

Article

Tactical Evolution of Serve + 1 Sequences in Elite Junior Female Tennis: A Comparison Between U12 and U14 Categories

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Featured Application

The identified sequential patterns establish the empirical baseline of tactical development in junior female tennis, identifying how tactical behaviors shift from predictable, constructive patterns at the U12 stage to more versatile, offensive systems at the U14 stage.

Abstract

The Serve + 1 sequence is critical in tennis, yet its tactical evolution during the key U12-to-U14 transition in elite female players remains under-studied. This study used sequence analysis to compare Serve + 1 patterns and characterize the tactical development between these two age groups. This study conducted an exploratory sequence analysis to identify and compare 1298 points from 12 international tournament matches involving a total of 17 unique players, distributed across the elite U12 ($n = 9$ unique players) and U14 ($n = 8$ unique players) players. Four-event sequences (Serve Direction > Third-Shot Type > Impact Zone > Bounce Zone) were systematically coded. Data were analyzed using sequence dissimilarity analysis (Hamming distance) and discriminative subsequence analysis. A significant tactical divergence was found on the first serve on the deuce court (Pseudo $F = 8.33$, $p < 0.01$; Pseudo $R^2 = 0.018$) and the second serve on the deuce court (Pseudo $F = 3.32$, $p < 0.01$; Pseudo $R^2 = 0.015$). U12 players relied on constructive, predictable patterns, favoring wide serves on the first serve (54.3%) and forehands (63.8%). Conversely, U14 players demonstrated offensive patterns, characterized by an immediate return error after a 'T' serve (33.7% unreturned serves) and the strategic integration of the backhand (36.9%) on second serves. This transition reflects a fundamental shift from point-building to aggressive, point-ending tactical behaviors. These findings provide an initial, exploratory data-driven framework for sequence-based training aligning with the developmental trajectory of junior female players.



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Keywords: female players; serve patterns; tactical development; notational analysis; sequence analysis; sequence dissimilarity analysis

1. Introduction

In modern elite tennis, victory and defeat are most often decided within the first four shots of a rally, a phase accounting for 50–70% of all points [1,2]. This reality places a critical strategic emphasis on the 'Serve + 1' sequence (the serve and the subsequent shot), transforming it into a primary determinant of match outcomes. A player's ability to

effectively link these first two actions, rather than just executing a powerful isolated serve, is fundamental to dominating the opening of a point [3,4].

Yet, despite its established importance, our scientific understanding of this crucial tactical sequence remains surprisingly incomplete, marked by three distinct knowledge gaps.

The first is a persistent gender bias. The majority of research on serve tactics and performance has focused on the men's circuit, leaving women's tennis under-studied [5–7]. This is problematic, as women's tennis possesses different characteristics than men's [8,9]. For example, differences have been documented in the kinematics of the serve motion chain [10] and in how physical attributes like height correlate with serve speed [11]. Tactically, women's tennis exhibits lower ace rates and higher return efficiencies than the men's game. Consequently, female players rarely rely on service power alone to end points, making the subsequent third shot (+1) far more decisive for establishing rally dominance.

The second gap is a lack of attention to the formative stages. The transition from junior categories to the professional elite is a complex process marked by a drastic evolution in physical, technical, and, above all, tactical aspects [12]. At the overall match-play level, junior competitions are broadly characterized by a higher proportion of unforced errors compared to winners and a longer average rally duration [3,9,13]. How young female players structure their Serve + 1 sequences in these critical stages is key to their tactical development but has been scarcely investigated.

Finally, a methodological limitation exists in many prior studies. Traditionally, tactical analysis has been fragmented, evaluating isolated variables such as serve direction, speed, or shot type [1,6,14]. This approach, while useful, fails to capture the dynamic and inter-dependent nature of the game. Tactical decisions are not isolated events but are part of action sequences [15]. While a traditional analysis merely reports the isolated frequency of wide serves, sequence analysis examines how that serve direction actively conditions the selection, contact zone, and trajectory of the third shot [14,16]. By studying the relationship between consecutive actions, sequence analysis uncovers hidden tactical intentions and strategic patterns, providing a deeper and more dynamic view of the game than traditional analyses [17].

Taken together, these gender, developmental, and methodological gaps mean that coaches and scientists are operating with an incomplete and distorted tactical map of female junior tennis. The current evidence base largely reflects male or adult patterns, failing to capture the unique strategic evolution occurring in this critical demographic.

In response to these limitations, the present study aims to analyze and compare the Serve + 1 sequential patterns between elite U12 and U14 female tennis players. By using sequence analysis, the study will explore the most utilized tactical strategies in each age group and examine the tactical evolution that occurs during this critical phase of athletic development. In doing so, this study provides the first sequential analysis tracking Serve + 1 behavioral dependencies between elite U12 and U14 categories during international junior tournaments, establishing an empirical baseline of multi-shot patterns in high-performance female tennis.

2. Materials and Methods

2.1. Sample

A total of 1298 points from 12 matches, corresponding to two international junior female tennis tournaments (Les Petit As and Super Open 12 Auray), were analysed, which are among the most representative tournaments worldwide in these categories. Purposive sampling was employed based on matches from the quarter-final stage onwards during the 2023 editions of the tournaments to ensure a high level of competitive performance. The dataset constitutes an international sample survey composed of elite junior players

representing 11 different nations across Europe, Asia, and North America. To control for tactical symmetry, being a right-handed player was a strict inclusion criterion; matches involving left-handed players were excluded. To maximize the number of unique players and broaden the sample's representativeness, the selection prioritized matches featuring different individuals. The sample was distributed across two age categories (Table 1):

- U12 Category, comprising 9 unique players across 6 matches (608 points). The distribution was as follows: three players were observed in two matches, and six players were observed in one match.
- U14 Category, comprising 8 unique players across 6 matches (690 points). The distribution was as follows: four players were observed in two matches, and four were observed in one match.

Table 1. Descriptive statistics of the sample.

	U14	U12
Number of matches	6	6
Number of players	8	9
Points per match	115.0 ± 22.66	101.33 ± 13.31
Total points	690	608
Shots per match	846.0 ± 362.79	615.50 ± 86.59
Total shots	5076	3693
Games per match	18 ± 4.15	16.5 ± 2.17
Total games	108	99
Total sets	12	12

This age group distinction (U12 vs. U14) served as the independent variable for all subsequent comparisons.

All players in the sample were right-handed (inclusion criterion) and employed a two-handed backhand (post hoc observation). All matches were played on indoor hard courts with a best-of-three-sets format. The sample size employed in this study is considered robust and is consistent with established precedents in the tennis performance analysis literature [18–20].

2.2. Data Collection and Procedure

Match footage was purposively sampled from the official media channels (<https://www.youtube.com/@lespetitsas>, accessed on 25 May 2024) of two top-level international tournaments: Les Petits As (Tarbes, France) and the Super 12 Auray (Auray, France). These events are widely recognized by the European Tennis Federation (Tennis Europe) as the most prestigious worldwide competitions for the U12 and U14 categories, featuring the top-ranked players in the international junior circuit.

To ensure high ecological validity and technical quality, the inclusion criteria for the videos were: (i) broadcast produced by the tournament's official media, (ii) an identical and uninterrupted elevated-rear court camera perspective (behind the baseline) across all analyzed matches, and (iii) a minimum resolution of 720p HD.

A systematic observational methodology was employed to analyze the serve and the immediate third shot of the rally. Video analysis was conducted via Kinovea software (v. 0.8.15; Kinovea Open Source Project, www.kinovea.org) by an expert observer (tennis researcher and high-performance coach, >10 years of experience). The court was divided into predefined zones according to a proposed model [14], as illustrated in Figure 1. Finally, all coded information was systematized in a custom Microsoft Excel spreadsheet (Microsoft Corp., Redmond, WA, USA).

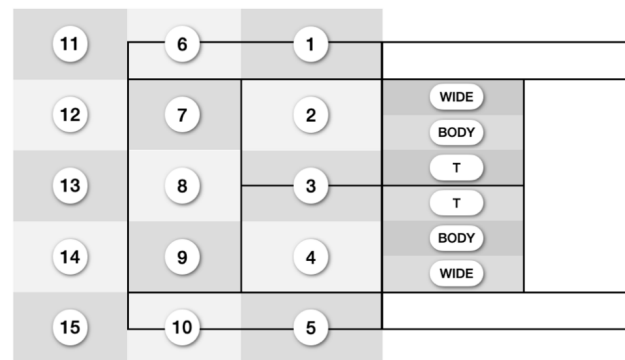


Figure 1. Court zones.

2.3. Sequence Construction and State Definition

For the purpose of sequence analysis, each Serve + 1 rally was defined as a four-event sequence:

[Serve Direction] > [Third-Shot Type] > [Third-Shot Impact Zone] > [Third-Shot Bounce Zone]

The possible states (the “alphabet”) for each of the four events were defined as follows:

- Serve direction: Refers to the ball’s bounce location relative to the receiver’s positioning, categorized into three strategic zones: wide, body, and T (Figure 1).
- Third-shot type: The type of stroke executed by the server after the return. States: Forehand, Backhand, Null. The state was coded as Null if no third shot was played (i.e., due to an ace, service winner, or return error).
- Third-shot impact zone: The court area where the server made contact with the third shot. States: Zone 1 to Zone 15 (per Figure 1), or Null if no third shot was played.
- Third-shot bounce zone: The specific court area where the ball landed after the third shot. States: Zone 2, 3, 4, 7, 8, 9, or Null if no third shot was played or if the shot did not land within the court boundaries. This specific alphabet represents the empirical distribution of all legal, in-bounds third shots observed in the study; any shot landing wide/long or failing to clear the net was categorized as Null.

For example, a point coded as [Wide > Forehand > Zone 14 > Zone 8] indicates a wide serve, followed by a third-shot forehand executed from the deep-cross impact zone, landing in the baseline-center bounce zone.

2.4. Reliability Analysis

An intra-observer reliability analysis was performed on a sample of 50 sequences, re-coded by the same observer with a two-month interval. Cohen’s Kappa coefficient was applied to evaluate concordance for all variables. The analysis yielded specific Kappa values of 0.919 for Serve direction, 1.000 for Third-shot type, 0.832 for Third-shot impact zone and 0.970 for Third-shot bounce zone. These outcomes indicate excellent reliability according to the thresholds established and confirm the robustness of the data collection process [21].

2.5. Data Analysis

Statistical analyses were performed using RStudio (version 1.3.959; Posit Software, PBC, Boston, MA, USA). Descriptive statistics (frequencies and percentages) were reported for each variable. As a secondary analysis to compare isolated frequencies of single tactical variables, Chi-square tests were used to evaluate differences between the U12 and U14 categories for individual variables, with Cramer’s V calculated to determine the effect size. The magnitude of the effect size was interpreted according to the thresholds [22]:

<0.10 (negligible), 0.10–0.20 (weak), 0.20–0.40 (moderate), 0.40–0.60 (relatively strong), and >0.60 (strong). Based on the total sample of 1298 points, a sensitivity analysis ($\alpha = 0.05$, Power = 0.80) indicates that these Chi-square procedures achieve a minimum detectable effect size (Cramer's V) below 0.10, ensuring sufficient statistical resolution to detect even negligible univariate variations.

To address our primary research question regarding overall multi-shot repertoire differences, sequence analysis was conducted using the “TraMineR” package (v2.2-6) [23]. First, a descriptive analysis identified and visualized the most frequent sequences for each age group. Second, a dissimilarity analysis was performed using Hamming distance to compare the overall variability of sequences between U12 and U14, followed by a pseudo-ANOVA. Hamming distance was chosen as it is well-suited for sequences of fixed length where the position of each event is theoretically critical. Unlike Optimal Matching, Hamming distance avoids insertion/deletion operations that disrupt tactical synchrony, restricting comparisons strictly to substitutions at identical positions.

Finally, to identify the specific tactical subsequences that significantly distinguished the two age groups, a discriminative analysis was performed. This analysis used a Chi-squared test on the standardized residuals of subsequence frequencies, applying a Bonferroni correction for multiple comparisons [24]. To ensure reproducibility, this analysis used default constraint parameters (1% minimum support, no maximum length, and no time constraints). Statistical significance for all analyses was set at $p < 0.05$. Although potential pseudo-replication from using individual points was mitigated by maximizing unique competitors, these statistical analyses and p -values should be interpreted cautiously as exploratory rather than strictly confirmatory metrics.

3. Results

3.1. First Serve—Deuce Side

The sequence analysis suggested statistically significant, though small, global tactical divergence between age groups on the first serve from the deuce court (Pseudo $F = 8.33$, $p < 0.01$; Pseudo $R^2 = 0.018$), indicating that the age category accounts for 1.8% of the overall sequence variance.

This tactical dichotomy and the overall distribution of full sequential behaviors (Figure 2) were supported by significant differences at the individual shot level (Table 2). A moderate association was found for serve direction ($\chi^2 = 38.90$, $p < 0.001$, representing a moderate association, $V = 0.29$), with U12 players favoring the wide serve while U14 players predominantly targeted the ‘T’. The third shot also exhibited a significant exploratory trend ($\chi^2 = 11.45$, $p < 0.05$, representing a weak association, $V = 0.16$); U12 players most often executed a forehand (63.8%), whereas U14 players achieved a notably higher percentage of unreturned serves (33.7%). Consequently, the impact zone of the third shot showed suggested a moderate variation ($\chi^2 = 45.47$, $p < 0.001$, $V = 0.32$), with U12 players concentrating their shots in zone 14, while U14s frequently impacted in zone 13.

Discriminative subsequence analysis identified that U14 players were significantly characterized by an offensive, direct subsequence involving a ‘T’ serve that resulted in an immediate return error (T → NULL) (Figure 3). Conversely, the most distinctive subsequence for U12 players was constructive, featuring a wide serve followed by a forehand (WIDE → FOREHAND) (Figure 3).

Deuce Side			
U12		U14	
Sequence	Frequency	Sequence	Frequency
WIDE > NULL > ZONE NULL > BOUNCE NULL	8.6%	WIDE > NULL > ZONE NULL > BOUNCE NULL	10.0%
WIDE > FOREHAND > ZONE 14 > BOUNCE 8	6.7%	T > NULL > ZONE NULL > BOUNCE NULL	5.2%
WIDE > FOREHAND > ZONE 14 > BOUNCE 9	5.7%	WIDE > FOREHAND > ZONE 14 > BOUNCE 7	3.6%
BODY > FOREHAND > ZONE 14 > BOUNCE 9	5.2%	WIDE > BACKHAND > ZONE 13 > BOUNCE 8	3.6%
BODY > FOREHAND > ZONE 14 > BOUNCE 8	3.3%	WIDE > FOREHAND > ZONE 14 > BOUNCE 8	3.2%
BODY > NULL > ZONE NULL > BOUNCE NULL	3.3%	BODY > NULL > ZONE NULL > BOUNCE NULL	2.8%
Advantage Side			
U12		U14	
Sequence	Frequency	Sequence	Frequency
T > NULL > ZONE NULL > BOUNCE NULL	8.2%	T > NULL > ZONE NULL > BOUNCE NULL	8.2%
BODY > NULL > ZONE NULL > BOUNCE NULL	6.0%	WIDE > NULL > ZONE NULL > BOUNCE NULL	4.6%
T > FOREHAND > ZONE 14 > BOUNCE 9	4.9%	BODY > FOREHAND > ZONE 13 > BOUNCE 8	3.6%
WIDE > BACKHAND > ZONE 12 > BOUNCE 8	4.3%	T > BACKHAND > ZONE 12 > BOUNCE 7	3.6%
WIDE > BACKHAND > ZONE 12 > BOUNCE 8	3.8%	WIDE > FOREHAND > ZONE 13 > BOUNCE 7	3.1%
T > BACKHAND > ZONE 12 > BOUNCE 7	3.8%	WIDE > FOREHAND > ZONE 8 > BOUNCE 9	3.1%

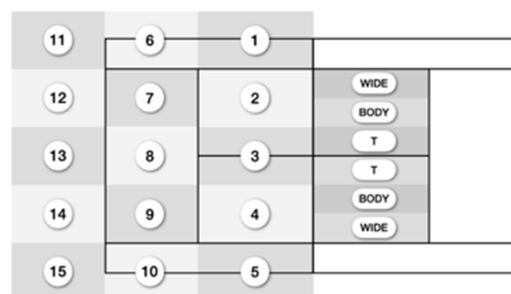


Figure 2. Most frequent sequences for U12 and U14 players on first serve.

Table 2. Serve and third-shot characteristics for U12 and U14 players on first serve.

Variable and Level	n	U12 (%)	U14 (%)	χ^2	<i>p</i>	<i>V</i>	n	U12 (%)	U14 (%)	χ^2	<i>p</i>	<i>V</i>
Deuce Side						Advantage Side						
Serve direction				38.90	<0.01	0.29				4.74	0.09	0.11
Wide	220	54.3 *	42.6				106	23.4	32.3			
Body	122	33.8 *	20.5				118	35.3	27.2			
T	117	11.9	37.0 *				155	41.3	50.5			
Third shot				11.45	<0.05	0.16				0.39	0.82	0.03
Forehand	254	63.8 *	48.2				171	43.5	46.7			
Backhand	131	13.8	18.1				148	40.2	37.9			
Null	74	22.4	33.7 *				60	16.3	15.4			
Impact zone				45.47	<0.01	0.32				17.47	0.13	0.21
7	12	1.4	3.6				39	11.4	9.2			
8	36	7.1	8.4				35	7.6	10.8			
9	32	6.2	7.6				3	0.5	1.0			
11	-	-	-				16	3.8	4.6			
12	36	7.6	8.0				85	22.8	22.1			
13	107	14.8	30.5 *				102	21.7	31.8			
14	114	30.5 *	20.1				30	11.4	4.6			
15	33	12.4 *	2.8				-	-	-			
Null	75	14.3	18.1				60	16.3	15.4			
Bounce zone				19.23	<0.01	0.20				3.14	0.07	0.09
2	14	1.9	4.0				10	2.7	2.6			
3	14	3.8	2.4				19	4.9	5.1			
4	17	5.2	2.4				15	3.8	4.1			
7	103	15.2	28.5 *				82	19.6	23.6			
8	105	24.8	21.3				78	20.7	20.5			
9	95	25.7 *	16.5				74	17.9	21.0			
Null	111	23.3	24.9				101	30.4	23.1			

Note. *n* = total number of points per category; *p* = *p*-value; *V* = Cramer's *V*. * indicates significant differences between groups.

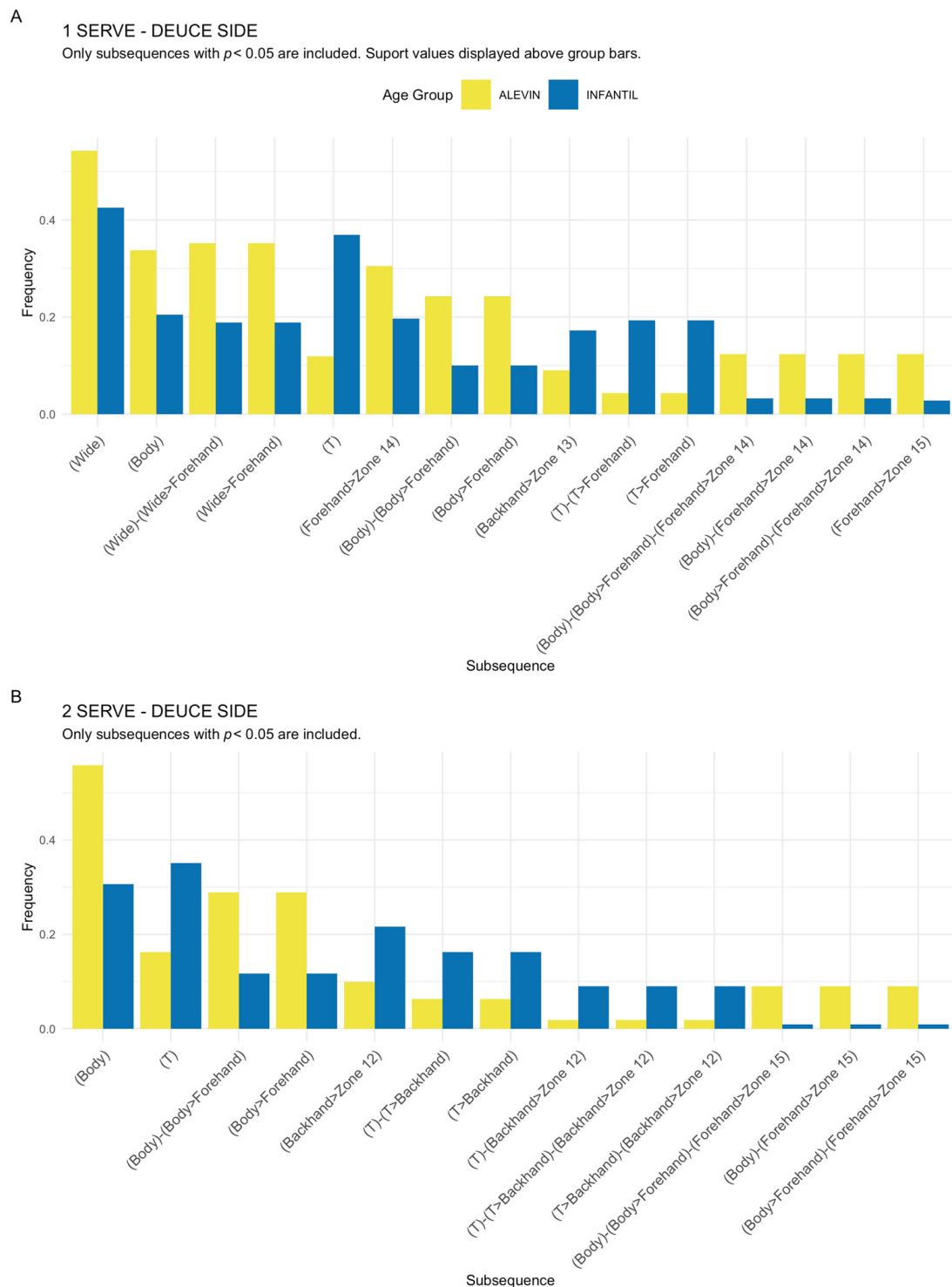


Figure 3. Significant subsequences for the first serves in U12 and U14 players: **(A)** subsequences on the deuce side; **(B)** subsequences on the advantage side.

3.2. First Serve—Advantage Side

In contrast to the deuce court, first serve patterns from the advantage side suggested a strong tactical convergence and homogeneity between developmental stages. The overall sequence repertoires did not differ significantly (Pseudo $F = 1.49$, $p = 0.13$; Pseudo $R^2 = 0.004$). At the full-sequence level, the most common pattern for both U12 and U14 players was identical: an unreturned serve targeted to the 'T' (T > NULL > ZONE NULL > BOUNCE NULL, 8.2% for both groups) (Figure 2).

Discriminative subsequence analysis captured only subtle underlying preferences during point construction (Figure 3). U14 players showed a tendency to execute a BODY → FOREHAND combination terminating in Zone 13, while U12 players exhibited a baseline preference for backhand strokes directed to deep zones (BACKHAND → ZONE 12) (Figure 3).

This similarity was evident at the individual shot level, as the analysis indicated no significant differences between the age groups for serve direction ($p = 0.09$), third-shot type ($p = 0.82$), third-shot impact zone ($p = 0.13$), or bounce zone ($p = 0.79$) (Table 2).

3.3. Second Serve—Deuce Side

The second serve from the deuce court suggested a statistically significant but minor strategic divergence (Pseudo $F = 3.32$, $p < 0.01$; Pseudo $R^2 = 0.015$). While this global effect size is small (explaining 1.5% of the total sequence variance), the underlying specific components revealed distinct distributions. Full sequence distribution data (Figure 4) and discriminative analyses highlighted preliminary trends regarding this tactical dichotomy: U14 players were characterized by an aggressive, frequent T → BACKHAND subsequence, often hitting into Zone 12 (Figure 4). Conversely, U12 players demonstrated a consistency-oriented behavior, prioritizing error avoidance through a structured BODY → FOREHAND pattern (Figure 5).

Deuce Side			
U12		U14	
Sequence	Frequency	Sequence	Frequency
NULL > NULL > ZONE NULL > BOUNCE NULL	15.3%	NULL > NULL > ZONE NULL > BOUNCE NULL	11.7%
BODY > NULL > ZONE NULL > BOUNCE NULL	14.4%	T > NULL > ZONE NULL > BOUNCE NULL	9.9%
BODY > FOREHAND > ZONE 14 > BOUNCE 8	5.4%	BODY > NULL > ZONE NULL > BOUNCE NULL	8.1%
BODY > FOREHAND > ZONE 14 > BOUNCE 9	4.5%	WIDE > NULL > ZONE NULL > BOUNCE NULL	3.6%
BODY > FOREHAND > ZONE 15 > BOUNCE 9	3.6%	WIDE > BACKHAND > ZONE 12 > BOUNCE 8	3.6%
BODY > BACKHAND > ZONE 12 > BOUNCE 8	3.6%	T > BACKHAND > ZONE 13 > BOUNCE 11	3.6%
Advantage Side			
U12		U14	
Sequence	Frequency	Sequence	Frequency
NULL > NULL > ZONE NULL > BOUNCE NULL	13.6%	BODY > NULL > ZONE NULL > BOUNCE NULL	14.1%
BODY > NULL > ZONE NULL > BOUNCE NULL	7.8%	NULL > NULL > ZONE NULL > BOUNCE NULL	10.4%
BODY > FOREHAND > ZONE 14 > BOUNCE 9	4.9%	WIDE > BACKHAND > ZONE 12 > BOUNCE 8	5.2%
WIDE > BACKHAND > ZONE 12 > BOUNCE 8	3.9%	BODY > FOREHAND > ZONE 13 > BOUNCE 8	5.2%
BODY > FOREHAND > ZONE 14 > BOUNCE 4	3.9%	BODY > BACKHAND > ZONE 12 > BOUNCE 9	5.2%
WIDE > FOREHAND > ZONE 14 > BOUNCE 9	2.9%	WIDE > BACKHAND > ZONE 12 > BOUNCE 7	3.7%

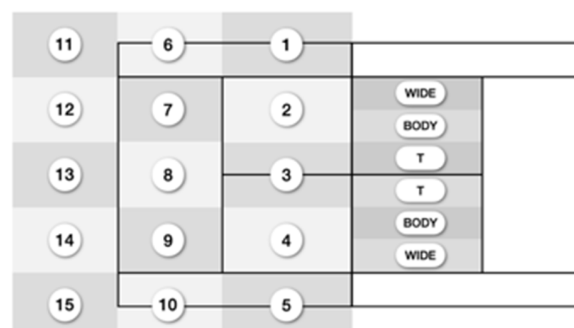


Figure 4. Most frequent sequences for U12 and U14 players on second serve.

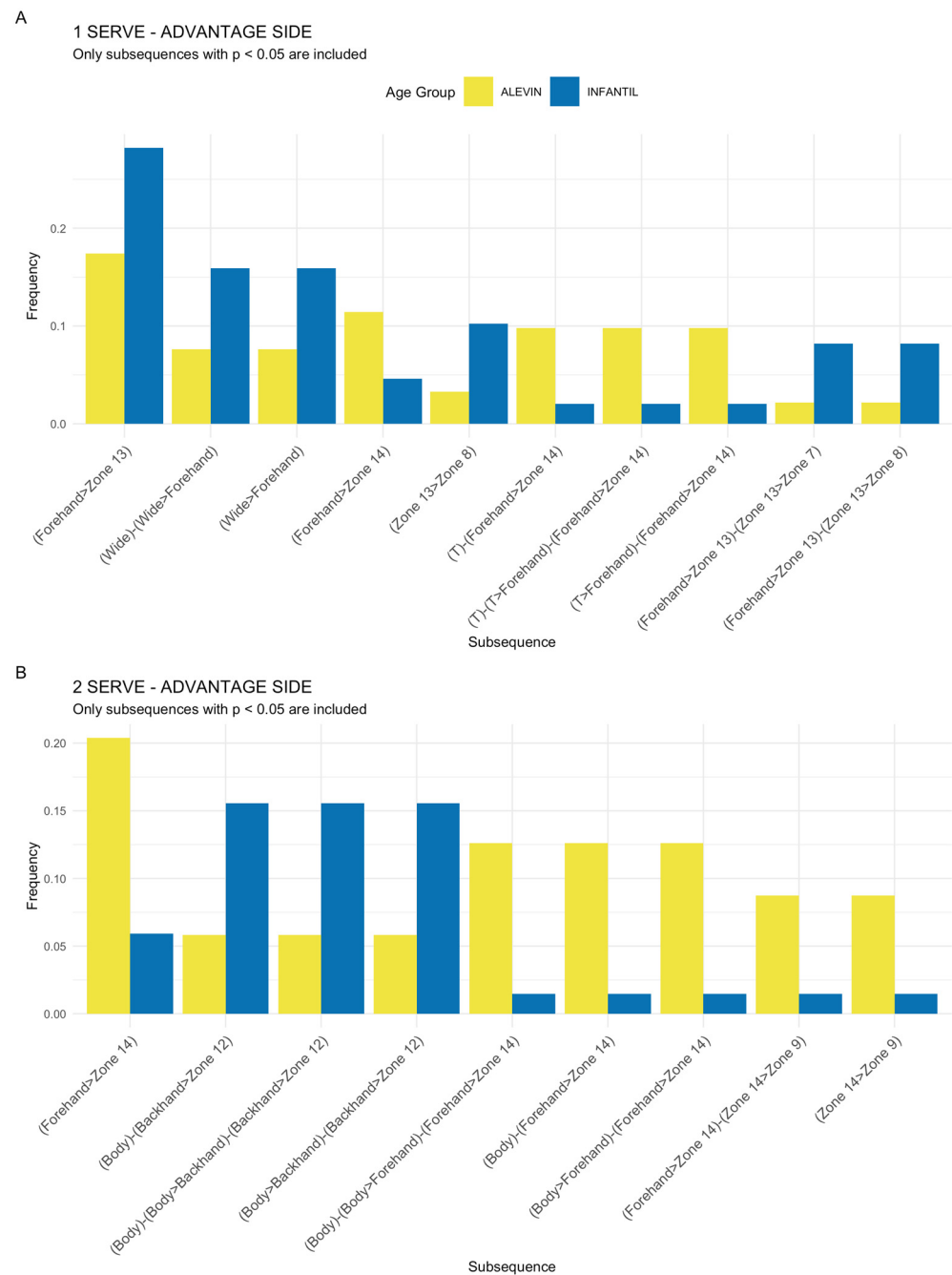


Figure 5. Significant subsequences for the second serves in U12 and U14 players: **(A)** subsequences on the deuce side; **(B)** subsequences on the advantage side.

Significant univariate associations across all individual shot characteristics provided further alignment of these patterns (Table 3). Regarding serve direction, a significant, moderate association was observed ($\chi^2 = 19.54$, $p < 0.001$, $V = 0.30$), with U12 players prioritizing consistency via body serves (55.9%) and U14 players taking more risks toward the 'T' (35.1%). Third-shot type profiles also differed significantly ($\chi^2 = 6.67$, $p < 0.05$, indicating a weak association, $V = 0.17$), showing that U12s relied heavily on the forehand (43.2%) while U14s actively integrated their backhand (36.9%). Finally, both the third-shot impact zone (moderate association, $V = 0.32$) and bounce zone (moderate association, $V = 0.20$) exhibited significant associations under this exploratory framework, U14 players tended to hit more from zone 12 (21.6%) and achieved more bounces in zone 7 (14.4%), whereas U12 players impacted from zone 14 (25.2%) and bounced in zone 9 (14.4%) (Table 3).

Table 3. Serve and third-shot characteristics for U12 and U14 players on second serve.

Variable and Level	n	U12 (%)	U14 (%)	χ^2	<i>p</i>	<i>V</i>	n	U12 (%)	U14 (%)	χ^2	<i>p</i>	<i>V</i>
Deuce Side						Advantage Side						
Serve direction				19.54	<0.01	0.30				1.67	0.09	0.11
Wide	39	12.6	22.5				70	32.0	27.4			
Body	96	55.9 *	30.6				112	42.7	50.4			
T	57	16.2	35.1 *				28	13.6	10.4			
DF	30	15.3	11.7				28	11.7	11.9			
Third shot				6.67	<0.05	0.17				5.28	0.71	0.15
Forehand	81	43.2 *	29.7				84	42.7	29.6			
Backhand	66	22.5	36.9 *				91	26.2	26.7			
Null	75	34.2	33.3				63	31.1	43.7			
Impact zone				13.12	<0.01	0.23				20.34	<0.01	0.30
11	2	1.8	0.0				15	4.9	7.4			
12	35	9.9	21.6 *				67	19.4	34.8 *			
13	36	15.3	17.1				53	23.3	21.5			
14	50	25.2 *	19.8				29	20.4 *	5.9			
15	16	9.9	4.5				-	-	-			
Null	75	34.2	33.3				63	26.2	26.7			
Bounce zone				3.55	0.74	0.13				8.79	0.18	0.19
2	11	6.3	3.6				6	1.9	3.0			
3	8	3.6	3.6				12	2.9	6.7			
4	3	0.9	1.8				8	6.8	0.7			
7	27	9.9	14.4				44	18.4	18.5			
8	54	23.4	25.2				51	20.4	22.2			
9	26	14.4	9.0				33	15.5	12.6			
Null	93	41.4	42.3				84	34.0	36.3			

Note. DF = double fault; *n* = total number of points per category; *p* = *p*-value; *V* = Cramer's *V*. * indicates significant differences between groups.

3.4. Second Serve—Advantage Side

On the second serve from the advantage court, primary strategies converged on a safety-oriented framework characterized by a high frequency of errors and body serves, showing no overall significant difference between sequence repertoires (Pseudo *F* = 1.91, *p* = 0.06; Pseudo *R*² = 0.008) (Figure 4).

Confirming the homogeneity of this sub-context, all other isolated comparisons were strictly non-significant, including serve direction (*p* = 0.09), third-shot type (*p* = 0.71), and bounce zone (*p* = 0.79). However, the analysis pointed to an isolated significant variation exclusively in the third-shot impact zone ($\chi^2 = 20.34$, *p* = 0.009, representing a moderate association, *V* = 0.30; Table 3). When the rally was successfully initiated, U14 players predominantly struck the ball from the deep backhand side (Zone 12 = 34.8%), whereas U12 players impacted more frequently from the deep forehand side (Zone 14 = 20.4%) (Table 3).

This baseline variation was further clarified by the discriminative subsequences (Figure 5), which showed that within this safe framework, U14 players integrated their backhand as a primary tactical tool (BODY → BACKHAND and BACKHAND → ZONE 12). Conversely, U12 players relied on a safe BODY → FOREHAND combination to direct the ball back to their preferred deep forehand zone (FOREHAND → ZONE 14) (Figure 5). This isolated spatial preference is unlikely to indicate meaningful tactical differences, given the systemic homogeneity across all other sequential components.

4. Discussion

By analyzing Serve + 1 sequential patterns, this study provides preliminary insight into the specific tactical progression between elite U12 and U14 female tennis players. Our findings suggest a critical transition from a constructive, forehand-dominant framework to a versatile, offensive strategy, demonstrating that tactical maturation at this elite level is determined by how effectively players chain the first two structural actions of the rally.

4.1. *The Evolving Function of the Serve: From Initiator to Offensive Weapon*

A key finding of this study is the marked evolution of the serve, which transitions from a simple point initiator in U12 players to an offensive weapon in U14 players, particularly on the deuce court. The preference of U14 players for the first serve to the 'T', which led to a high rate of unreturned serves, aligns with previous findings [9,25] demonstrating that the serve's role as a key offensive weapon may begin to emerge by age 14. This proactive strategy, aimed at concluding the point early, aligns with a potentially more advanced tactical orientation consistent with findings in professional players where serves to the 'T' or wide increase success and favor shorter points [26]. This approach aligns with the principle that serve precision improves with experience, increasing the likelihood of unreturned serves and facilitating dominance at the start of the rally [9,27]. However, this tactical outcome must be qualified, as the observed high effectiveness of the 'T' serve may also partially reflect the developing return efficiency and lower defensive quality of junior opponents, rather than purely indicating autonomous tactical sophistication.

In contrast, the U12 players' reliance on the wide serve was more preparatory, designed to open the court for their subsequent forehand. This reflects the patterns described [3], where the third shot in younger players is primarily used to construct the point rather than to seek an immediate winner. This difference was also evident on the second serve from the deuce court. Our results provide a nuanced context to other findings [28], which indicated that junior female players primarily serve to the body. While our U12 players did indeed favor the safer body serve to prioritize consistency, the U14 players exhibited tendencies toward greater tactical confidence by frequently employing the higher-risk 'T' serve, suggesting a potential shift towards a more offensive mentality. These category-specific variations should be interpreted through the lens of structural organismic constraints. Between the U12 and U14 stages, young female tennis players undergo rapid physical growth, averaging a 10 cm increase in stature alongside the development of longer arms and legs [29]. From a biomechanical perspective, the shorter limb levers and lower ball-impact heights characteristic of U12 players significantly restrict their ability to clear the net with sufficient downward angle and margin when targeting the 'T' [29]. Consequently, the observed U12 distribution toward wide and body trajectories should be understood as a necessary physical and experience-based adaptation to guarantee baseline consistency, rather than a purely autonomous tactical preference.

4.2. *Beyond the Serve: The Strategic Integration of the Backhand in Serve + 1 Sequences*

The most profound tactical shifts were observed in the chained Serve + 1 sequences. Our data suggest a clear transition from a predictable, forehand-dominated game in U12s to a more versatile and strategically complex game in U14s. The typical pattern for U12 players, as also noted in previous studies [14], was to serve wide and then play a forehand from behind the baseline, reflecting a heavy reliance on their stronger groundstroke to control the exchange.

A notable indicator of tactical maturation is the U14 players' sequence on the second serve from the advantage court, serving to the body or wide to then attack with their backhand to deep zones on the opponent's backhand side. This pattern points toward an

exploration of how to exploit the opponent's weaker side, using their own backhand not just defensively, but as a strategic tool to dominate the game. This ability to maintain dominance is crucial, as shot depth keeps the opponent out of offensive court positions [30]. Curiously, the tactical homogeneity found on the first serve from the advantage side ($T \rightarrow \text{Null}$ for both groups) suggests a working hypothesis where junior coaches systematically prioritize standardized trajectories on the advantage court to exploit the opponent's backhand or mitigate crosscourt return angles, rather than reflecting a deliberate developmental variation between categories, a finding consistent with the known effectiveness of corner serves in professionals [9].

4.3. Tactical Adaptations and Implications for Training

These findings suggest that a one-size-fits-all coaching approach is not optimal. Instead of prescribing rigid, repetitive drills, coaches should use these discriminative subsequences to design representative learning environments by manipulating task constraints, allowing players to explore tactical adaptations based on their developmental stage [31]:

1. U14 First Serve Deuce-Side $T \rightarrow \text{NULL}$: This serves as a point-ending model. For advanced U12 training, task constraints (e.g., scoring bonuses for unreturnable T-serves) can enhance the exploration of a more conclusive mindset.
2. U14 Second Serve Deuce-Side $T \rightarrow \text{BACKHAND} \rightarrow \text{Zone 12}$: This represents a backhand integration model. Creating game-like scenarios where returners are structurally restricted can foster the emergence of third-shot solutions directed deep to the opponent's backhand.
3. U12 BODY $\rightarrow \text{FOREHAND}$: This functions as a neutral transition baseline. Training should manipulate space constraints to guide U12 players away from predictable, reactive patterns toward active, offensive third-shot selections.

This approach ensures training remains representative, helping coaches design category-specific environments where players dynamically couple perception and action rather than executing automated templates.

4.4. Limitations and Future Research

Several limitations must be acknowledged. First, the global sequence dissimilarities, although statistically significant, showed small effect sizes (Pseudo $R^2 < 0.02$) likely influenced by the large sample size. Consequently, the meaningful tactical differences between categories are better reflected by the moderate effect sizes (Cramer's V) observed in the individual components rather than the global sequence architecture. Additionally, although this cross-sectional study offers valuable baseline data, its design prevents tracking individual tactical development over time. Furthermore, the sample was limited to right-handed players with two-handed backhands on indoor hard courts, and the footage came from only two tournaments, which may reflect specific environmental or tactical conventions. Additionally, the analysis did not account for situational variables like opponent quality, score configurations, or within-match tactical adaptations across sets. Future research should employ longitudinal designs, analyze outdoor environments or different surfaces, and compare these results with male cohorts to identify gender-specific development pathways.

Future research should employ longitudinal and intervention designs, incorporating male cohorts to identify gender-specific pathways. Additionally, expanding this model to U16 and U18 categories will map the complete tactical trajectory toward professional standards. Integrating movement-tracking data (e.g., player positioning and post-serve speed) with these sequential choices will provide a holistic physical-tactical framework for player development and coach education curricula.

5. Conclusions

This study provides preliminary evidence suggesting a critical tactical evolution from U12 to U14 in elite female tennis, characterized by a transition from a constructive, forehand-dominant framework to a more versatile and offensive Serve + 1 strategy. Methodologically, tracking the sequential dependencies of events proved essential to uncovering these subtle patterns of behavior that standard frequency analyses fail to detect. Ultimately, these findings provide a data-driven blueprint for talent development and coach education curricula, offering concrete parameters to design progressive, age-specific training environments.

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Abbreviations

Under 12 years old (U12); Under 14 years old (U14).

References

1. Born, P.; Malejka, L.; Behrens, M.; Grambow, R.; Meffert, D.; Breuer, J.; Vogt, T. Stroke Placement in Women's Professional Tennis: What's after the Serve? *Sport Sci.* **2021**, *3*, 37–45. [[CrossRef](#)]
2. Carboch, J.; Sklenarik, M.; Siman, J.; Blau, M. Match Characteristics and Rally Pace of Male Tennis Matches in Three Grand Slam Tournaments. *Phy. Act. Rev.* **2019**, *7*, 49–56. [[CrossRef](#)]
3. Klaus, A.; Bradshaw, R.; Young, W.; O'Brien, B.; Zois, J. Success in national level junior tennis: Tactical perspectives. *Int. J. Sports Sci. Coach.* **2017**, *12*, 618–622. [[CrossRef](#)]
4. Mecheri, S.; Rioult, F.; Mantel, B.; Kauffmann, F.; Benguigui, N. The serve impact in tennis: First large-scale study of big Hawk-Eye data. *Stat. Anal. Data Min.* **2016**, *9*, 310–325. [[CrossRef](#)]
5. Abidin, A.W.Z.; Ruslan, N.A.S. Exploring the Importance of Players' Characteristics and Performance on Serve and Return of Serve in Winning the Women's Singles Grand Slam Tennis Tournaments. *J. Phys. Conf. Ser.* **2020**, *1496*, 012008. [[CrossRef](#)]
6. Cui, Y.; Gómez, M.-Á.; Gonçalves, B.; Sampaio, J. Performance profiles of professional female tennis players in grand slams. *PLoS ONE* **2018**, *13*, e0200591. [[CrossRef](#)] [[PubMed](#)]
7. Lesyk, M. Women in tennis—A history of the fight for equality. *Kob. Bizn.* **2023**, *32*, 57–67.
8. Carboch, J. Comparison of game characteristics of male and female tennis players at grand-slam tournaments in 2016. *Trends Sport Sci.* **2017**, *24*, 151–155. [[CrossRef](#)]
9. Kovalchik, S.A.; Reid, M. Comparing Matchplay Characteristics and Physical Demands of Junior and Professional Tennis Athletes in the Era of Big Data. *J. Sports Sci. Med.* **2017**, *16*, 489–497. [[PubMed](#)] [[PubMed Central](#)]

10. Whiteside, D.; Bane, M.; Reid, M. Differentiating top-ranked male tennis players from lower-ranked players using Hawk-Eye data: An investigation of the 2012–2014 Australian Open tournaments. In *Proceedings of the 33 International Conference of Biomechanics in Sports 2015*; International Society of Biomechanics in Sport: Konstanz, Germany, 2015.
11. Vaverka, F.; Cernosek, M. Association between body height and serve speed in elite tennis players. *Sports Biomech.* **2013**, *12*, 30–37. [[CrossRef](#)] [[PubMed](#)]
12. Reid, M.; Morgan, S.; Whiteside, D. Matchplay characteristics of Grand Slam tennis: Implications for training and conditioning. *J. Sports Sci.* **2016**, *34*, 1791–1798. [[CrossRef](#)] [[PubMed](#)]
13. Rodríguez, C.; Montoya, J. Analysis of game variables in a tennis match during a national tournament in Costa Rica. *Pensar Mov.* **2018**, *16*, e32480. [[CrossRef](#)]
14. Rodríguez-Campos, M.; Martínez-Gallego, R. Analysis of serve and first shot sequences in U-12 and U-14 tennis players. *ITF Coach. Sport Sci. Rev.* **2024**, *32*, 49–55. [[CrossRef](#)]
15. Carvalho, A.; Carvalho, J.; Araújo, D. Perturbations created from the baseline in tennis: A test of barker’s behaviour setting theory. *Int. J. Sport Psychol.* **2022**, *53*, 51–74. [[CrossRef](#)]
16. Meffert, D.; O’Shannessy, C.; Born, P.; Grambow, R.; Vogt, T. Tennis serve performances at break points: Approaching practice patterns for coaching. *Eur. J. Sport Sci.* **2018**, *18*, 1151–1157. [[CrossRef](#)] [[PubMed](#)]
17. Broadbent, N.; Buszard, T.; Farrow, D.; Reid, M. Scaling junior sport competition: A body-scaling approach? *J. Sport Sci.* **2021**, *39*, 2746–2754. [[CrossRef](#)] [[PubMed](#)]
18. Fernández García, A.I.; Juan Campos, J.M.; Giménez Egido, J.M. Análisis de las variables técnico-tácticas relacionas con el último golpe del punto en el tenis de alto rendimiento. *J. Univers. Mov. Performance* **2020**, *2*, 48–56. [[CrossRef](#)]
19. Martínez-Gallego, R.; Guzmán, J.F.; James, N.; Ramón-Llin, J.; Crespo, M.; Vuckovic, G. The relationship between the incidence of winners/errors and the time spent in different areas of the court in elite tennis. *J. Hum. Sport Exerc.* **2013**, *8*, 601–607. [[CrossRef](#)]
20. Sánchez-Pay, A.; Ortega-Soto, J.A.; Sánchez-Alcaraz, B.J. Notational analysis in female Grand Slam tennis competitions. *Kinesiology* **2021**, *53*, 154–161. [[CrossRef](#)]
21. Landis, J.R.; Koch, G.G. The measurement of observer agreement for categorical data. *Biometrics* **1977**, *33*, 159–174. [[CrossRef](#)] [[PubMed](#)]
22. Rea, M.L.; Parker, R.A. *Designing and Conducting Survey Research: A Comprehensive Guide*; Jossey-Bass: San Francisco, CA, USA, 1992.
23. Studer, M.; Ritschard, G. A comparative review of sequence dissimilarity measures. *LIVES Work. Pap.* **2014**, *33*, 1–47. [[CrossRef](#)]
24. Ritschard, G.; Bürgin, R.; Studer, M. Exploratory Mining of Life Event Histories. In *Contemporary Issues in Exploratory Data Mining in the Behavioral Sciences*; McArdle, J.J., Ritschard, G., Eds.; Routledge: New York, NY, USA, 2013; pp. 221–253. [[CrossRef](#)]
25. O’Donoghue, P.; Ingram, B. A notational analysis of elite tennis strategy. *J. Sports Sci.* **2001**, *19*, 107–115. [[CrossRef](#)] [[PubMed](#)]
26. Prieto-Lage, I.; Paramés-González, A.; Argibay-González, J.C.; Reguera-López-de-la-Osa, X.; Ordóñez-Álvarez, S.; Gutiérrez-Santiago, A. Match Analysis in Women’s Tennis on Clay, Grass and Hard Courts. *Int. J. Environ. Res. Public Health* **2022**, *19*, 7955. [[CrossRef](#)] [[PubMed](#)]
27. Crespo, M.; Martínez-Gallego, R.; Filipcic, A. Determining the tactical and technical level of competitive tennis players using a competency model: A systematic review. *Front. Sports Act. Living* **2024**, *6*, 1406846. [[CrossRef](#)] [[PubMed](#)]
28. Hizan, H.; Whipp, P.; Reid, M. Gender differences in the spatial distributions of the tennis serve. *Int. J. Sports Sci. Coach.* **2015**, *10*, 87–96. [[CrossRef](#)]
29. Germic, A.; Filipcic, T.; Filipcic, A. Anthropometric Characteristics and Somatotype of Young Slovenian Tennis Players. *Appl. Sci.* **2025**, *15*, 8584. [[CrossRef](#)]
30. Martínez-Gallego, R.; Guzmán, J.; James, N.; Pers, J.; Ramón-Llin, J.; Vuckovic, G. Movement characteristics of elite tennis players on hard courts with respect to the direction of ground strokes. *J. Sports Sci. Med.* **2013**, *12*, 275–281. [[PubMed](#)] [[PubMed Central](#)]
31. Torres-Luque, G.; Cabello-Manrique, D.; Hernández-García, R.; Garatachea, N. An analysis of competition in young tennis players. *Eur. J. Sport Sci.* **2011**, *11*, 39–43. [[CrossRef](#)]

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