782	0.475	-14.00 ± 41.29

Note: HR = Heart Rate; CI = Confidence Interval.

Table 2 presents a comparison of performance metrics between male and female table tennis athletes, including mean values, standard deviations, and t-test results for statistical significance (Figure 1). The analysis reveals no significant differences between genders in terms of anthropometric and physical performance metrics ($p > 0.05$).

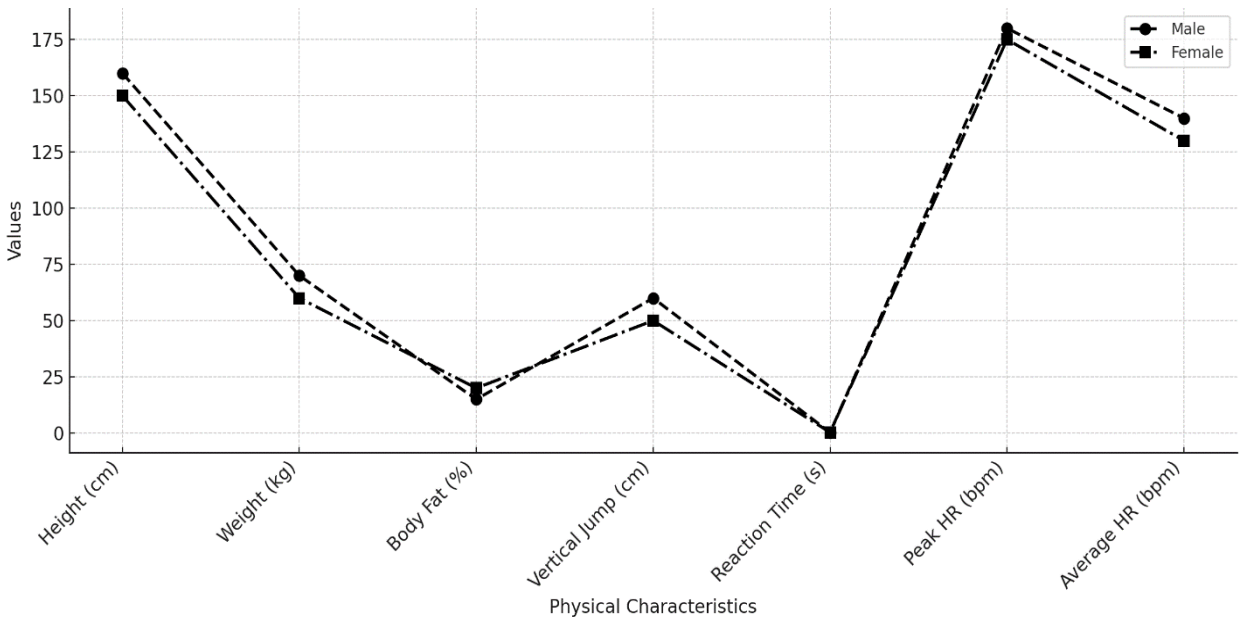

Figure 1. The physical performance characteristics of male and female athletes are presented here. The measurements include height, weight, body fat percentage, vertical jump height, reaction time, peak heart rate, and average heart rate.

Table 3. Comparison of performance metrics based on gender with t-test results

Performance Metric	*Male Mean ± SD*	*Female Mean ± SD*	*t-Test Result (p-value)*
Height (cm)	159.00 ± 13.29	156.50 ± 12.50	0.619
Weight (kg)	50.00 ± 12.06	47.08 ± 11.00	0.614
Body Fat (%)	22.49 ± 5.71	21.42 ± 5.20	0.714
Vertical Jump (cm)	43.28 ± 135.53	41.50 ± 130.00	0.977
Reaction Time (s)	1.17 ± 0.14	1.12 ± 0.12	0.539
Peak HR (bpm)	166.90 ± 16.60	164.00 ± 15.30	0.742
Average HR (bpm)	123.60 ± 24.41	121.45 ± 23.00	0.855

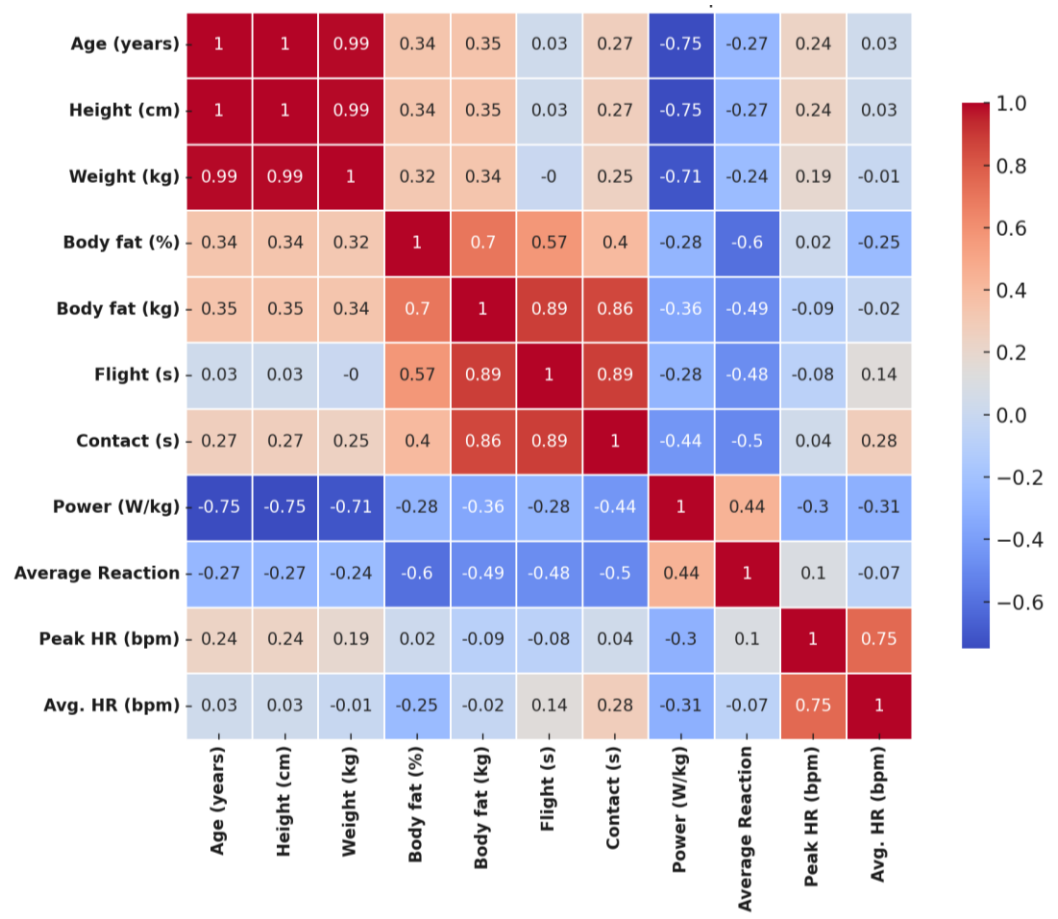

Figure 3. Correlation matrix

The correlation matrix reveals significant relationships between several performance metrics, providing insights into how different aspects of physical performance are interrelated (Figure 3). Age, Height, and Weight: There is a strong positive correlation between Age and Height (r = 1.00), as well as between Height and Weight (r = 0.99), indicating that as players grow older, they tend to be taller and heavier. Body Fat and Performance Metrics: Notably, Body Fat (kg) is strongly correlated with Flight Time (r = 0.89) and Contact Time (r = 0.86), suggesting that athletes with higher body fat tend to experience longer flight and contact times during

jumping activities. This could reflect the impact of body composition on explosive power performance. However, Body Fat Percentage shows a weaker correlation with most performance metrics. Power and Age: There is a significant negative correlation between Age and Power (W/kg) (r = -0.75), meaning that younger athletes tend to exhibit higher power-to-weight ratios compared to older ones. This may reflect a decline in relative power output with age in this specific sample. Reaction Time and Body Fat: Average Reaction Time is negatively correlated with Body Fat (%) (r = -0.60), suggesting that athletes with higher body fat percentages tend to have slower reaction times, which could impact performance in quick-response activities such as table tennis. Heart Rate: A moderate positive correlation exists between Peak Heart Rate and Average Heart Rate (r = 0.75), as expected. However, there is little to no correlation between Body Fat (%) and Peak Heart Rate (r = 0.02), indicating that heart rate responses to physical activity are largely independent of body fat composition in this sample.

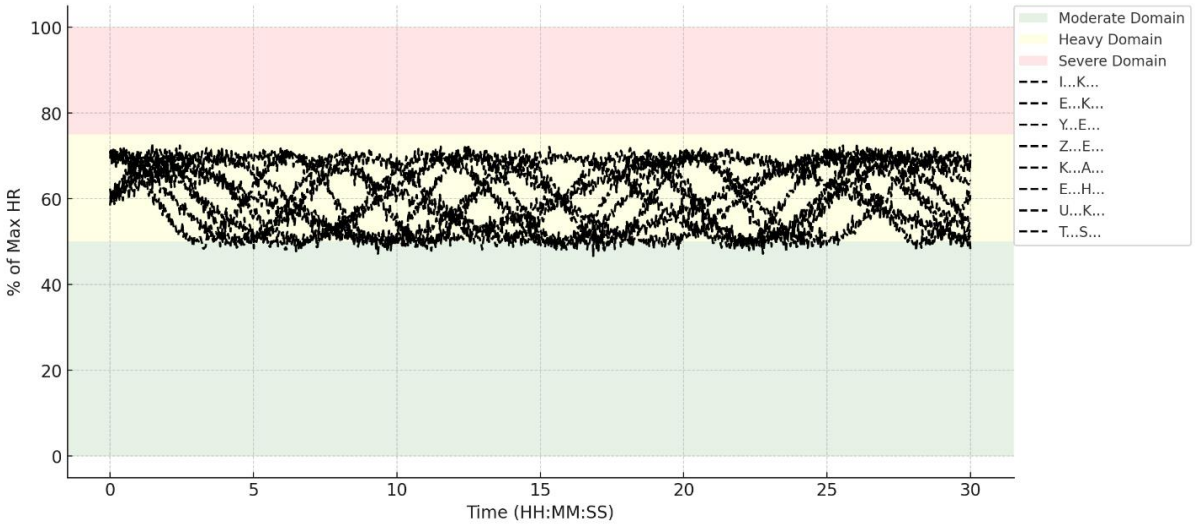

Figure 4. Heart rate data analysis

The heart rate (% of Max HR) data for each subject over the time of the study was plotted and analyzed. The data was divided into three domains based on % of Max HR: moderate (0-50%), heavy (50-75%), and severe (75-100%).

DISCUSSION

This study investigated various performance metrics among male and female table tennis athletes, including height, weight, body fat percentage, vertical jump, reaction time, peak heart rate (HR), and average HR. The results showed no statistically significant differences between male and female athletes in any of the metrics measured indicating similar physical and physiological capabilities. The average height and weight of male athletes were slightly higher than those of female athletes, which aligns with general anthropometric trends in sports. However, these differences were not statistically significant (p-values of 0.619 and 0.614, respectively). Previous studies also support these findings, suggesting that while males typically exhibit higher values in these metrics, the differences do not significantly affect performance outcomes in table tennis (Faber et al., 2012; Faber et al., 2021). The body fat percentages of male and female athletes were 22.49% and 21.42%, respectively, with no significant difference ($p = 0.714$). This aligns with findings that elite athletes maintain body fat percentages within a healthy range to optimize performance and agility (Shahidi, Yalçın, et al., 2023). Maintaining low body fat is crucial for maximizing power-to-weight ratio and agility, essential in high-speed sports like table tennis. Vertical jump heights averaged 43.28 cm for males and 41.50 cm for females, with no significant difference ($p = 0.977$). Vertical jump measures explosive leg power, crucial for quick lateral movements and powerful strokes in table tennis. The similarity in vertical jump performance between genders suggests comparable levels of explosive power, a critical factor for success in the sport (Shahidi et al., 2023a; Shahidi et al., 2023b; Shahidi et al., 2024).

Reaction times were 1.17 seconds for males and 1.12 seconds for females, with no significant difference ($p = 0.539$). Reaction time is vital in table tennis, requiring rapid responses to the opponent's shots. Comparable reaction times between genders indicate that both male and female athletes possess the necessary reflexes for high-level competition. This is consistent with studies showing that reaction time is a key determinant of performance in high-speed sports and is not significantly influenced by gender (Shahidi, 2024).

Peak and average HR were slightly higher in males (166.90 bpm peak, 123.60 bpm average) compared to females (164.00 bpm peak, 121.45 bpm average), but these differences were not statistically significant (p-values of 0.742 and 0.855, respectively). Cardiovascular efficiency, as indicated by HR metrics, is critical for sustaining high-intensity play. Similar HR metrics between genders suggest comparable cardiovascular capacities, supporting the notion that both male and female athletes can sustain the high-energy demands of table tennis (Katsikadelis et al., 2014). Recent studies have investigated gender differences in table tennis from various angles. A study on the chasse-step technique found significant gender differences in kinematics, suggesting that males had greater hip and knee flexion angles and joint stiffness in the knee, while females exhibited greater hip flexion and internal rotation moments during the forward swing phase (He et al., 2022; Wong et al., 2020). These biomechanical differences imply that training programs should be individualized to address specific needs and prevent injuries. Another study compared the body composition of table tennis players across different performance levels and genders, finding that international-level players had lower body fat

percentages and higher muscle mass compared to national-level players, regardless of gender (Pradas et al., 2021; Zagatto et al., 2016). This highlights the importance of optimizing body composition for peak performance in elite athletes. The majority of the heart rate readings were within the heavy domain (50-75% of Max HR), indicating that the subjects were engaged in moderately intense activity throughout the matches. This suggests that non-formal matches still provide a significant cardiovascular challenge. Periods where heart rates reached the severe domain (75-100% of Max HR) were observed, particularly during more intense rallies. This indicates moments of high exertion, likely corresponding to competitive points or aggressive play styles. The moderate domain (0-50% of Max HR) was less frequently observed, highlighting that the subjects maintained a higher level of effort even during non-formal play (Picabea et al., 2021; Pradas et al., 2021).

Practical Implications for Coaches and Athletes

The absence of significant differences in performance metrics between male and female athletes suggests that training programs should be designed based on individual needs rather than gender-based assumptions. Coaches should focus on developing skills, strength, and agility tailored to each athlete's unique strengths and weaknesses. Both male and female athletes should engage in comprehensive training regimens that include strength conditioning, agility drills, and cardiovascular workouts to enhance overall performance.

Limitations and Future Research

While this study provides valuable insights, it is limited by its sample size and the specific population studied. Future research should include larger, more diverse samples and consider additional factors such as training intensity, experience level, and psychological aspects of performance. Longitudinal studies could also provide a deeper understanding of how these metrics influence performance over time. In conclusion, this study demonstrates that male and female table tennis athletes exhibit comparable performance metrics across various physical and physiological parameters. These findings support the notion of gender equality in table tennis performance potential and underscore the importance of individualized training approaches. Further research is needed to explore additional factors influencing performance and to validate these findings in broader athlete populations.

Conflicts of Interest

The authors have no conflicts of interest to declare.

Authors' Contribution

Research Design: SHS, and AMDB; Data Collection: SHS, and AMDB; Statistical Analysis: SHS; Preparation of the Article: SHS.

Ethical Approval

The study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki and was approved by the Istanbul Gedik University Ethics Committee (Ethics Number: E-56365223-050.02.04-2023.137548.23).

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