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Gender Differences in Serve Performance of Professional Tennis Players in the Four Grand Slam Tournaments

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Abstract

The purpose of this study is to analyze gender differences in professional tennis players' serve technical and tactical performance and to explore serve characteristics across court surfaces. It used data from 255 Grand Slam final matches (2019-2023) involving 123 players (57 male, 66 female), employing cluster analysis and one-way ANOVA. **Conclusions**: In service point winning percentage, men outperformed women in overall, first-serve, and deuce/advantage court wide/inside placement percentages; second-serve advantage was limited to men at the AO, with men leading in body serve percentage only at the RG and US Open. Men dominated in total and first-serve aces (no second-serve difference), with variations by court (e.g., deuce court aces except WD, advantage court consistently male-led). In serve placements, men led in specific wide positions, women in most body placements, and men in inside placements (notably RG/US Open). These gender-specific traits support strategy, training, and match decisions, with future research needed on tactical applications.

Keywords: Serve Performance, Technical And Tactical Analysis, Gender Differences, The Four Grand Slams

Introduction

Tennis originated in Europe and, through continuous development, has become one of the world's most popular ball sports. At the elite level, the four Grand Slam tournaments—Australian Open, Roland-Garros, Wimbledon, and US Open—are staged annually on three distinct court surfaces: hard, clay, and grass. These events represent not only the highest competitive standard in professional tennis but also provide a unique context for examining how court characteristics shape technical and tactical performance.

Among all performance indicators in tennis, the serve plays a decisive role in determining match outcomes. Its importance has been extensively explored by numerous scholars, including G. Peter O'Donoghue and Emily Brown (2008), with subsequent research expanding across multiple dimensions. From a biomechanical perspective, studies by Javier Maquirriain et al. (2016), Frantisek Vaverka et al. (2018), Edelmann-Nusser et al. (2019), and Kashiwagi et al. (2021) revealed a dynamic balance mechanism between serve speed and accuracy. Building on this foundation, researchers began to examine how contextual factors influence serve performance.

One important contextual factor is court surface. Comparative investigations by Stephanie Kovalchik and Machar Reid (2018), Frantisek Vaverka et al. (2018), Melonio et al. (2021), and Ruslan et al. (2024) systematically analyzed how different court characteristics affect serve speed and strategic choices. These findings suggest that surface-specific physical properties significantly shape serving patterns. In addition, individual characteristics have also been shown to influence serving performance. For example, Ruslan et al. (2024) verified the relationship between serve performance and players' age and height through tracking-based analyses.

Beyond surface and anthropometric factors, gender differences constitute another major research direction. Hazuan Hizan et al. (2015) conducted comprehensive analyses of gender-related serving characteristics, while David Whiteside and Machar Reid (2017) focused on single-gender investigations. Torres-Luque et al. (2019) further compared male and female players, highlighting distinct technical and tactical patterns. Additional research has examined serving and return performance among adolescents (Hizan et al., 2011) and compared adolescents with professional players (Kovalchik & Reid, 2017). Tactical contexts such as tiebreak situations (Meffert et al., 2019), positional correlations between serve and forehand strokes (Caprioli et al., 2025), serve and return typologies (Kovalchik & Reid, 2018), and the interaction between serving and baseline rallies (Fitzpatrick et al., 2019) have also been systematically investigated. Moreover, Abidin and Ruslan (2020) explored the relationship between physical characteristics and serve/return performance, and Rouli Ye et al. (2023) proposed the Serve Performance Relevance (SPR) model to evaluate serving effectiveness.

Taken together, existing studies have comprehensively demonstrated the critical role of serving in Grand Slam tournaments from the perspectives of technical optimization, court adaptation, individual differences, and tactical application. However, despite this rich body of literature, an important limitation remains. Many comparative analyses of serve technical and tactical performance have focused on a single court surface (Torres-Luque & Fernández-García, 2019; Hizan, Whipp, & Reid, 2015), which restricts a holistic understanding of how gender differences interact with varying surface characteristics at the highest competitive level.

In light of this gap, the present study conducts a comprehensive cross-surface analysis of serve techniques and tactics among male and female professional tennis players across the four Grand Slam tournaments. By systematically comparing serving performance under different court conditions, this study aims to clarify gender-specific technical and tactical patterns and to provide data-driven support for athletes and coaches to optimize training strategies according to surface characteristics.

Method

Subjects/Sample

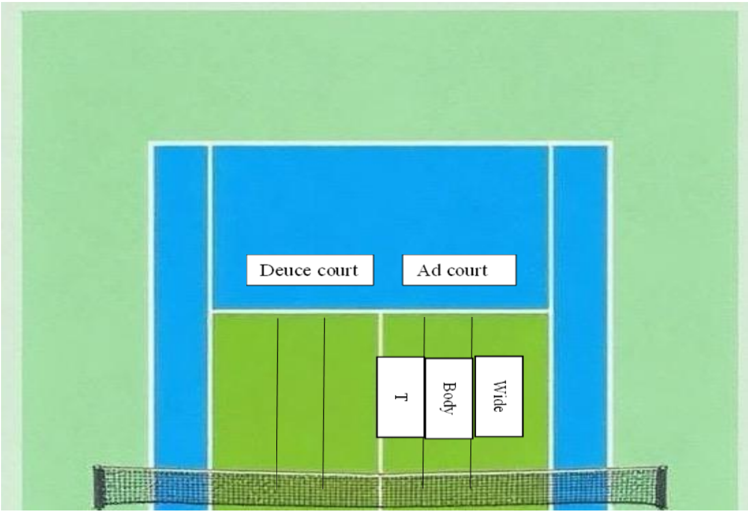
This study targets athletes in the final stages of the four Grand Slam tennis tournaments from 2019 to 2023, focusing on their technical and tactical performance. The sample includes 57 male and 66 female athletes. Data on age in 2023 shows that male athletes have an average age of 28.25 years with a standard deviation of 5.13 years, concentrated in the range of 23-33 years old (mean ± standard deviation), which is the prime of their professional careers. Female athletes have an average age of 28.68 years with a standard deviation of 4.74 years, slightly higher than that of males, with an age range of 24-33 years old. Their age structure is similar to that of males, and the trend of their professional cycles is consistent.

In terms of the year-end rankings in 2023, male athletes have an average ranking of 24th with a standard deviation of 16.58, ranging from 7th to 40th, covering top and mid-level players and presenting a rich competitive hierarchy. Female athletes have an average ranking of 27.59th with a standard deviation of 16.95; their rankings are slightly lower, with a similar degree of dispersion, also covering different competitive levels. In terms of the number of years since turning professional, male athletes have an average of 11.84 years with a standard deviation of 4.85 years, reflecting the professional rhythm shaped by more than a decade of competitive refinement. Female athletes have an average of 12.67 years with a standard deviation of 4.77 years, slightly longer than that of males, possibly due to an earlier start to their professional careers.

Variables and operational definitions

1. Deuce court: also called right half court or first court. In singles, the server serves in the area behind the baseline and to the right of the center line, and the target is near the center line of the right court of the opponent.
2. AD court: also called left half court or second court. In singles, the server serves in the area behind the baseline and to the left of the center line, and the target is near the center line of the left serving area of the opponent's court.
3. Wide: refers to the area where the serve or hit falls near the sideline, that is, the serve at a large angle that flies to the outside of the court after the serve lands. If it is a serve, it is served to the outside area away from the opponent's body, usually near the doubles sideline.
4. Body: refers to serving or hitting the ball directly towards the opponent's body, making it difficult for the opponent to receive the ball comfortably and making awkward movements to deal with it.
5. T: refers to the "T" point on the tennis court, which is the T-shaped intersection formed by the intersection of the center serving line and the serving line. When serving, players often serve the ball near the T point to create a tricky angle, making it difficult for the opponent to return the ball.
6. First serve success rate (1st In): number of successful first serves/total number of first serves × 100%.
7. First serve winning rate (1st won): number of winning balls generated by any technical behavior after the player's first serve enters the legal area/number of successful first serve balls × 100%.

8. Second serve winning rate (2nd won): number of winning balls generated by any technical behavior after the player's second serve enters the legal area/number of successful second serve balls × 100%
9. 1st1-3shots/Won: After the first serve, the stalemate stage begins, and the serving side's 1-3 shot winning rate
10. 2nd1-3shots/won: After the second serve, the stalemate stage begins, and the serving side's 1-3 shot winning rate



Data Reliability
On Grand Slam courts equipped with the Hawk-Eye system, eight to ten high-speed video cameras are located around the arena and they are synchronised to accurately track the three-dimensional movement of ball and player with a reported measurement mean error between 2 and 5 mm (Iwan, Colin, & Neil, 2005). The system can also automatically determine the stroke types (forehand or backhand) with validated high accuracy (Bal &Dureja, 2012; Whiteside & Reid, 2016).

To ensure the reliability of the data, in each of the four Grand Slam tournaments, 10 full matches were randomly selected. Three experienced tennis performance analysts observed these matches and collected non-tracking data. All three observers were professional tennis coaches with more than 10 years of coaching experience and were full-time coaches working in youth tennis development programmers. They were affiliated with the Saidian Tennis Club in Linyi, Shandong Province, China, and all of them held a national youth tennis referee certification issued by the Chinese Tennis Association. Their extensive practical experience in on-court coaching and match officiating ensured a high level of expertise in performance analysis and match event identification. The minimum Cohen's kappa value for all the variables exceeded 0.90 (the minimum value was for the unforced error variable), while the intra-class coefficients (ICC) ranged from 0.95 to 1 and standardized typical errors varied from 0.03 to 0.11, supporting high inter-rater reliability (Hopkins, 2000). All the matches were played according to the International Tennis Federation rules (International Tennis Federation, 2020). indicating that the following variables have high reliability: service won, Ace, serving direction, serving influence, and service in rate.

Statistical Analysis

One-way analysis of variance (ANOVA) is used to test the differences in the mean values of multiple level groups of a dependent variable affected by one influencing factor. While conducting inter-group comparisons, if there are significant differences in the inter-group means, multiple comparisons, also known as post-hoc comparisons, are required to identify which groups among several level groups have significant differences in their means.The one-way ANOVA method has prerequisite conditions for its applicability. Firstly, the samples are derived from a normally distributed population; secondly, the sample variances should be homogeneous.In this paper, one-way ANOVA is used to analyze the differences in the correlation between each diagnostic indicator and the winning probability, including the evaluation parameters of serving technical and tactical links, the evaluation parameters of receiving technical and tactical links, the data of net play, and the data of the rally phase.

Table1

Comparison and Analysis Results of Serve Basics for the Four Grand Slam Tournaments

		AO					RG					WD					US				
		Mean	SD	F	P		Mean	SD	F	P		Mean	SD	F	P		Mean	SD	F	p	
serve-won	male	65.2%	10.3%	16.370	0.000	***	61.6%	7.5%	12.863	0.000	***	65.2%	6.1%	14.265	0.000	***	63.8%	6.7%	14.208	0.000	***
	female	59.0%	7.6%				56.5%	8.8%				59.7%	8.1%				58.1%	10.3%			
Ace	male	10.6%	6.8%	14.719	0.000	***	5.0%	3.4%	12.450	0.001	***	8.2%	5.3%	10.722	0.001	***	8.1%	4.8%	8.022	0.005	**
	female	6.7%	4.9%				3.2%	2.7%				4.8%	4.8%				5.9%	4.2%			
Wide---%	male	44.2%	7.7%	3.931	0.049	*	46.2%	8.2%	3.618	0.059		41.5%	7.0%	0.226	0.635		43.3%	8.8%	3.731	0.056	
	female	41.2%	10.1%				43.0%	11.3%				40.7%	10.0%				39.8%	12.0%			
Body---%	male	17.3%	8.7%	14.425	0.000	***	16.9%	8.5%	31.029	0.000	***	20.2%	8.7%	5.534	0.021	*	19.2%	9.1%	22.639	0.000	***
	female	23.2%	9.8%				27.9%	13.5%				24.9%	10.8%				27.8%	11.7%			
T---%	male	38.6%	7.1%	4.688	0.032	*	36.9%	8.1%	24.600	0.000	***	38.3%	7.3%	5.615	0.020	*	37.6%	8.6%	10.612	0.001	***
	female	35.6%	9.0%				29.1%	9.8%				34.5%	8.8%				32.4%	9.8%			
1stwon	male	72.4%	11.4%	4.891	0.029	*	67.4%	8.1%	15.770	0.000	***	73.4%	6.9%	15.516	0.000	***	72.9%	8.0%	16.576	0.000	***
	female	68.4%	9.9%				61.1%	10.1%				66.1%	10.9%				65.6%	12.3%			
1stAce	male	15.5%	8.3%	9.107	0.003	**	7.5%	5.3%	9.195	0.003	**	12.7%	7.9%	12.465	0.001	***	13.1%	7.9%	6.589	0.011	*
	female	11.2%	8.4%				4.9%	4.6%				7.4%	7.0%				9.7%	7.4%			
1stwide	male	48.5%	7.5%	5.340	0.022	*	49.6%	7.7%	4.339	0.039	*	45.9%	7.7%	2.638	0.108		46.8%	8.1%	3.713	0.056	*
	female	44.7%	11.3%				46.1%	11.3%				42.8%	11.3%				43.5%	11.5%			
1stBody	male	7.1%	6.0%	19.747	0.000	***	9.4%	6.7%	37.642	0.000	***	9.0%	7.1%	13.030	0.000	***	8.2%	8.1%	19.069	0.000	***
	female	13.3%	10.1%				20.9%	13.5%				15.0%	9.3%				16.5%	13.2%			
1stT	male	44.5%	7.5%	2.168	0.143		41.0%	8.8%	18.049	0.000	***	45.0%	7.6%	1.918	0.169		44.9%	9.5%	6.366	0.013	*
	female	42.0%	11.7%				33.0%	12.5%				42.3%	11.5%				40.0%	12.7%			
2ndwon	male	51.5%	12.5%	10.535	0.001	***	50.9%	9.4%	2.372	0.126		50.9%	8.3%	2.000	0.160		49.1%	9.9%	1.064	0.304	
	female	44.9%	11.7%				47.8%	13.4%				48.2%	10.6%				47.2%	11.9%			
2ndAce	male	1.5%	6.2%	2.013	0.158		0.3%	1.0%	0.336	0.563		0.5%	1.3%	0.131	0.718		0.6%	1.2%	0.017	0.897	
	female	0.4%	1.7%				0.6%	4.0%				0.4%	1.4%				0.6%	1.7%			
2ndwide	male	36.0%	14.8%	0.035	0.852		40.3%	15.1%	1.392	0.240		34.1%	12.9%	0.878	0.351		37.3%	14.4%	1.474	0.227	
	female	36.5%	15.0%				36.9%	17.8%				37.0%	17.4%				33.8%	18.7%			
2ndBody	male	36.2%	18.2%	0.383	0.537		30.4%	16.9%	9.645	0.002	**	39.1%	17.4%	0.371	0.544		36.7%	17.0%	7.316	0.008	**
	female	38.0%	16.4%				40.3%	19.8%				41.3%	18.7%				44.8%	18.0%			
2ndT	male	27.8%	11.3%	1.684	0.197		29.3%	11.3%	12.359	0.001	***	26.7%	10.9%	4.166	0.044	*	26.0%	12.0%	5.382	0.022	*
	female	25.4%	10.3%				22.6%	10.5%				21.6%	13.6%				21.3%	11.6%			

Note： "*"， significant， 0.01 < P ≤ 0.05; "**"， Highly significant， 0.001 < P ≤ 0.01; "***",Extremely significant, P ≤ 0.001.

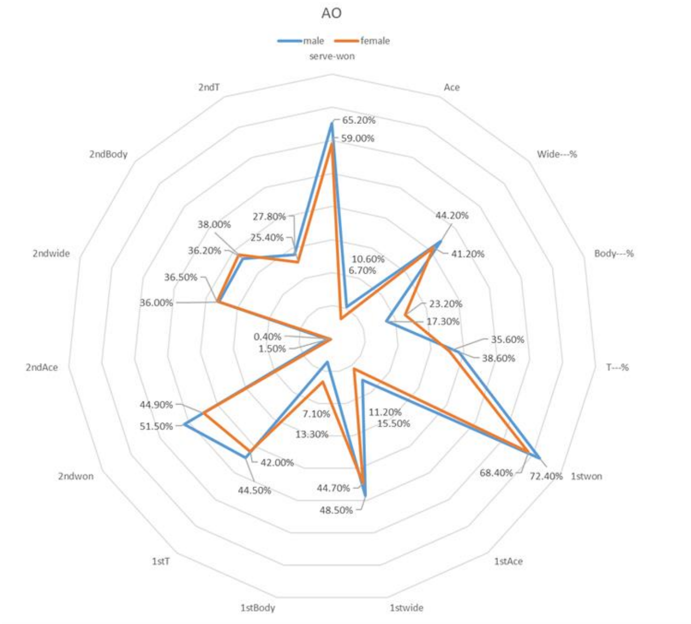


Figure 4.4.1 Australian Open
Radar plot of Serve Basics between male and female players during the final stages of the Australian Open (2019–2023). Values represent mean percentages.

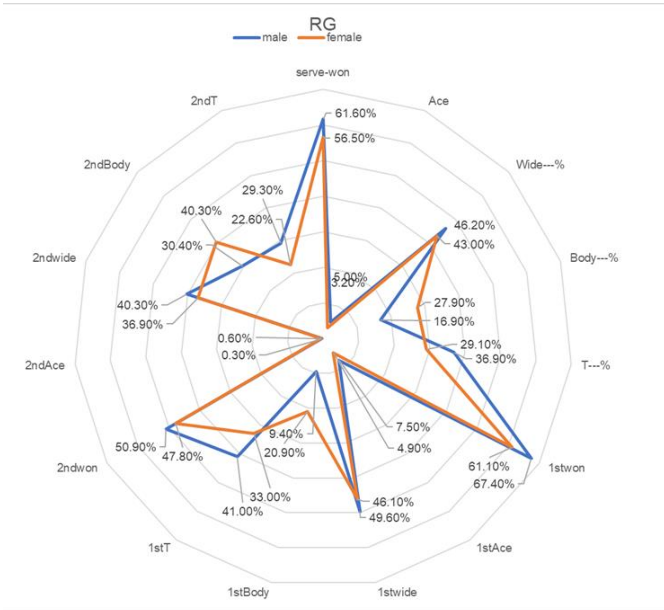


Figure 4.4.2 Roland Garros
Radar plot illustrating Serve Basics for male and female players during the final stages of the Australian Open (2019–2023). The values shown represent mean percentages.

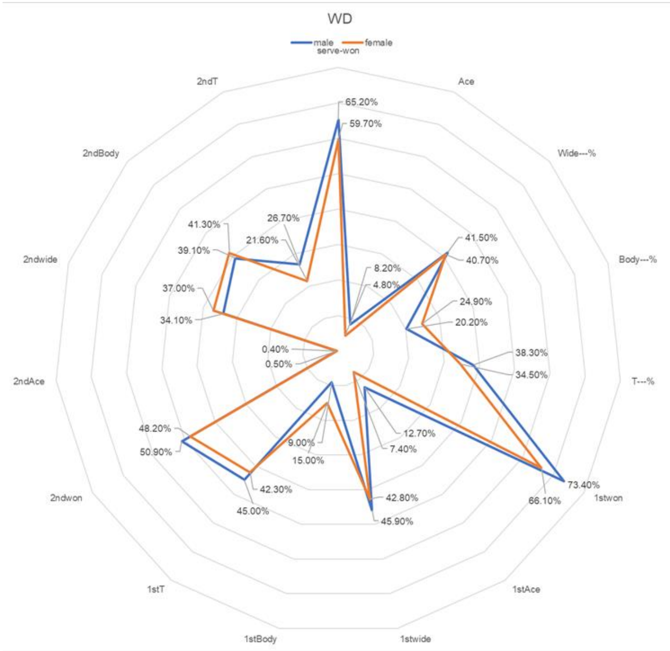


Figure 4.4.3 Wimbledon

Radar plot of Serve Basics between male and female players during the final stages of the Australian Open (2019–2023). Values represent mean percentages.

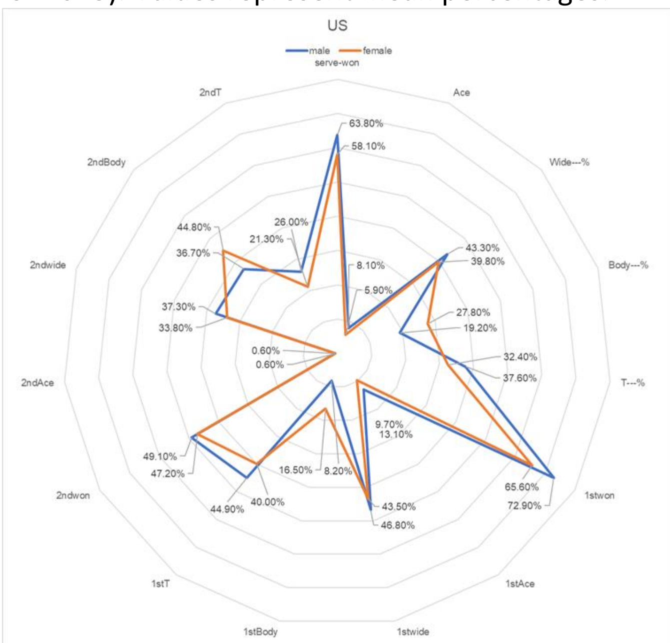


Figure4.4.4 US Open

Radar plot of Serve Basics between male and female players during the final stages of the Australian Open (2019–2023). Values represent mean percentages

Table2

Comparison and Analysis Results of Serve Directions for the Four Grand Slam Tournaments

		AO					RG					WD					US				
		Mean	SD	F	P		Mean	SD	F	P		Mean	SD	F	P		Mean	SD	F	p	
1stDC-Wide	male	48.3%	10.8%	3.531	0.062		47.5%	15.0%	1.060	0.305		46.1%	11.5%	0.027	0.869		50.3%	11.5%	1.619	0.205	
	female	44.4%	13.5%				44.0%	22.6%				45.7%	13.4%				47.0%	17.5%			
1stDC-Body	male	7.3%	7.0%	18.817	0.000	***	9.9%	7.9%	36.145	0.000	***	9.3%	8.5%	7.924	0.006	**	7.9%	8.5%	26.079	0.000	***
	female	14.5%	12.0%				22.8%	15.4%				15.1%	11.9%				19.1%	15.9%			
1stDC-T	male	44.5%	10.4%	2.648	0.106		42.7%	15.8%	9.677	0.002	**	44.6%	12.5%	5.281	0.024	*	41.8%	13.7%	10.209	0.002	**
	female	41.0%	14.4%				33.2%	19.0%				39.1%	11.4%				33.9%	15.1%			
1stAd-Wide	male	48.9%	10.9%	3.149	0.078		51.5%	14.0%	0.815	0.368		45.6%	10.6%	5.589	0.020	*	42.1%	12.2%	1.709	0.193	
	female	44.8%	16.3%				48.9%	18.5%				39.0%	16.7%				38.8%	16.6%			
1stAd-Body	male	6.5%	7.4%	10.529	0.001	***	9.0%	7.6%	20.078	0.000	***	8.4%	7.5%	13.498	0.000	***	8.8%	9.1%	9.612	0.002	**
	female	11.9%	11.8%				18.5%	15.4%				14.8%	9.7%				14.7%	12.7%			
1stAd-T	male	44.5%	10.8%	0.279	0.598		39.6%	14.9%	5.652	0.019	*	46.0%	10.6%	0.009	0.924		49.2%	12.6%	0.990	0.321	
	female	43.3%	15.9%				32.6%	18.9%				46.2%	17.0%				46.5%	18.1%			
2ndDC-Wide	male	33.1%	22.4%	5.427	0.021	*	28.4%	26.1%	1.634	0.203		31.2%	20.6%	0.013	0.908		28.0%	20.8%	0.262	0.610	
	female	23.8%	24.2%				22.6%	26.2%				31.8%	28.6%				30.1%	24.7%			
2ndDC-Body	male	37.5%	20.8%	3.133	0.079		34.0%	18.4%	13.033	0.000	***	42.2%	19.4%	1.279	0.261		38.8%	19.9%	8.792	0.004	**
	female	43.6%	19.9%				47.3%	23.5%				47.3%	25.2%				49.3%	21.3%			
2ndDC-T	male	29.7%	19.0%	0.753	0.387		37.7%	23.8%	4.059	0.046	*	26.7%	18.4%	2.129	0.148		33.2%	22.6%	13.608	0.000	***
	female	32.6%	21.6%				30.1%	19.9%				21.0%	20.6%				20.6%	16.7%			
2ndAd-Wide	male	38.5%	23.0%	7.585	0.007	**	53.2%	27.3%	0.059	0.808		36.9%	22.2%	0.988	0.323		46.3%	24.1%	2.310	0.131	
	female	49.7%	25.1%				52.0%	29.3%				41.9%	27.7%				40.0%	24.3%			
2ndAd-Body	male	35.3%	21.7%	0.547	0.461		26.4%	20.0%	3.803	0.053	*	35.8%	21.1%	0.013	0.910		33.9%	21.2%	1.411	0.237	
	female	32.6%	21.7%				34.3%	25.9%				36.4%	25.3%				38.4%	23.0%			
2ndAd-T	male	26.3%	20.8%	8.203	0.005	**	20.4%	22.3%	4.125	0.044	*	27.4%	19.4%	2.609	0.109		19.8%	18.2%	0.357	0.551	
	female	17.7%	13.7%				13.7%	15.3%				21.9%	14.5%				21.7%	19.3%			

Note： "*"， significant， 0.01 < P ≤ 0.05; "**"， Highly significant， 0.001 < P ≤ 0.01; "***",Extremely significant, P ≤ 0.001

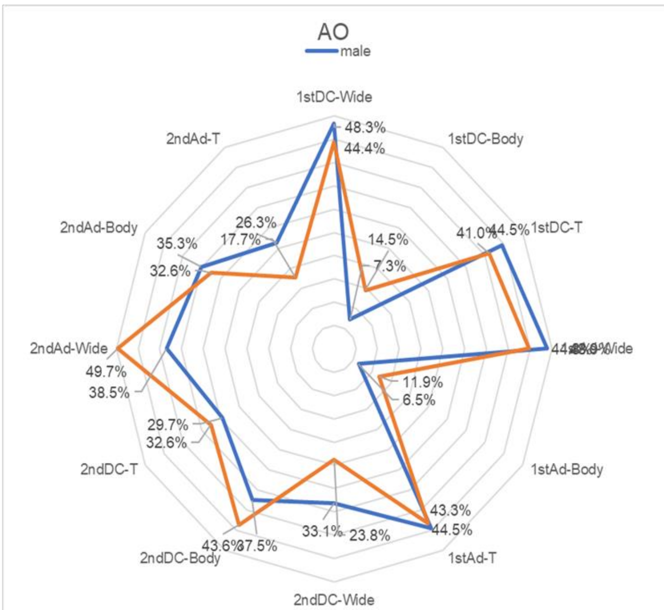


Figure 4.4.5 Australian Open

Radar plot of serve placement distribution between male and female players during the final stages of the Australian Open (2019–2023). Values represent mean percentages.

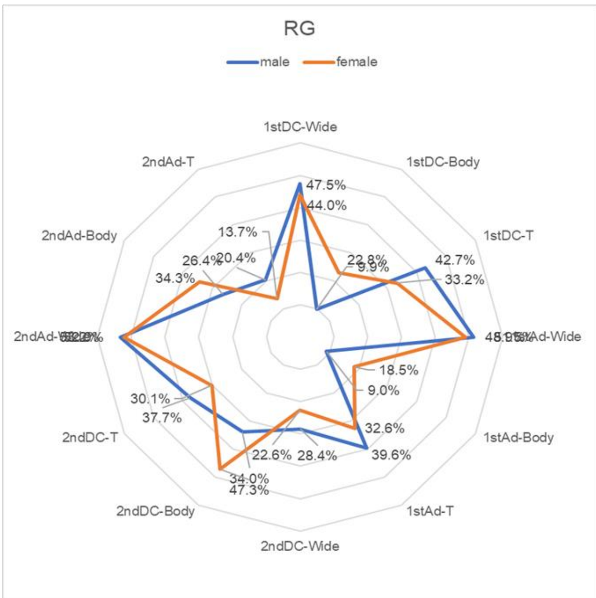


Figure4.4.6 Roland Garros
Radar plot of serve placement distribution between male and female players during the final stages of Roland Garros (2019–2023). Values represent mean percentages.

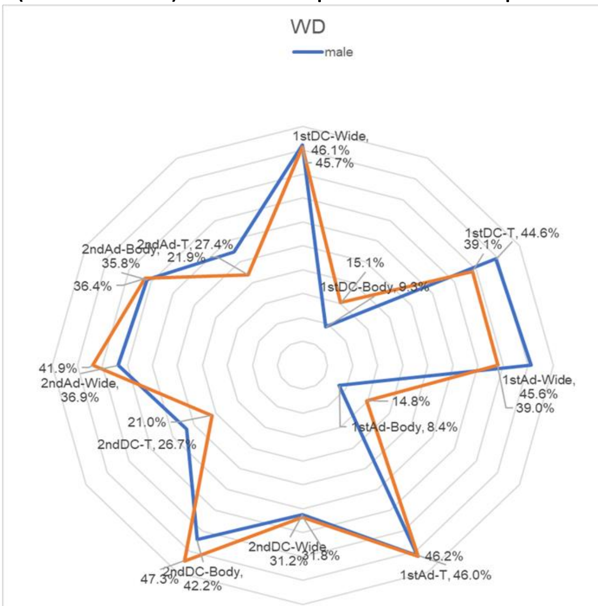


Figure 4.4.7 Wimbledon
Radar plot of serve placement distribution for first and second serves in the deuce and advantage courts between male and female players during the final stages of Wimbledon (2019–2023). Values represent mean percentages.

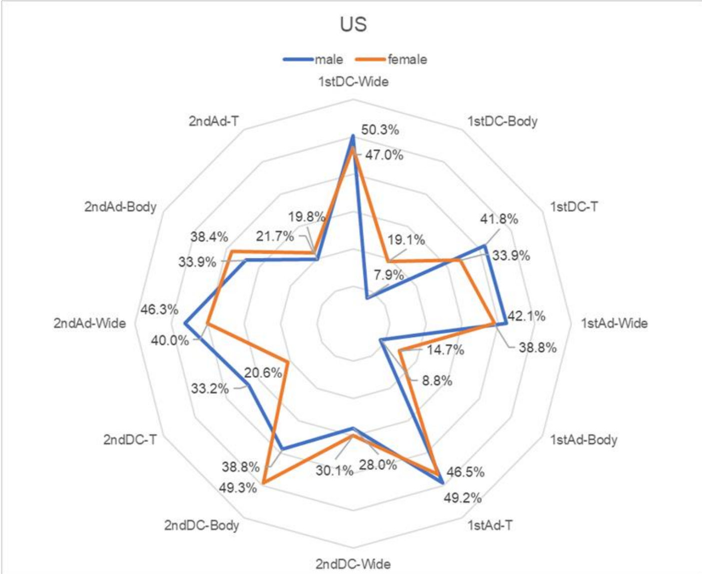


Figure4.4.8 US Open
Radar plot of serve placement distribution for first and second serves in the deuce and advantage courts between male and female players during the final stages of the US Open (2019–2023). Values represent mean percentages.

Results Analysis

Results of Serve Basic Analysis

Serve Winning Percentage (serve-won):

As analyzed in Table 1, the serve winning percentage of male players was extremely significantly higher than that of female players across all four Grand Slams (P<0.001). This result confirms the high conversion efficiency of male players' serving aggression into points—whether on hard courts (Australian Open, US Open), clay courts (Roland-Garros), or grass courts (Wimbledon), male players demonstrated significantly stronger abilities than females in scoring directly via serves (Aces) or forcing opponents into return errors. Court surface type did not weaken this gender difference.

Aces:

The proportion of Aces by male players was extremely significant (and partially strongly significant) higher than that by female players. On hard courts (AO, US) and grass courts (WD), males amplified the threat of Aces through fast serve speeds combined with precise placements (e.g., inside T, wide angles);On clay courts (RG), although slower ball speed and higher bounce reduced Ace production, males still maintained a significant advantage through combinations of spin and trajectory (e.g., slice wide, topspin body serves).

Serve Placement Distribution:

Wide Percentage (Wide-%): There were significant difference in the proportion of wide serves between males and females on hard courts (AO, US) and clay (RG). A significant difference existed at AO, while differences at US and RG approached significance, with no significant difference observed at WD. This indicates that the strategy of hitting wide serves is a basic tactic common to both genders, aiming to force opponents into extensive movement. Gender differences in preference for this strategy are minimal.

Body Percentage (Body-%): The proportion of body serves by female players was extremely significantly higher than that by males. On clay (RG), due to slower ball speed and longer return time, the tactical effect of females compressing opponents' return space via body serves was maximized; on hard courts (AO, US) and grass (WD), this strategy still helped females limit opponents' offensive intentions, reflecting a placement logic centered on "body pressure as the core."

Inside T Percentage (T-%): Male players had an extremely significantly higher proportion of inside T serves than females at RG and US (P<0.001), while at AO and WD, males and females adopted consistent technical and tactical strategies for inside T serves, with males using more such serves than females. The high bounce on RG clay and the low-friction of WD grass amplified the spin threat of males' inside T serves (e.g., topspin inside T forcing opponents into high-lob returns); on hard courts (AO, US), males relied on fast serve speeds to directly compress opponents' return angles, reflecting their aggressive strategy of "direct scoring via inside T serves."

First/Second Serves (1st/2nd Serve):
First Serve (1st Serve):
First serve winning percentage (1stwon): Males were extremely significantly higher than females, confirming the winning percentage of the first serve as a core offensive tool for males;
First serve Aces (1stAce): Males had an extremely significantly higher proportion than females, highlighting the reinforcing effect of fast courts (hard, grass) on Ace production from males' first serves;
Placement distribution (1stT/1stBody): Males had a significantly higher proportion of wide first serves (1stwide) than females at AO, RG, and US, with no significant difference at WD; males had a significantly higher proportion of inside T first serves (1stT) at RG and US (P<0.01), while no significant gender difference was observed at AO and WD; females had a significantly higher proportion of body first serves (1stBody) (P<0.001), continuing the gender differentiation in overall placement strategies.

Second Serve (2nd Serve):
Second serve winning percentage (2ndwon): Males were significantly higher than females only at AO (51.5%±12.5% vs 44.9%±11.7%, P<0.001), with no statistical significance in differences across other courts (RG, WD, US) (P>0.05). This indicates that due to slower speed and stronger spin of the second serve, the impact of gender on score conversion is significantly weakened, and only the fast nature of hard courts (AO) allows males to maintain an advantage.

Second serve Aces (2ndAce): There was no significant gender difference in second serve Aces (P>0.05), indicating minimal gender impact on Aces from second serves.

Placement distribution (2ndT/2ndBody): Males had a significantly higher proportion of inside T second serves (2ndT) at RG (P<0.05) and US (P<0.001), while females had an advantage in body second serves (2ndBody) at RG (P<0.01) and US (P<0.01). The strategic differentiation was consistent with that of first serves, but the magnitude of differences was reduced due to lower aggression.

Results of Serve Direction Analysis

Gender Differentiation in First Serve (1st Serve) Direction

Deuce Court (1stDC)

Wide: The overall proportion of wide first serves for males and females was relatively close (males: 48.3%±10.8% vs females: 44.4%±13.5%). Only at the Australian Open (AO), males have a slightly higher proportion (F=3.531, P=0.062, approaching significance), with no statistical differences at Roland-Garros (RG), Wimbledon (WD), and the US Open (US). This indicates that gender differentiation in the strategy of wide first serves in the deuce court is not obvious, as both genders tend to adopt the universal tactic of pulling opponents wide via wide placements to force extensive movement, with minimal gender differences in preference for this strategy.

Body: The proportion of body first serves by females was extremely significantly higher than that by males (P<0.001), and this trend was consistent across all four Grand Slams (RG: P<0.001; WD: P<0.01; US: P<0.001). This reflects that females rely more on body placements in first serves to the deuce court to compress opponents' return space, using physical pressure to limit opponents' offensive intentions.

T (Inside): The proportion of inside T first serves was balanced between males and females at the Australian Open (AO: males 44.5%±10.4% vs females 41.0%±14.4%). However, males had a significantly higher proportion at Roland-Garros (RG: males 42.7% vs females 33.2%, P<0.01), Wimbledon (WD: males 44.6% vs females 39.1%, P<0.05), and the US Open (US: males 41.8% vs females 33.9%, P<0.01). This suggests that males demonstrate more aggressive inside T strategies in first serves to the deuce court on clay (RG), grass (WD), and hard courts (US), aiming to score directly through fast attacks.

Ad Court (1stAd)

Wide: The difference in the proportion of wide first serves between males and females was generally balanced (males: 48.9%±10.9% vs females: 44.8%±16.3%), with males having a significantly higher proportion only at Wimbledon (WD: males 45.6% vs females 39.0%, P<0.05) and no statistical differences at other courts. This indicates that gender differentiation in the strategy of wide first serves in the ad court is limited, as both genders focus more on core tactics in the ad court (e.g., inside attacks).

Body: The proportion of body first serves by females was extremely significantly higher than that by males (AO: P<0.001), and this trend continued at Roland-Garros (RG: P<0.001), Wimbledon (WD: P<0.001), and the US Open (US: P<0.01). This reflects that females more frequently use body placements in first serves to the ad court to create rhythm changes.

T (Inside): There was no significant difference in the proportion of inside T first serves between males and females, with males having a higher proportion only at Roland-Garros (RG: males 39.6% vs females 32.6%, P<0.05). This indicates that gender differences in inside T strategies for first serves in the ad court are mainly concentrated on clay (RG), where males are more inclined to score directly via inside T serves.

Gender Differentiation in Second Serve (2nd Serve) Direction

Deuce Court (2ndDC)

Wide: Males had a significantly higher proportion of wide second serves than females at the Australian Open (AO: males 33.1%±22.4% vs females 23.8%±24.2%, P<0.05), with no differences at Roland-Garros (RG), Wimbledon (WD), and the US Open (US). This suggests that males prefer the wide-pulling strategy in second serves to the deuce court at the Australian Open (hard court), using the fast ball speed on hard courts to expand opponents' movement range.

Body: Females had an extremely significantly higher proportion of body second serves than males at Roland-Garros and the US Open (RG: P<0.001; US: P<0.01). At the Australian Open (AO), it approached significance (P=0.079) without reaching significance, but females still had a higher proportion, while proportions were balanced at Wimbledon (WD). This reflects that females rely more on body placements in second serves to the deuce court to increase return difficulty, with this strategy being a higher priority especially on Roland-Garros clay (RG) and US Open hard courts (US).

T (Inside): There was no significant difference in inside T second serves between males and females on fast courts (AO, WD). However, males had a significantly higher proportion at Roland-Garros (RG: males 37.7% vs females 30.1%, P<0.05) and the US Open (US: males 33.2% vs females 20.6%, P<0.001). This indicates that the aggression of males' inside T second serves to the deuce court is dynamically enhanced with court type (hard → clay → grass), aiming to score through combinations of spin and placement.

Ad Court (2ndAd)

Wide: Females had a significantly higher proportion of wide second serves in the Ad court than males at the Australian Open (AO: females 49.7%±25.1% vs males 38.5%±23.0%, P<0.01), with no differences at Roland-Garros (RG), Wimbledon (WD), or the US Open (US). This indicates that females are more inclined to use the wide-expansion strategy in second serves to the Ad court at the Australian Open (hard court), using the width of hard courts to limit opponents' return angles.

Body: The overall difference in the proportion of body second serves in the Ad court between males and females was balanced, with females having a higher proportion only at Roland-Garros (RG: females 34.3%±25.9% vs males 26.4%±20.0%, P=0.053, approaching significance). Gender differentiation in body strategies for second serves in the Ad court is mainly concentrated on Roland-Garros clay (RG), where females focus more on controlling rhythm via body placements.

T (Inside): Males had a significantly higher proportion of inside T second serves than females (AO: males 26.3%±20.8% vs females 17.7%±13.7%, P<0.01; RG: males 20.4%±22.3% vs females 13.7%±15.3%, P<0.05), with no differences at Wimbledon (WD) or the US Open (US). This reflects that the aggression of males' inside T second serves to the ad court is more prominent on hard courts (AO) and clay (RG), aiming to compress opponents' return space through combinations of spin and placement.

Discussion

The purpose of this study is to analyze gender differences in serving performance among professional tennis players in the four Grand Slam tournaments, and to reveal significant gender disparities in serving efficiency, tactical choices, and rally control. Possessing excellent serving ability is a crucial starting point for athletes to control the direction of rallies (Abidin, A. Z., & Ruslan, N. A. S., 2020). As the first attempt in the serving sequence, the first serve is typically characterized by a relatively fast ball speed, and in terms of placement selection, it is generally believed to be more inclined to target the wide (W) and T (T) positions. This is because serving to these areas can effectively create distance from the receiver, significantly increasing the difficulty of returning the ball. In contrast, the tactical logic of the second serve differs significantly: due to the fact that a fault on the second serve will directly result in losing the point, its strategic selection needs to be more cautious (Vandenbussche, R., 2023). Therefore, although the second serve still retains a certain potential for attack, some studies have speculated that a higher proportion of second serves will target the body (B) position in the middle of the service box to balance the risk of faults and tactical effectiveness (Gillet, E., Leroy, & Stein, J. F., 2009).

These findings provide quantitative basis for understanding the differentiation in competitive strategies between male and female athletes, and also echo the core conclusions of recent studies on tennis performance.

Gender Differentiation in Serving Aggression: Physiological Foundations and Tactical Execution

Males showed extremely significant advantages in serve winning percentages across all four Grand Slams ($P<0.001$), and this advantage was not affected by court type. This is consistent with the biomechanical research conclusion by Martin, C. (2019)—due to stronger load-bearing capacity of shoulder and elbow joints, males can generate higher serve speeds, thereby improving the efficiency of direct scoring (Ace) or forcing opponents into errors. Analysis of winning percentages in the deuce court (DC) and ad court (Ad) showed that males had extremely significantly higher winning percentages in all divisions ($P<0.01$ or $P<0.001$), and their advantage in Ace percentage persisted across hard courts, clay courts, and grass courts (except the deuce court at Wimbledon), indicating the full-area coverage feature of their aggression (Paserman, M. D. ,2023). In contrast, females only held an advantage in the wide strategy of the Ad court during second serves at the Australian Open ($P<0.01$), reflecting their flexibility in compensating for strength disadvantages through placement expansion in specific courts and divisions.

Specifically, males amplified the threat of Aces on hard courts (AO, US) and grass courts (WD) through "speed + precise placement" (e.g., inside T, wide), while maintaining significant advantages on clay courts (RG) through spin combinations (slice wide, topspin body serves) (Krumer, A., Rosenboim, M., & Shapir, O. M. ,2016). This indicates that male serving strategies have strong adaptability to court surfaces, and their aggression not only relies on physiological advantages but also achieves full-court coverage through tactical adjustments.

In contrast, females have weaker serving aggression but form a differentiated strategy through placement choices: the proportion of body serves (Body-%) is extremely significantly higher than that of males ($P<0.001$). Especially on clay courts, the slower ball speed provides sufficient time for body serves to compress opponents' return space, which is consistent with the view proposed by Pluim, B. M. et al. (2023) that "females rely more on spatial pressure to control rallies". This strategic choice not only avoids the disadvantage in absolute strength but also achieves tactical balance by limiting opponents' offensive intentions.

Strategic Differentiation in Serve Placements: Gender Specificity and Court Adaptation
As a basic tactic common to both genders, the difference in the proportion of wide placements (Wide-%) is only significant at the Australian Open, nearly significant at Roland-Garros and the US Open, and not significant at Wimbledon, confirming that "pulling opponents sideways" is the core logic of tennis serving (Pradas, F., Toro-Román, V., Castellar, C., & Carrasco, L.,2023). However, males' advantage in producing Aces with wide placements (AO: $P<0.01$; WD: $P<0.001$) highlights their ability to convert placement advantages into points, which is directly related to the characteristic of fast courts amplifying the wide-angle pressure effect (Ye, R., & Liu, W. ,2025).

Body serves (Body-%) are the core strategy for females, with extremely significantly higher proportions in first serves to both the deuce court and ad court ($P<0.001$), and this trend continues in second serves on clay courts (RG) and hard courts (US), though the difference is not significant in second serves at Wimbledon. This is consistent with the characteristic that females pay more attention to rhythm control in multi-shot confrontations (Söğüt, M., Kirazci, S., & Korkusuz, F.,2012); body serves reduce the quality of opponents' returns, creating favorable conditions for subsequent rally phases.

Inside T placements (T-%) are the concentrated embodiment of male aggression, with highly significant proportions in first serves to the deuce court at Roland-Garros (RG) and the US Open (US) ($P<0.01$). The high bounce on clay courts and the fast ball speed on hard courts respectively amplify the spin threat and angle pressure of male inside T serves, which is consistent with the tactical logic that "male inside T serves aim at direct scoring or initiating attacks" (Ye, R., & Liu, W. 2025).

Conclusion
This study analyzed gender differences in the serving performance of professional tennis players across the four Grand Slam tournaments, confirming significant gender differences in serve efficiency, tactical choices, and rally control, thereby providing a quantitative basis for coaches and athletes in training and strategy formulation.

For male athletes, their serving advantage stems from physiologically supported aggressiveness. They can achieve high point-winning rates across all court types through a combination of "speed + precise placement" (e.g., inner T zone, wide outer zone) and exhibit strong control in short rallies (1-3 shots). Therefore, training should continuously enhance the accuracy of inner and outer zone placements for first serves, optimize spin and speed combinations based on different court characteristics (e.g., emphasizing slice on wide outer zones for clay courts, and reinforcing flat speed for hard and grass courts), and further convert serving aggressiveness into immediate points or offensive initiative.

For female athletes, despite weaker absolute power in serving, they have formed differentiated advantages through the spatial pressure strategy of body serves and demonstrated higher stability in long rallies (10+ shots). Training should focus on consolidating the execution quality of body serves, especially strengthening the compression of opponents' return space on slow-paced courts such as clay. Meanwhile, attention should also be paid to return training, particularly return training for body serves, to improve technical and tactical strategies for handling body serves. As experience accumulates, targeted improvement in the point-conversion ability of wide outer zone serves is needed, along with enhancing line-changing skills in extended rallies following second serves, so as to fully leverage the advantages in extended rallies on fast hard courts like the US Open.

In coaching, individualized plans should be formulated based on athletes' gender, age, and court characteristics: for young players, emphasis should be placed on basic placement control in line with their physiological development stage (e.g., females first strengthening body serves, males balancing corner and body serves); for professional players, targeted optimization of "serve-rally" tactical combinations is required—males reinforcing fast-attack transitions in short rallies, and females improving line-changing rhythm in long rallies—ultimately achieving precise alignment between serving strategies and competitive capabilities.

Limitations and Future Directions

This study focuses on the final stage, which may ignore the impact of fatigue on serving performance during the tournament; future research can be extended to multi-round analysis. In addition, combining the correlation between biomechanical parameters of serving actions (such as toss height, swing angle) and tactical choices may further reveal the underlying mechanisms of gender differences (Yu, L., & Ji-he, Z.,2020). For practical applications, males can strengthen accuracy training for inside T first serves, while Female players prioritize serve quality and increase the deployment of wide serves and T serves., especially exploiting advantages on fast hard courts.

Implications

Overall, the present study holds important theoretical and practical significance. From a theoretical perspective, it advances existing research by integrating gender comparison and cross-surface analysis within the unified competitive framework of the four Grand Slam tournaments—Australian Open, Roland-Garros, Wimbledon, and US Open. Unlike previous studies that were limited to a single court surface or a single gender group, this research systematically compares serve technical and tactical performance across different surfaces and between male and female players, thereby providing a more comprehensive understanding of how environmental context and gender interact to shape performance patterns. This cross-contextual and cross-gender analytical framework represents the primary novelty of the study.

From the perspective of social sciences, the findings contribute to performance analysis, gender studies in sport, and evidence-based coaching methodology. By revealing how structural factors (court surface) and individual factors (gender characteristics) jointly influence decision-making and technical execution, the study enriches the understanding of adaptive behavior in competitive environments. Moreover, it provides empirical support for differentiated training strategies, promoting more precise and equitable resource allocation in athlete development systems. Therefore, this research not only supplements the existing body of sport performance literature but also offers valuable insights for optimizing high-performance training models within professional tennis.

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