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Tactical and Technical Analysis of the Serve-Winning Factors among Professional Tennis Players During Four Grand Slams

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Abstract

This study aims to explore the differences in serving technical and tactical performance in Grand Slam tournaments based on the match outcomes (win/loss) of professional tennis players. Data were collected from 255 matches involving 123 players (57 males and 66 females) across Grand Slam tournaments from 2019 to 2023. Guided by the theory of technical and tactical performance differences, cluster analysis was employed to categorize players based on match outcomes. Subsequently, one-way analysis of variance (ANOVA) were used to analyze the differences in serving performance between winning and losing players, identifying the decisive factors in the serving phase.Conclusions:The service point win rate of winning players, both male and female, was significantly higher than that of losing players, with males showing an overall advantage.The impact of ACEs on match outcomes varied across different Grand Slams for female players, while their discriminatory power was low for male players.Serving direction: Significant differences in the proportion of winning and losing players (by gender) were observed across different Grand Slams and serving directions. Male players had key directions to establish advantages, while female players demonstrated specific strategic differences, which were significantly influenced by court characteristics. Serving influence: Winning players dominated in short rallies. In medium-to-long rallies, male players maintained more stable advantages, whereas female players showed complex disparities, which were closely related to Grand Slam characteristics and tactical adaptability. Serving breakdown: Male players relied on serve quality, while ACEs emerged as a differentiating factor for female players in some Grand Slams. The discriminatory power of serving accuracy for distinguishing between winning and losing players was weaker than that of service point win rate.Serving indicators can effectively evaluate player performance. The gender-specific characteristics provide support for understanding serving strategies,

optimizing training, and informing match decisions. Future research could deepen the investigation into tactical applications.
Keywords: Professional Tennis Players, Tactical and Technical Analysis, Tennis Service, Grand Slams

Introduction

Tennis, originating in Europe, has evolved into one of the most popular ball sports worldwide through continuous development. The serve, as a technical skill that combines fundamental and strategic importance, plays a crucial shaping role in match outcomes. It is the only active offensive technique unaffected by opponents, and a high-quality serve is pivotal for gaining initiative in subsequent tactical implementations. The significance of serves has been thoroughly explored by numerous scholars (Peter O'Donoghue & Emily Brown, 2008).

Over the past decade, China's professional tennis has experienced rapid development, increasing commercialization, and globalization, gradually aligning with international standards. A series of major international events, including the Shanghai Masters, China Open, and Wuhan Open, have been successively hosted in China. Li Na once achieved historic results for Chinese professional tennis, and outstanding Chinese female players have made remarkable appearances and won championships on the global tennis stage. A decade after Li Na's era, Zheng Qinwen secured the women's singles gold at the 2024 Paris Olympics, again setting a new record for Chinese female tennis players. Among China's competitive sports, tennis remains a potential 优势项目 (advantage sport) yet to be fully developed. For Chinese men's tennis, there remains a substantial gap in overall competitive strength. Although the number of international professional events has increased in recent years, few Chinese players qualify for high-level tournaments. Most still face low rankings and difficulties in securing entries, making the goal of "breaking into the top 100" highly challenging—primarily due to generally low rankings.

In professional tennis, the four Grand Slam tournaments represent the pinnacle of competition, where top players vie for the highest honors. Within these events, extensive research on serves has been conducted by scholars, covering multiple dimensions: Regarding serve speed and accuracy, Javier Maquirriain et al. (2016), Frantisek Vaverka et al. (2018), Edelmann-Nusser et al. (2019), and Kashiwagi et al. (2021) have revealed the dynamic balance between speed and accuracy through biomechanical analyses and experimental studies. Concerning differences in serve speed across court surfaces, comparative research by Stephanie Kovalchik & Machar Reid (2018), along with further analyses by Frantisek Vaverka et al. (2018), Kashiwagi et al. (2021), and Ruslan et al. (2024), systematically elucidates how court surface characteristics influence serving strategies. Exploring subtle differences in serve-related tactical performance between winning and losing players in these top-tier events holds significant value for athlete development and tactical analysis.

Over the years, tennis serve research has achieved notable progress at the technical level. For example, Fett et al. (2020) found that male athletes' serve speed significantly decreases after high-intensity fatigue (Δ-3.2 km/h, $p<0.05$), while Rouli Ye & Wenming Liu (2025) showed that female players exhibit a larger decrease in serve speed post-simulated matches (Δ-4.1 km/h, $p<0.01$), revealing gender differences in the impact of physical exertion on serves. Regarding placement strategies, Melonio VPF et al. (2021) analyzed Australian

Open data and found that male players favor wide serves on hard courts (42.7% share), whereas female players more frequently use central placements on clay courts (35.6% share), illustrating how court surfaces influence serve direction choices. In terms of score correlation, Bozděch M (2024) developed a model using Grand Slam data and found that for every 5% increase in serve win rate, male players' match win probability rises by 12.3% (OR=1.123, $p<0.001$) and female players' by 9.8% (OR=1.098, $p<0.01$), confirming the direct impact of serve win rates on match outcomes.

However, critical gaps remain in existing research. First, systematic analysis of gender differences is insufficient. Although Venn-Moncur et al. (2024) compared 男女选手 (male and female players) in terms of serve win rates, ACEs, and placement distribution, cross-court comparisons across the four Grand Slams are lacking. Second, integrated research on multi-dimensional indicators is scarce. For instance, Antúnez RM et al. (2012) only analyzed the correlation between serve speed and ACEs ($r=0.68$, $p<0.001$) in isolation, without comprehensive modeling incorporating variables like serve direction or rally length. Third, research on the influence of serves across different rally phases is weak. While Cant, Olivia (2020) noted that servers win significantly more short rallies (1–3 shots) than long rallies (>10 shots), tactical gender differences across rally phases remain unexplored—e.g., male players maintain a 62.3% win rate in medium-long rallies (7–9 shots), whereas female players only achieve 51.7%. Additionally, existing studies lack sufficient analysis of the correlation between serve direction and tactical execution.

This study collects data from 255 matches involving 123 professional tennis players (57 male, 66 female) across the four Grand Slams from 2019–2023. Based on the theory of tactical performance differences, cluster analysis classifies athletes by match outcomes. One-way ANOVA (with post-hoc multiple comparison using the LSD method) is then used to analyze performance differences in the serving phase between winning and losing players across court surfaces, identifying decisive factors in serving. By analyzing differences between winning and losing players in Grand Slam finals, this study identifies serve-related decisive factors, compares cross-court surface differences horizontally, and contrasts winning vs. losing players vertically. It provides data-driven tactical support for losing players to reduce unfavorable serving strategies and narrow result gaps. Additionally, it offers coaches a reference for developing gender- and court surface-specific training programs, enhancing practice of decisive serving tactics to ultimately improve athletes' match performance.

Methodology

Sample

This study focuses on the technical and tactical performance of athletes in the final stages of the four Grand Slam tournaments from 2019 to 2023, with the sample including 57 male and 66 female players.

According to the age data in 2023, the average age of male players is 28.25 years old, 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. The average age of female players is 28.68 years old, with a standard deviation of 4.74 years, slightly higher than that of male players. The age range is 24-33 years old, with an age structure similar to that of male players, and the trend of the professional cycle is consistent.

In terms of the year-end rankings in 2023, the average ranking of male players is 24th, with a standard deviation of 16.58, spanning from 7th to 40th, covering top and mid-level players, showing a rich competitive level. The average ranking of female players is 27.59th, with a standard deviation of 16.95, slightly lower in rankings, but with a similar degree of dispersion, also covering different levels.

Regarding the number of years as professional players, male players have an average of 11.84 years, with a standard deviation of 4.85 years, reflecting the professional rhythm of more than ten years of competitive polishing. Female players have an average of 12.67 years, with a standard deviation of 4.77 years, slightly longer than that of male players, which may be due to an earlier start of their professional careers.

Variables and Operational Definitions

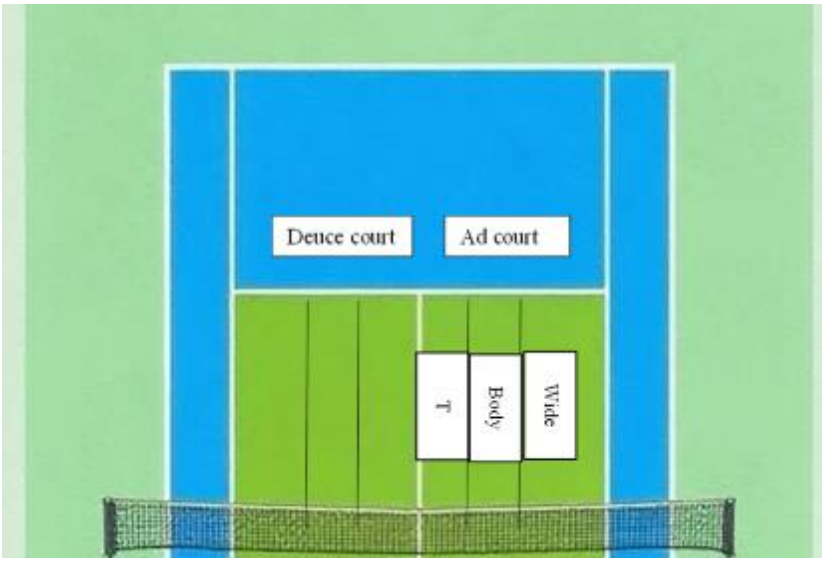
Deuce court: also called right half court or first court. In singles, the server serves in the area behind the baseline and to the right of the center line, and the target is near the center line of the right court of the opponent. In doubles, the serve is also in this area, but the effective landing point range of the serve is larger, including the area inside the doubles sideline.

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. In doubles, the serving area is the same, and the effective landing point includes the area inside the doubles sideline.

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.

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.

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.



First serve success rate (1st In): number of successful first serves/total number of first serves × 100%.
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%.
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%
1st1-3shots/Won: After the first serve, the stalemate stage begins, and the serving side's 1-3 shot winning rate
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. Subsequently, comparisons were made between different analysts and between analysts and the statistical data of consecutive matches. For continuous variables not included in the sequence data, the intraclass correlation coefficient (ICC) and standardized typical error were calculated between different operators, within the same operator, and between operators and official data. The ICC results ranged from 0.96 to 1, and the standardized typical errors ranged from 0.02 to 0.11, 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.

Table 1

Results of analysis of serve basics of male winners and losers in the Grand Slams

		AO					RG					WD					US				
		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*p*	
serve-won	Winner	71.2%	6.6%	36.076	0.000	***	66.9%	5.1%	61.370	0.000	***	69.2%	4.4%	35.126	0.000	***	67.8%	5.7%	36.394	0.000	***
	Loser	59.2%	9.9%				56.3%	5.6%				61.2%	4.8%				59.8%	5.1%			
Ace	Winner	10.5%	5.0%	0.005	0.945		5.7%	4.0%	2.292	0.135		9.1%	5.7%	1.574	0.216		8.7%	5.2%	1.093	0.300	
	Loser	10.7%	8.3%				4.4%	2.7%				7.2%	4.9%				7.5%	4.5%			
Wide---%	Winner	44.5%	7.4%	0.138	0.711		44.9%	7.0%	1.618	0.208		41.3%	5.2%	0.033	0.856		43.5%	9.8%	0.055	0.815	
	Loser	43.8%	8.1%				47.5%	9.2%				41.7%	8.6%				43.0%	7.9%			
Body---%	Winner	16.1%	8.1%	1.387	0.243		17.0%	7.6%	0.010	0.919		19.5%	9.7%	0.369	0.5468		18.9%	9.1%	0.065	0.800	
	Loser	18.5%	9.1%				16.8%	9.4%				21.0%	7.7%				19.5%	9.3%			
T---%	Winner	39.4%	6.5%	0.996	0.322		38.1%	6.7%	1.396	0.242		39.1%	6.0%	0.566	0.4558		37.5%	7.9%	0.005	0.944	
	Loser	37.7%	7.6%				35.7%	9.2%				37.5%	8.4%				37.7%	9.4%			
1stwon	Winner	78.3%	5.8%	25.358	0.000	***	72.3%	5.9%	35.362	0.000	***	77.6%	5.2%	26.688	0.000	***	77.1%	6.3%	25.425	0.000	***
	Loser	66.5%	12.6%				62.6%	7.1%				69.3%	6.0%				68.7%	7.3%			
1stAce	Winner	15.4%	7.4%	0.005	0.943		8.4%	6.0%	1.788	0.186		14.0%	8.9%	1.458	0.2335		14.2%	8.8%	1.402	0.241	
	Loser	15.6%	9.2%				6.7%	4.3%				11.3%	6.8%				11.9%	6.9%			
1stwide	Winner	49.3%	6.9%	0.904	0.345		49.4%	6.9%	0.032	0.859		46.0%	5.4%	0.003	0.9558		46.3%	8.1%	0.263	0.610	
	Loser	47.6%	8.2%				49.8%	8.5%				45.9%	9.6%				47.3%	8.2%			
1stBody	Winner	5.8%	5.4%	3.211	0.078		8.8%	5.7%	0.618	0.435		9.0%	8.1%	0.000	1		9.0%	9.3%	0.545	0.463	
	Loser	8.3%	6.3%				10.1%	7.5%				9.0%	6.0%				7.5%	6.9%			
1stT	Winner	44.9%	6.7%	0.209	0.649		41.8%	7.1%	0.547	0.462		45.1%	5.5%	0.001	0.9702		44.7%	9.4%	0.028	0.868	
	Loser	44.1%	8.4%				40.2%	10.2%				45.0%	9.4%				45.1%	9.8%			
2ndwon	Winner	57.5%	12.2%	21.093	0.000	***	56.4%	7.9%	33.252	0.000	***	54.1%	7.4%	7.952	0.0071	**	52.8%	9.8%	10.364	0.002	**
	Loser	45.5%	9.6%				45.3%	7.5%				47.8%	8.0%				45.5%	8.6%			
2ndAce	Winner	1.1%	2.4%	0.356	0.553		0.6%	1.4%	3.972	0.051	*	0.5%	1.4%	0.000	1		0.7%	1.2%	0.248	0.620	
	Loser	1.9%	8.4%				0.1%	0.4%				0.5%	1.3%				0.5%	1.3%			
2ndwide	Winner	35.0%	16.0%	0.299	0.586		36.7%	14.3%	3.749	0.057	*	33.4%	14.0%	0.169	0.6831		38.9%	15.4%	0.840	0.363	
	Loser	37.0%	13.6%				43.9%	15.2%				34.9%	11.9%				35.7%	13.3%			
2ndBody	Winner	36.2%	19.4%	0.000	0.990		32.0%	16.8%	0.601	0.441		38.0%	20.5%	0.213	0.6467		34.5%	15.3%	1.104	0.297	
	Loser	36.2%	17.3%				28.8%	17.1%				40.3%	13.9%				38.9%	18.5%			
2ndT	Winner	28.9%	12.0%	0.594	0.443		31.2%	11.8%	1.912	0.172		28.5%	11.2%	1.412	0.241		26.6%	11.0%	0.158	0.692	
	Loser	26.8%	10.6%				27.3%	10.6%				24.8%	10.4%				25.4%	13.1%			

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

Table 2

Results of analysis of serve basics of female winners and losers in the Grand Slams

		AO					RG					WD					US				
		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*p*	
serve-won	Winner	64.3%	4.7%	63.232	0.000	***	62.8%	5.9%	74.466	0.000	***	65.5%	5.8%	51.554	0.000	***	64.4%	7.8%	40.312	0.000	***
	Loser	53.7%	6.3%				50.2%	6.4%				54.0%	5.8%				51.9%	8.6%			
Ace	Winner	9.5%	4.8%	33.363	0.000	***	3.6%	2.8%	1.527	0.221		6.3%	5.1%	5.489	0.023	*	7.3%	4.5%	9.145	0.004	**
	Loser	3.9%	3.1%				2.8%	2.6%				3.3%	4.0%				4.5%	3.3%			
Wide---%	Winner	42.5%	9.5%	1.312	0.256		43.8%	12.3%	0.383	0.538		40.1%	9.5%	0.171	0.681		37.9%	10.7%	1.731	0.193	
	Loser	39.8%	10.7%				42.1%	10.3%				41.3%	10.6%				41.6%	13.0%			
Body---%	Winner	19.9%	9.1%	8.961	0.004	**	27.2%	15.1%	0.163	0.688		23.2%	9.7%	1.322	0.256		29.4%	13.8%	1.393	0.242	
	Loser	26.6%	9.5%				28.5%	11.9%				26.6%	11.7%				26.1%	9.0%			
T---%	Winner	37.6%	9.0%	3.495	0.066		29.0%	11.5%	0.021	0.885		36.7%	10.2%	3.533	0.066		32.7%	10.6%	0.059	0.809	
	Loser	33.6%	8.6%				29.3%	7.9%				32.2%	6.8%				32.1%	9.0%			
1stwon	Winner	74.7%	7.4%	46.776	0.000	***	67.1%	8.2%	37.332	0.000	***	73.0%	8.1%	33.050	0.000	***	71.0%	10.1%	16.487	0.000	***
	Loser	62.1%	8.0%				55.1%	8.2%				59.3%	9.0%				60.2%	12.0%			
1stAce	Winner	15.8%	8.3%	29.244	0.000	***	5.5%	4.7%	0.969	0.328		9.9%	7.5%	7.402	0.009	**	11.8%	7.9%	6.307	0.014	*
	Loser	6.7%	5.6%				4.4%	4.6%				4.9%	5.6%				7.5%	6.3%			
1stwide	Winner	45.5%	11.2%	0.325	0.570		47.6%	12.7%	1.235	0.270		41.8%	12.7%	0.341	0.562		42.2%	11.0%	0.957	0.331	
	Loser	43.9%	11.4%				44.6%	9.7%				43.7%	9.9%				44.9%	11.9%			
1stBody	Winner	9.9%	8.8%	8.484	0.005	**	19.9%	15.0%	0.369	0.546		14.3%	9.0%	0.236	0.629		17.1%	15.8%	0.164	0.687	
	Loser	16.6%	10.3%				21.9%	12.0%				15.6%	9.8%				15.9%	10.1%			
1stT	Winner	44.7%	11.1%	3.598	0.062		32.6%	13.6%	0.098	0.755		43.9%	11.8%	1.011	0.320		40.8%	15.0%	0.246	0.622	
	Loser	39.4%	12.0%				33.5%	11.5%				40.7%	11.1%				39.3%	10.1%			
2ndwon	Winner	48.5%	10.1%	7.393	0.008	**	55.2%	10.6%	31.008	0.000	***	52.1%	11.4%	7.922	0.007	**	54.2%	10.2%	37.673	0.000	***
	Loser	41.2%	12.2%				40.3%	11.9%				44.3%	8.3%				40.1%	9.0%			
2ndAce	Winner	0.6%	2.0%	0.621	0.433		0.2%	1.0%	0.744	0.391		0.5%	1.5%	0.084	0.773		0.8%	2.1%	1.701	0.197	
	Loser	0.3%	1.2%				1.1%	5.6%				0.4%	1.4%				0.3%	1.2%			
2ndwide	Winner	39.5%	14.4%	2.858	0.095		35.7%	17.9%	0.345	0.559		37.0%	18.3%	0.000	1.000		31.4%	15.9%	1.180	0.281	
	Loser	33.5%	15.1%				38.2%	17.9%				37.0%	16.9%				36.3%	21.2%			
2ndBody	Winner	34.4%	14.8%	3.571	0.063		41.0%	20.5%	0.080	0.779		37.2%	16.7%	2.631	0.111		47.8%	17.7%	1.990	0.163	
	Loser	41.7%	17.3%				39.6%	19.3%				45.5%	20.0%				41.8%	18.1%			
2ndT	Winner	26.1%	9.4%	0.294	0.590		23.3%	10.8%	0.292	0.590		25.7%	16.6%	4.982	0.030	*	20.7%	10.6%	0.202	0.655	
	Loser	24.8%	11.2%				21.9%	10.3%				17.6%	8.3%				21.9%	12.8%			

Note : "*", significant, $0.01 < P \leq 0.05$; "**", Highly significant, $0.001 < P \leq 0.01$; "***",Extremely significant, $P \leq 0.001$.

Table 3

Results of analysis of serve directions of male winners and losers in the Grand Slams

		AO					RG					WD					US				
		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*p*	
1stDC-Wide	Winner	49.1%	8.8%	0.326	0.570		45.3%	16.0%	1.318	0.255		47.3%	9.2%	0.469	0.497		49.6%	12.2%	0.208	0.650	
	Loser	47.6%	12.7%				49.6%	13.8%				45.0%	13.6%				50.9%	11.0%			
1stDC-Body	Winner	5.6%	6.0%	4.171	0.045	*	8.8%	6.7%	1.288	0.261		9.0%	9.2%	0.034	0.854		8.7%	9.8%	0.638	0.427	
	Loser	8.9%	7.6%				11.0%	9.0%				9.5%	7.9%				7.0%	6.9%			
1stDC-T	Winner	45.2%	8.2%	0.339	0.562		46.0%	15.5%	2.869	0.095		43.6%	10.9%	0.277	0.601		41.6%	14.9%	0.020	0.887	
	Loser	43.8%	12.3%				39.4%	15.7%				45.5%	14.1%				42.1%	12.6%			
1stAd-Wide	Winner	50.6%	10.7%	1.660	0.202		53.3%	12.2%	1.107	0.297		44.4%	9.9%	0.687	0.411		42.5%	12.0%	0.058	0.810	
	Loser	47.3%	11.0%				49.6%	15.6%				46.9%	11.3%				41.8%	12.5%			
1stAd-Body	Winner	5.5%	7.9%	1.202	0.277		9.1%	7.1%	0.002	0.961		8.8%	8.1%	0.093	0.761		9.3%	10.2%	0.236	0.629	
	Loser	7.5%	6.9%				9.0%	8.2%				8.1%	7.0%				8.2%	7.9%			
1stAd-T	Winner	43.9%	11.1%	0.266	0.607		37.7%	14.1%	1.053	0.309		47.0%	11.4%	0.418	0.521		48.2%	11.1%	0.397	0.531	
	Loser	45.2%	10.7%				41.5%	15.6%				45.0%	10.0%				50.2%	14.1%			
2ndDC-Wide	Winner	37.7%	23.5%	3.122	0.082		24.8%	21.4%	1.253	0.267		36.2%	22.6%	2.885	0.096		32.6%	22.6%	3.228	0.077	
	Loser	28.3%	20.5%				32.1%	29.9%				26.3%	17.5%				23.5%	18.2%			
2ndDC-Body	Winner	33.7%	20.5%	2.321	0.132		33.6%	15.3%	0.044	0.835		39.0%	22.4%	1.282	0.263		35.5%	18.0%	1.846	0.179	
	Loser	41.2%	20.8%				34.5%	21.3%				45.3%	15.8%				42.2%	21.4%			
2ndDC-T	Winner	28.5%	17.6%	0.238	0.627		41.9%	22.6%	1.987	0.164		24.8%	18.3%	0.503	0.482		31.9%	21.7%	0.192	0.663	
	Loser	30.8%	20.5%				33.6%	24.6%				28.6%	18.7%				34.4%	23.7%			
2ndAd-Wide	Winner	31.1%	22.1%	8.034	0.006	**	50.8%	25.7%	0.486	0.488		30.8%	21.0%	3.807	0.057	*	45.2%	23.7%	0.138	0.712	
	Loser	45.9%	21.8%				55.6%	29.1%				43.0%	22.0%				47.4%	24.7%			
2ndAd-Body	Winner	39.5%	24.6%	2.677	0.106		30.0%	21.9%	2.089	0.153		36.5%	24.0%	0.041	0.840		33.4%	21.0%	0.041	0.841	
	Loser	31.1%	17.7%				22.8%	17.5%				35.2%	18.2%				34.5%	21.8%			
2ndAd-T	Winner	29.6%	23.5%	1.776	0.187		19.2%	17.9%	0.184	0.669		32.8%	22.5%	3.958	0.053	*	21.4%	20.1%	0.491	0.486	
	Loser	23.0%	17.5%				21.6%	26.2%				22.0%	14.3%				18.2%	16.2%			

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

Table 4

Results of analysis of serve directions of female winners and losers in the Grand Slams

		AO					RG					WD					US				
		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*p*	
1stDC-Wide	Winner	42.8%	13.2%	1.001	0.321		49.6%	25.5%	4.827	0.031	*	44.8%	14.0%	0.224	0.638		48.5%	17.0%	0.499	0.483	
	Loser	46.1%	13.8%				37.9%	18.7%				46.6%	12.9%				45.5%	18.2%			
1stDC-Body	Winner	11.9%	10.5%	3.232	0.077		19.4%	15.2%	4.316	0.042	*	14.8%	10.9%	0.034	0.854		18.7%	18.8%	0.035	0.852	
	Loser	17.0%	13.0%				26.9%	15.0%				15.4%	13.0%				19.5%	12.6%			
1stDC-T	Winner	45.3%	13.2%	6.464	0.013	*	31.1%	21.4%	0.638	0.427		40.3%	11.7%	0.625	0.433		32.8%	16.9%	0.400	0.529	
	Loser	36.8%	14.5%				34.7%	16.5%				37.8%	11.1%				35.1%	13.1%			
1stAd-Wide	Winner	48.0%	15.8%	2.824	0.097		48.1%	21.0%	0.125	0.725		38.0%	17.8%	0.156	0.695		35.5%	15.9%	2.896	0.093	
	Loser	41.5%	16.3%				49.7%	16.2%				39.9%	15.9%				42.2%	16.8%			
1stAd-Body	Winner	7.6%	8.7%	10.388	0.002	**	17.7%	15.0%	0.244	0.623		13.8%	9.1%	0.509	0.479		15.2%	14.2%	0.119	0.731	
	Loser	16.1%	13.0%				19.5%	15.8%				15.8%	10.3%				14.1%	11.3%			
1stAd-T	Winner	44.4%	15.1%	0.306	0.582		34.1%	19.8%	0.424	0.517		48.2%	17.6%	0.665	0.419		49.3%	19.2%	1.686	0.199	
	Loser	42.3%	16.8%				31.2%	18.1%				44.3%	16.4%				43.7%	16.9%			
2ndDC-Wide	Winner	24.2%	23.3%	0.016	0.899		22.3%	23.7%	0.018	0.894		32.4%	32.1%	0.025	0.875		26.5%	22.2%	1.471	0.229	
	Loser	23.5%	25.5%				23.1%	28.7%				31.2%	25.3%				33.6%	26.9%			
2ndDC-Body	Winner	40.3%	16.9%	1.858	0.177		46.2%	23.1%	0.069	0.794		39.3%	23.4%	5.687	0.021	*	52.8%	18.6%	1.858	0.177	
	Loser	46.8%	22.4%				47.7%	24.4%				55.3%	24.8%				45.9%	23.4%			
2ndDC-T	Winner	35.5%	21.4%	1.190	0.279		31.6%	21.9%	0.312	0.578		28.3%	24.3%	7.323	0.009	**	20.8%	14.1%	0.004	0.949	
	Loser	29.8%	21.7%				28.9%	18.1%				13.7%	13.0%				20.5%	19.1%			
2ndAd-Wide	Winner	53.7%	23.6%	1.783	0.186		50.5%	29.4%	0.225	0.637		39.4%	28.6%	0.413	0.523		39.7%	23.1%	0.005	0.942	
	Loser	45.7%	26.3%				53.9%	29.9%				44.4%	27.1%				40.2%	25.7%			
2ndAd-Body	Winner	28.8%	21.1%	2.123	0.150		35.9%	28.7%	0.233	0.631		38.0%	26.6%	0.224	0.638		41.0%	25.0%	0.842	0.362	
	Loser	36.3%	22.0%				32.8%	23.6%				34.7%	24.3%				35.9%	20.9%			
2ndAd-T	Winner	17.6%	12.5%	0.011	0.917		13.6%	13.9%	0.003	0.960		22.6%	15.2%	0.137	0.713		19.4%	18.8%	1.029	0.314	
	Loser	17.9%	14.9%				13.4%	16.7%				21.1%	13.9%				24.1%	19.9%			

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

Table5

Results of analysis of serve influence of male winners and losers in the Grand Slams

		AO					RG					WD					US				
		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*p*		Mean	SD	F	*p*	
1st1-3shots/Won	Winner	70.2%	7.1%	34.606	0.000	****	67.3%	6.1%	32.543	0.000	***	69.6%	6.0%	20.376	0.000	***	69.7%	7.3%	23.465	0.000	***
	Loser	59.2%	8.4%				58.3%	6.6%				61.4%	6.5%				60.9%	7.5%			
1st4-6shots/won	Winner	59.6%	11.4%	29.915	0.000	***	56.4%	9.6%	12.266	0.001	***	56.3%	11.1%	6.081	0.017	*	53.9%	12.6%	2.462	0.122	
	Loser	43.6%	13.1%				48.2%	9.1%				48.8%	9.9%				49.1%	12.2%			
1st7-9shots/won	Winner	60.3%	22.0%	9.799	0.003	**	56.4%	14.5%	2.437	0.124		61.7%	18.6%	7.878	0.007	**	51.8%	16.5%	0.707	0.404	
	Loser	44.0%	21.6%				50.7%	14.5%				46.4%	19.2%				48.3%	17.6%			
1st10+shots/won	Winner	45.2%	28.5%	0.280	0.598		50.8%	20.8%	1.898	0.173		51.3%	23.8%	3.708	0.061		45.1%	18.3%	0.831	0.366	
	Loser	41.4%	31.1%				43.8%	20.1%				37.9%	21.3%				41.1%	17.7%			
2nd1-3shots/won	Winner	60.0%	13.4%	16.383	0.000	***	58.9%	8.4%	23.077	0.000	***	57.1%	7.2%	8.300	0.006	**	57.7%	10.9%	12.183	0.001	***
	Loser	48.2%	11.0%				49.0%	8.1%				50.0%	9.6%				49.1%	9.0%			
2nd4-6shots/won	Winner	57.5%	15.2%	13.827	0.000	***	57.2%	10.8%	16.303	0.000	***	53.3%	11.8%	9.973	0.003	**	54.5%	12.7%	8.829	0.004	**
	Loser	43.9%	15.3%				46.2%	10.9%				41.8%	13.3%				46.2%	10.0%			
2nd7-9shots/won	Winner	59.0%	20.3%	12.119	0.001	***	59.0%	13.1%	4.982	0.029	*	58.6%	21.2%	4.706	0.035	*	59.3%	16.3%	10.572	0.002	**
	Loser	41.8%	21.0%				50.6%	16.7%				44.7%	23.0%				47.2%	13.7%			
2nd10+shots/won	Winner	54.9%	27.3%	13.293	0.001	***	50.4%	24.3%	6.285	0.015	*	53.2%	27.0%	5.866	0.020	*	54.7%	19.1%	11.654	0.001	***
	Loser	33.3%	22.0%				36.0%	21.7%				34.6%	21.8%				38.9%	18.4%			

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

Table6

Results of analysis of serve influence of female winners and losers in the Grand Slams

		AO					RG					WD					US				
		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*p*		Mean	SD	F	*p*	
1st1-3shots/Won	Winner	66.2%	8.2%	26.038	0.000	***	62.6%	8.1%	37.090	0.000	***	66.1%	10.5%	17.997	0.000	***	64.9%	11.3%	15.719	0.000	***
	Loser	56.2%	8.1%				50.5%	8.5%				55.0%	8.2%				53.9%	11.8%			
1st4-6shots/won	Winner	52.2%	16.5%	2.922	0.092		55.7%	14.6%	16.991	0.000	***	56.3%	18.0%	5.234	0.026	*	51.9%	14.5%	6.843	0.011	*
	Loser	45.6%	16.0%				42.6%	11.9%				47.1%	10.0%				43.1%	13.7%			
1st7-9shots/won	Winner	54.9%	28.4%	0.023	0.881		55.2%	28.2%	2.606	0.111		58.5%	27.8%	1.316	0.257		53.7%	25.4%	1.425	0.237	
	Loser	53.9%	28.2%				44.9%	25.1%				50.1%	24.2%				46.5%	24.4%			
1st10+shots/won	Winner	46.7%	31.5%	0.319	0.575		48.1%	34.0%	1.277	0.263		59.0%	34.7%	5.117	0.032	*	48.8%	33.7%	0.466	0.498	
	Loser	41.7%	33.5%				38.9%	27.9%				35.8%	17.1%				42.6%	27.4%			
2nd1-3shots/won	Winner	51.3%	11.1%	10.141	0.002	**	59.0%	10.9%	26.291	0.000	***	57.0%	12.6%	11.252	0.002	**	57.8%	11.1%	28.684	0.000	***
	Loser	43.1%	10.3%				44.7%	12.3%				46.3%	10.3%				44.0%	10.4%			
2nd4-6shots/won	Winner	50.9%	18.8%	8.047	0.006	**	58.5%	15.7%	19.015	0.000	***	54.7%	20.2%	2.768	0.103		54.1%	16.7%	9.009	0.004	**
	Loser	39.5%	14.5%				41.8%	16.4%				46.1%	16.6%				42.9%	14.4%			
2nd7-9shots/won	Winner	57.6%	31.7%	3.499	0.066		63.5%	23.6%	5.349	0.024	*	56.5%	29.7%	0.009	0.924		63.8%	27.6%	5.697	0.020	*
	Loser	43.1%	33.4%				48.7%	29.6%				55.6%	32.4%				48.4%	25.5%			
2nd10+shots/won	Winner						54.7%	36.4%	0.558	0.458		48.2%	26.4%	1.115	0.300		75.7%	31.2%	4.913	0.032	
	Loser						47.5%	36.0%				59.4%	32.2%				55.9%	27.4%			

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

Table7

Results of analysis of serve breakdown of male winners and losers in the Grand Slams

		AO					RG					WD					US				
		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*p*		Mean	SD	F	*P*	
DCwon	Winner	70.8%	8.8%	23.716	0.000	***	67.0%	7.6%	34.839	0.000	***	69.7%	7.3%	20.580	0.000	***	68.8%	7.0%	16.487	0.000	***
	Loser	61.1%	7.8%				56.1%	7.1%				60.2%	7.2%				61.7%	7.4%			
DCAce	Winner	11.7%	5.7%	4.254	0.043	*	5.4%	5.1%	0.914	0.343		9.6%	7.0%	1.495	0.228		8.7%	5.9%	0.293	0.590	
	Loser	9.0%	5.4%				4.3%	3.7%				7.3%	5.9%				7.9%	5.5%			
DC1stIn	Winner	66.3%	6.4%	0.115	0.736		66.3%	6.7%	0.313	0.578		67.1%	5.6%	6.572	0.014	*	62.6%	6.4%	0.246	0.622	
	Loser	65.8%	7.1%				65.3%	7.1%				62.8%	5.9%				63.5%	8.3%			
ADwon	Winner	72.0%	7.5%	28.880	0.000	***	67.3%	5.6%	50.435	0.000	***	68.4%	4.5%	16.652	0.000	***	66.6%	7.5%	25.858	0.000	***
	Loser	60.3%	10.6%				56.2%	6.8%				62.1%	6.1%				57.8%	6.4%			
ADAce	Winner	9.2%	5.7%	0.513	0.476		5.9%	4.0%	3.126	0.082		8.5%	5.7%	0.797	0.377		8.9%	6.0%	2.102	0.152	
	Loser	10.1%	4.9%				4.3%	3.2%				7.1%	4.6%				7.0%	4.4%			
AD1stIn	Winner	66.1%	8.1%	1.546	0.218		66.9%	10.1%	2.269	0.137		60.7%	8.1%	0.012	0.913		60.0%	7.2%	0.007	0.936	
	Loser	63.7%	8.3%				63.5%	7.6%				61.0%	7.7%				60.2%	7.9%			
Wwon	Winner	72.7%	6.9%	19.975	0.000	***	68.8%	6.3%	41.355	0.000	***	72.1%	7.2%	20.959	0.000	***	69.2%	7.4%	26.150	0.000	***
	Loser	63.9%	9.4%				57.2%	8.1%				62.8%	6.9%				60.4%	6.6%			
WAce	Winner	11.1%	6.5%	0.087	0.768		5.5%	4.8%	2.234	0.140		9.6%	8.2%	0.461	0.501		8.4%	5.7%	0.181	0.672	
	Loser	10.7%	5.6%				3.8%	4.0%				8.2%	6.2%				7.8%	4.7%			
W1stIn	Winner	74.3%	10.1%	1.677	0.200		73.9%	9.1%	8.166	0.006	**	71.9%	10.0%	1.672	0.202		66.3%	9.8%	1.103	0.298	
	Loser	71.1%	10.2%				67.6%	8.3%				68.3%	9.2%				68.9%	9.9%			
Bwon	Winner	59.3%	19.0%	6.694	0.012	*	59.4%	15.4%	6.168	0.016	*	57.3%	18.8%	3.049	0.087		56.6%	14.4%	2.797	0.099	
	Loser	49.9%	9.7%				48.8%	18.5%				49.5%	10.7%				51.5%	10.3%			
B1stIn	Winner	22.8%	17.6%	2.267	0.137		34.9%	21.4%	0.559	0.458		27.7%	19.1%	0.312	0.579		27.2%	19.2%	0.615	0.436	
	Loser	29.8%	21.4%				38.7%	18.7%				25.1%	11.5%				23.8%	15.4%			
Twon	Winner	74.6%	8.3%	27.320	0.000	**	69.5%	7.9%	20.154	0.000	***	70.8%	7.0%	8.635	0.005	**	70.6%	8.2%	13.353	0.001	***
	Loser	63.5%	9.4%				60.0%	9.0%				65.2%	6.4%				63.2%	8.4%			
TAce	Winner	14.5%	7.8%	0.718	0.400		8.3%	5.6%	1.059	0.307		13.5%	9.1%	1.995	0.165		13.5%	8.8%	1.543	0.219	
	Loser	12.9%	7.9%				7.0%	4.8%				10.3%	6.7%				11.0%	7.2%			
T1stIn	Winner	76.0%	8.8%	0.005	0.943		73.2%	7.7%	0.004	0.953		74.4%	8.4%	0.075	0.785		73.2%	9.0%	0.800	0.374	
	Loser	75.8%	7.7%				73.3%	9.0%				75.1%	9.4%				75.4%	10.7%			

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

Table8

Results of analysis of serve breakdown of female winners and losers in the Grand Slams

		AO					RG					WD					US				
		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*P*		Mean	SD	F	*P*	
DCwon	Winner	64.0%	8.5%	29.275	0.000	***	62.1%	7.4%	39.186	0.000	***	65.2%	8.2%	16.448	0.000	***	64.5%	9.4%	34.182	0.000	***
	Loser	53.8%	7.2%				50.5%	8.1%				53.0%	12.9%				51.5%	9.2%			
DCAce	Winner	10.3%	6.3%	29.450	0.000	***	3.7%	3.1%	3.403	0.069		7.0%	5.4%	0.179	0.674		7.6%	5.7%	7.707	0.007	**
	Loser	3.7%	3.3%				2.5%	2.4%				6.0%	10.8%				4.3%	3.9%			
DC1stIn	Winner	63.9%	9.0%	4.590	0.036	*	63.7%	7.4%	0.494	0.485		63.9%	6.7%	0.245	0.623		61.6%	11.7%	0.756	0.388	
	Loser	59.3%	9.0%				65.1%	10.1%				62.6%	11.8%				59.3%	10.8%			
ADwon	Winner	64.5%	6.5%	24.232	0.000	***	63.5%	10.2%	36.748	0.000	***	65.5%	8.7%	26.957	0.000	***	64.4%	10.0%	18.427	0.000	***
	Loser	53.4%	11.6%				49.9%	8.4%				52.5%	9.3%				52.5%	13.1%			
ADAce	Winner	8.9%	6.6%	12.042	0.001	***	3.4%	3.6%	0.219	0.641		5.9%	6.0%	5.335	0.025	*	7.1%	6.1%	3.845	0.054	*
	Loser	4.3%	4.1%				3.0%	4.5%				2.6%	4.3%				4.7%	4.4%			
AD1stIn	Winner	57.4%	10.3%	4.098	0.047	*	65.8%	10.9%	0.159	0.692		61.2%	11.0%	1.594	0.213		61.1%	12.2%	0.380	0.540	
	Loser	62.5%	11.1%				64.9%	9.5%				65.0%	10.3%				59.3%	12.6%			
Wwon	Winner	64.8%	7.4%	16.221	0.000	***	64.6%	12.7%	17.544	0.000	***	68.0%	9.9%	15.348	0.000	**	65.1%	11.6%	12.646	0.001	***
	Loser	56.5%	9.8%				53.4%	9.5%				57.4%	9.5%				55.1%	11.9%			
WAce	Winner	10.1%	6.7%	13.834	0.000	***	3.6%	3.9%	0.223	0.639		6.0%	5.6%	6.461	0.014	*	6.6%	5.9%	1.945	0.168	
	Loser	4.8%	5.2%				3.2%	3.7%				2.5%	4.1%				4.8%	4.8%			
W1stIn	Winner	64.7%	10.1%	1.580	0.213		71.4%	13.2%	0.352	0.555		66.2%	17.0%	0.540	0.466		69.1%	13.8%	0.570	0.453	
	Loser	68.0%	11.7%				69.7%	11.8%				69.2%	11.9%				66.3%	17.4%			
Bwon	Winner	54.6%	13.3%	6.270	0.015	*	53.5%	12.5%	9.767	0.003	**	59.7%	12.9%	17.655	0.000	***	56.2%	10.3%	21.990	0.000	***
	Loser	46.3%	14.3%				43.9%	13.3%				42.2%	17.0%				42.9%	13.3%			
B1stIn	Winner	31.1%	19.1%	1.785	0.186		42.7%	17.5%	2.956	0.090		37.0%	18.6%	0.001	0.981		32.9%	20.9%	0.398	0.530	
	Loser	37.3%	20.1%				50.3%	19.6%				36.8%	16.5%				35.8%	17.6%			
Twon	Winner	66.3%	12.1%	12.534	0.001	***	66.8%	12.8%	25.303	0.000	***	66.4%	13.1%	9.927	0.003	**	69.3%	12.2%	18.894	0.000	***
	Loser	56.8%	10.3%				51.9%	12.0%				56.2%	10.2%				56.4%	12.6%			
TAce	Winner	15.7%	13.0%	15.328	0.000	***	6.7%	6.3%	1.754	0.190		10.6%	8.9%	3.549	0.065		14.4%	11.6%	7.538	0.008	**
	Loser	6.4%	5.3%				4.7%	6.4%				6.3%	7.2%				8.3%	6.3%			
T1stIn	Winner	72.4%	9.7%	0.373	0.544		71.7%	8.3%	0.471	0.495		75.2%	12.0%	1.491	0.228		75.0%	10.8%	0.408	0.525	
	Loser	70.8%	12.0%				73.4%	12.8%				79.2%	11.8%				73.1%	13.0%			

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

Finding

Analysis result of serve basic technical and tactical performance between winners and losers

Analysis from Tables 1 and 2, service point win rate: The service point win rates of both male and female winning players are significantly higher than those of losing players (with significant differences in P-values). The average values of male winning players (e.g., AO: 71.2%) are overall higher than those of female winning players (e.g., AO: 64.3%), demonstrating stronger dominance.

First serve points won: The first serve win rates of both male and female winning players are extremely significantly higher than those of losing players (P = 0.000). The average values of male winning players (e.g., AO: 78.3%) are higher than those of female players (e.g., AO: 74.7%), reflecting that male players have better first serve aggressiveness and stability.

Second serve points won: The second serve win rates of both male and female winning players are significantly higher than those of losing players. The average values of male winning players (e.g., AO: 57.5%) are higher than those of female players (e.g., AO: 48.5%), indicating that male players have stronger overall serving strength, and the second serve advantages of female players vary across different Grand Slams.

In terms of Aces: For female players, the average Ace values of winning players in AO, US, and WD (9.5%, 7.3%, 6.3%) are significantly higher than those of losing players (3.9%,

4.5%, 3.3%), with P-values of 0.000, 0.004, and 0.023 respectively; there is no significant difference in average Ace values between winning and losing players in RG (RG: P = 0.221). Female winning players in the Australian Open and US Open enhance their serving threat through Aces, while Aces have low discriminatory power for winning and losing in the French Open and Wimbledon. For male players, there are no significant differences in average Ace values between winning and losing players in the four Grand Slams. Aces have a weaker impact on the outcome of male matches compared to female matches, which may be due to male players' serving strategies, tournament environment, etc. Thus, Aces are not a key serving indicator to distinguish the outcome of male matches.

In summary, service points won (including first and second serves) are crucial to the outcome of both men's and women's matches in the four Grand Slams. The service point win rates (including first and second serves) of male winning players are overall higher than those of female players, demonstrating stronger serving dominance; the impact of Aces on the outcome of female matches varies by Grand Slam, while they have low discriminatory power for the outcome of male matches. Serving-related indicators can serve as important bases for evaluating the performance of male and female players in the four Grand Slams, and there are obvious differences in the serving performance characteristics between male and female players.

Analysis Result of Serve Directions Technical and Tactical Performance between Winners and Losers

Analysis from Table 3 shows the serving direction analysis for male players: In the 1stDC-Body dimension in the AO, the mean value of winning players is 5.6% and that of losing players is 8.9%, with F=4.171 and P=0.045. The proportion of serves by losing players is higher, and the difference is significant (P < 0.05); there are no significant differences between winning and losing players in other tournaments. In the 1stDC-T dimension in the RG, the mean value of winning players is 46.0% and that of losing players is 39.4%, with F = 2.869 and P = 0.095. The proportion of serves by winning players is higher, approaching a significant difference (P is close to 0.05). In the 2ndAd -Wide dimension in the AO, the mean value of winning players is 31.1% and that of losing players is 45.9%, with F=8.034 and P=0.006. The proportion of serves by winning players is higher, and the difference is highly significant (P < 0.01); in the WD tournament, the mean value of winning players is 30.8% and that of losing players is 43.0%, with F = 3.807 and P = 0.057. The winning players have an advantage, and the difference is close to significant.

Analysis from Table 4 shows the serving direction analysis for female players: In the 1stDC - Wide dimension, in the RG tournament, the mean value of winning players is 49.6% and that of losing players is 37.9%, with F = 4.827 and P = 0.031. The proportion of serves by winning players is significantly higher than that by losing players. In the 1stDC - Body dimension, in the AO tournament, the mean value of winning players is 11.9% and that of losing players is 17.0%, with F = 3.232 and P = 0.077. The proportion of serves by losing players is higher, but the difference is close to significant; in the RG, the mean value of winning players is 19.4% and that of losing players is 26.9%, with F = 4.316 and P = 0.042. The proportion of serves by losing players is significantly higher (P < 0.05). In the 1stDC-T dimension, in the AO, the mean value of winning players is 45.3% and that of losing players is 36.8%, with F = 6.464 and P = 0.013. The proportion of serves by winning players is significantly higher (P < 0.05). In

the 1stAd - Body dimension, in the AO, the mean value of winning players is 7.6% and that of losing players is 16.1%, with F = 10.388 and P = 0.002. The proportion of serves by losing players is higher with a relatively significant difference (P < 0.01). In the 2ndDC - Body dimension, in the WD, the mean value of winning players is 39.3% and that of losing players is 55.3%, with F=5.687 and P=0.021. The proportion of serves by losing players is significantly higher (P < 0.05); in the 2ndDC - T dimension, in the WD tournament, the mean value of winning players is 28.3% and that of losing players is 13.7%, with F =7.323 and P=0.009. The proportion of serves by winning players is significantly higher with a relatively significant difference (P < 0.01).

In summary, among male players in the four Grand Slams, some serving directions (such as 1stDC-Body and 2ndAd-Wide in the Australian Open) have a significant or extremely significant impact on the outcome of the match, becoming key factors for winning players to establish advantages; due to the characteristics of different court surfaces (clay, grass, hard court) in different Grand Slams, the technical and tactical effects of serving directions vary. The differences in serving directions in the French Open are low, while some second serve directions in Wimbledon have a potential significant impact on the outcome. These differences provide a basis for understanding the application of serving strategies in men's tennis, optimizing training and match decisions. In the future, we can further explore the precise application logic of serving directions in combination with the characteristics of opponents and court adaptability to improve competitive performance. For female players, under different Grand Slams and serving directions, the differences in the proportion of serves between winning and losing players are obvious. There are significant differences between groups in some dimensions (such as 1stDC - Wide and 1stDC - Body in RG, 1stDC - T and 1stAd - Body in AO, 2ndDC - Body and 2ndDC - T in WD, etc.), reflecting that winning players may have more advantages in specific serving direction strategies. In the future, we can further explore the path of how serving directions affect match results in combination with the tournament environment and players' tactical systems.

Analysis Result of Serve Influence Technical and Tactical Performance between Winners and Losers

Analysis from Table 5 reveals the analysis of men's serving influence: In short rallies (1st1-3shots/won), the mean value of winning players is extremely significantly higher than that of losing players (P < 0.001). The winning advantage of winning players after serving in short rallies is extremely significant, reflecting the tactical value of serving to directly suppress opponents. Medium-short rallies (1st4-6shots/won): Winning players are superior in most Grand Slams (with significant differences in AO, RG, WD), but there is no significant difference in the US Open (US). This indicates that the differentiation between winning and losing in this dimension at the US Open is weaker than in other Grand Slams, which may be related to the court surface and receiving strategies. Medium-long rallies (1st7-9shots/won): Showing diverse characteristics, losing players are superior in the Australian Open (AO), winning players are superior in Wimbledon (WD), and there are no significant differences in the French Open (RG) and the US Open (US), affected by tactical styles and opponents' responses. Long rallies (2nd series and 10+shots/won): The advantages of winning players are generally significant. Winning players have a high winning rate in 2nd short and medium rallies (P < 0.001), and also maintain advantages in long rallies (2nd7-9, 2nd10+), reflecting the role of the continuity of serving tactics.

Analysis from Table 6 shows the situation for female players: Short rallies (1st1-3shots/won): The mean value of winning players is significantly higher than that of losing players ($P < 0.001$). The winning advantage of winning players after serving in short rallies is extremely significant, consistent with the pattern of male players. Medium-short rallies (1st4-6shots/won): Winning players are superior in the French Open (RG), Wimbledon (WD), and the US Open (US), while there is no significant difference in the Australian Open (AO). This reflects that the differentiation between winning and losing in this dimension at the Australian Open is weaker than in other Grand Slams. Medium-long rallies (1st7-9shots/won): There are no significant differences between winning and losing players in the four Grand Slams. Affected by the subsequent tactics of serving and the resilience of opponents' returns, it is difficult to form a stable advantage. Long rallies (2nd series and 10+shots/won): Showing complex differentiation with Grand Slam specificity. The advantage of winning players in 2nd short rallies is extremely significant, but in medium-long rallies (such as 2nd7-9, 2nd10+), the differentiation between winning and losing varies across Grand Slams. It is greatly interfered by the court surface and tactical adaptability, resulting in obvious fluctuations in tactical effectiveness. There is a relatively significant difference in advantages, and the differentiation in this dimension at Wimbledon is weaker than in other Grand Slams.

In summary, both male and female players show a winning advantage for winning players in short rallies (1st1-3shots/won), but there are significant differences in medium-long rallies: Male winning players have more stable advantages in medium-long rallies, while female players show complex differentiation, which is more deeply affected by Grand Slam characteristics and tactical adaptability. Different Grand Slams have different effects on shaping the winning rate of serving influence for male and female players (for example, there is no significant difference in 1st4-6shots/won for male players at the US Open, but female players show significant differentiation in this dimension). This suggests that the effectiveness of serving rally tactics is closely related to gender styles, Grand Slam court attributes, and tournament rhythm. In the future, we can combine serving technical indicators (spin rate, placement) with opponents' receiving data (positioning, return quality) to deepen the transmission mechanism of "tactical execution - match results" and provide support for customizing serving strategies for players.

Analysis Result of Serve Breakdown Technical and Tactical Performance between Winners and Losers

Analysis from Table 7 shows the decomposition analysis of men's serves: In terms of win rates (such as DCwon, ADwon, W won, T won): In the DCwon dimension, the mean values of winning players are significantly higher than those of losing players, with all P-values less than 0.001 (AO: $F=23.716$, $P=0.000$; RG: $F=34.839$, $P=0.000$), indicating an extremely significant advantage in service point win rate for winning players. In the ADwon dimension, across the four Grand Slams, the mean values of winning players are significantly higher than those of losing players with $P < 0.001$ (e.g., AO: $F=28.880$, $P=0.000$), showing an extremely significant advantage. Similar patterns are observed in the W won and T won dimensions, where winning players have far stronger abilities to win points directly from serves in the four Grand Slams than losing players, reflecting the core value of serving as a scoring means.

For ACEs (such as DCAce, ADAce, W Ace, T Ace): In the DCAce dimension, the mean value of winning players in AO is 11.7% and that of losing players is 9.0%, with $F=4.254$ and

P=0.043, indicating a significant advantage for winning players; there are no significant differences between winning and losing players in this dimension in RG, WD, and US, reflecting that male players in the Australian Open have an obvious advantage in scoring with ACEs, while in other Grand Slams, due to the influence of court surfaces and receiving strategies, ACEs have weak discriminatory power for winning and losing. In the ADAce, W Ace, and T Ace dimensions, there are no significant differences between winning and losing players in most Grand Slams, indicating that although ACEs are a highlight of serving, they are not the core differentiating indicator for male players to win in the four Grand Slams.

For service in rates (such as DC1stIn, AD1stIn, W1stIn, T1stIn): In the DC1stIn dimension, the mean values of winning and losing players in the four Grand Slams are close with no significant differences, reflecting that the first serve in-play rate has little impact on the winning and losing of such serving indicators. The AD1stIn, W1stIn, and T1stIn dimensions also show similar patterns, with slight differences in first serve in-play rates between winning and losing players, indicating that in the competition of core serving indicators for male players, first serve stability is not a key distinguishing point, and they rely more on serving quality rather than simply the in-play rate.

In the Bwon and B1stIn dimensions: In the Bwon dimension, for winning and losing players in AO, F=6.694 and P=0.012, showing a significant difference; for those in RG, F=6.168 and P=0.016, showing a significant difference; for those in WD, F=3.049 and P=0.087, showing a difference close to significant; for those in US, F=2.797 and P=0.099, showing a difference close to significant. This reflects that winning players have advantages in multiple Grand Slams under this serving indicator, which may be related to the diversity of serving tactics. In the B1stIn dimension, there are no significant differences between winning and losing players in the four Grand Slams (e.g., AO: F=2.267, P=0.137; RG: F=0.559, P=0.458, etc.), indicating that this indicator has low discriminatory power for winning and losing.

Analysis from Table 8 shows the service point win rates for female players (such as DCwon, ADwon, Wwon, Twon): In the DCwon dimension, the mean values of winning players are significantly higher than those of losing players, with all P-values less than 0.001 (AO: F=29.275, P=0.000; RG: F=39.186, P=0.000), showing an extremely significant direct service point win rate for winning players. In the ADwon dimension, the mean values of winning players are significantly higher than those of losing players with P<0.001 (e.g., AO:F=24.232, P=0.000), showing an extremely significant advantage. Similar patterns are presented in the Wwon and Twon dimensions, where winning players have far stronger abilities to win points directly from serves in the four Grand Slams than losing players, reflecting the core value of serving as a scoring means.

For ACEs (such as DCAce, ADAce, WAce, TAce): In the DCAce dimension, for winning and losing players in AO, F=29.450 and P=0.000, showing an extremely significant advantage for winning players; there are no significant differences between winning and losing players in RG and WD; for those in US, F=7.707 and P=0.007, showing a highly significant difference. This reflects that female players in the Australian Open and US Open have an obvious advantage in scoring with ACEs, while in the French Open and Wimbledon, due to the influence of court surfaces and receiving strategies, ACEs have weak discriminatory power for winning and losing. In the ADAce dimension, the mean value of winning players in AO is 8.9%

and that of losing players is 4.3%, with F=12.042 and P=0.001, showing an extremely significant difference; there is no significant difference between winning and losing players in RG (P=0.641); for those in WD, F=5.335 and P=0.025, showing a significant difference; for those in US, F=3.845 and P=0.054, showing a difference close to significant, indicating that ACEs can be a differentiating indicator for female players to win in some Grand Slams.

For service in rates (such as DC1stIn, AD1stIn, W1stIn, T1stIn): In the DC1stIn dimension, for winning and losing players in AO, F=4.590 and P=0.036, with winning players being better than losing players and a significant difference; there are no significant differences between winning and losing players in RG, WD, and US, reflecting that the first serve in-play rate of female players in the Australian Open has a certain discriminatory power for winning and losing, while it has little impact in other Grand Slams. In the AD1stIn dimension, for the comparison between winning and losing players in AO, F=4.098 and P=0.047, with losing players being superior and a significant difference; there are no significant differences between winning and losing players in this dimension in RG, WD, and US, indicating that first serve stability only has a certain effect on the deuce court and ad court for female players in the Australian Open. Overall, the discriminatory power of female players' serving accuracy indicators for winning and losing is lower than that of win rate indicators.

In the Bwon and B1stIn dimensions: In the Bwon dimension, for the comparison between winning and losing players in AO, F=6.270 and P=0.015, with winning players being superior and a significant difference; for those in RG, F=9.767 and P=0.003, with winning players being superior and a highly significant difference; the mean value of winning players in WD is 59.7% and that of losing players is 42.2%, with F=17.655 and P=0.000, with winning players being superior and an extremely significant difference; for those in US, F=21.990 and P=0.000, showing an extremely significant difference. This reflects that winning players have significant advantages in multiple Grand Slams under this serving indicator, which may be related to the diversity of serving tactics. In the B1stIn dimension, there are no significant differences between winning and losing players in the four Grand Slams, reflecting that this indicator has low discriminatory power for winning and losing.

In summary, service point win rate is the core differentiating indicator for winning and losing among male and female players, with extremely significant advantages for winning players; ACEs play a significant role in some Grand Slams for females, but have limited impact on males; serving accuracy (first serve in-play rate) has low discriminatory power for winning and losing among both males and females, with males relying more on serving quality and females only showing a certain correlation in the Australian Open; the Bwon dimension reflects the advantages of winning male and female players in tactical diversity, with females performing more prominently. These differences provide key bases for understanding the serving tactical characteristics of male and female players and optimizing training.

Discussion

In terms of serving basics: service point winning percentage emerged as a key indicator distinguishing winning and losing players between genders. Male winners exhibited an overall higher winning percentage; for instance, in the Australian Open, male winners had an average winning percentage of 71.2% in the DCwon dimension, compared to 64.3% for female winners. This indicates that male players, on average, possess stronger serving dominance,

potentially stemming from their superior physical fitness, enabling them to deliver more powerful serves. Among female players, in the 1stBody direction, the proportion of serves by losers (16.6%) was significantly higher than that by winners (9.9%), suggesting that losers hit more first-serve body shots than winners, reflecting a distinction between winning and losing performances.

Regarding ACEs, the findings showed gender-specific patterns. ACE performance had a more pronounced impact on female players in specific Grand Slams (e.g., Australian Open, US Open). In the Australian Open, female winners accounted for 9.5% of ACEs, compared to 3.9% for losers (P=0.000), whereas male players showed no significant difference in ACE proportions between winners and losers across all Grand Slams (P>0.05). This suggests that female players may rely more on the explosive scoring advantage of ACEs in specific tournaments, possibly related to overall differences in serving strategies between genders (Fernández-García, & Torres-Luque, 2019 ; Wang& Cui, 2024).

In Terms of Serving Direction and Tactical Performance: Male and Female players also displayed distinct characteristics. In men's tennis, specific serving directions in some Grand Slams significantly influenced match outcomes. In the Australian Open, in the 1stDC-Body direction, winners accounted for 5.6% of serves, compared to 8.9% for losers (F=4.171, P=0.045). The higher proportion of body serves by losers in the deuce court may leave them vulnerable to aggressive returns. In the 2ndAd-Wide direction in the Australian Open, losers accounted for 45.9% of serves, versus 39.5% for winners (F=8.034, P=0.006). This implies that male losers hit more serves to the body in the deuce court and to the wide in the ad court than winners; considering these two directions, they are prone to being attacked by opponents' forehand returns. Thus, male players should formulate serving direction strategies based on the characteristics of different courts. In Wimbledon, winners hit more serves to the ad court T, while losers hit more serves to the ad court wide.

For female serving directions: In the Australian Open, winners hit more first serves to the deuce court T (inside) than losers, while losers hit more body serves to the ad court than winners. In the French Open, winners hit more first-serve wide shots in the deuce court than losers, whereas losers hit more first-serve body shots than winners. In Wimbledon, losers hit more second-serve body shots in the deuce court than winners, while winners hit more second-serve T (inside) shots than losers. These differences may be related to female players' playing styles and court adaptability (Ruslan, & Rauf, 2024; Prieto-Lage, & Gutiérrez-Santiago, 2022; Sánchez-Pay, & Sánchez-Alcaraz,2021).

In terms of the impact of serving on tactical performance, both male and female winners held significant advantages in short rallies (1st1-3shots/won), indicating that a strong serve can quickly establish an advantage in the early stages of a rally. However, in medium-to-long rallies, male winners maintained more stable advantages, while female players' performance was more susceptible to factors such as Grand Slam characteristics and tactical adaptability. For example, in men's medium-short rallies (1st4-6shots/won), winners had significant advantages in most Grand Slams except the US Open; in contrast, female players showed no significant difference in this dimension in the Australian Open, but had significant advantages in other Grand Slams. This further highlights the complexity and gender specificity

of tennis serving performance across different rally scenarios (Hizan, Whipp & Reid, 2015; Torres-Luque, & Fernández-García, 2019; García, Egido, & Luque, 2021).

Breakdown analysis of serving: Across the four Grand Slams, winners outperformed losers in service point winning percentages, including those in the deuce court, ad court, wide, and inside directions. Differences in body serve winning percentages between winners and losers were only observed in the Australian Open and French Open. In terms of first-serve in percentages, winners had advantages in first-serve in percentages for wide directions in the French Open and for the deuce court in Wimbledon, with no significant differences in other first-serve in percentages between winners and losers（Cui et al., 2019；Abidin & Ruslan, 2020；Gao, Liu & Zhang, 2024).

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