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Article

Influence of Category and Gender in Temporary Variables in Young Elite Tennis

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Abstract: Background: Understanding the structure of the game during developmental stages makes it possible to design training sessions adapted to the variable characteristics of play. Methods: In this study, we selected 24 matches played by right-handed players in the semifinals and finals of U-12 (Open Super 12–Auray) and U-14 (Les Petits As) competitions. The temporal structure was analyzed by examining total match duration, average duration per set and per game, point duration, and percentage of active time. The formal structure was assessed through the number of sets per match, games per set, points per game, shots per point, and hitting frequency. The research followed a structured, external, and non-participatory observational methodology. Results: The findings revealed no gender-based differences. When grouped by category, however, significant differences emerged: U-12 players exhibited longer point duration ($p < 0.001$) and a higher number of shots per point ($p < 0.001$), whereas U-14 players showed higher hitting frequency ($p < 0.008$). Conclusions: We conclude that the observed changes in game intensity align with prior tactical studies and the expected maturation processes of puberty.

Keywords: tennis; notational; structure; young; gender; category

1. Introduction

Praxiological analysis of sports games examines the set of systems that shape the structure and in-game actions [1]. Along with other performance indicators, it helps to elucidate the complexity of competitive tennis performance [2,3], which is influenced by tactical, technical, and conditioning factors [4]. Several authors [5–7] assert that sports performance analysis should include field-based studies in natural contexts, reflecting the sport's inherent diversity and competitiveness through representative samples. Furthermore, the analysis must consider the influence of both individual and interactive constraints on athletes' behavior [8,9].

Observational methodology [10,11] is well suited for providing a scientific approach to describing and analyzing the sociomotor dynamics of sports performance. Notational analysis based on video recordings is the most commonly employed method to obtain quantitative performance information in a natural context, in a direct and non-participatory manner, without the subjects' awareness, thereby avoiding any potential bias in data collection [12,13].

In net sports with alternating participation, such as tennis, temporal and formal variables are regarded as performance indicators inherent to the game structure, and have been analyzed at various units of observation (match, set, game, and point) [14]. Regarding the intermittent nature of tennis, active time is characterized by moderate-to-high intensity efforts arising from short-duration, repetitive anaerobic actions that involve reactive acceleration and deceleration movements, multidirectional agility, and explosive jumps. However, the large number of rest periods leads to prolonged match durations, highlighting the importance of the aerobic system in recovery [15].

Meanwhile, pause time is governed by ITF regulations [16], which stipulate a maximum of 20 seconds between points, 90 seconds at changeovers when the total number of games is odd, and 60 seconds between sets.

Currently, there is growing interest in identifying and enhancing the tactical variables that determine match outcomes. As in other sports, these variables in tennis are influenced by external parameters stemming from the game—such as ball type, playing surface, the number of sets in a match, and ranking—as well as internal parameters, including category-gender, strategy, level of play, and physical attributes. Most studies have focused on professional tennis, with relatively few examining developmental players. Moreover, many such investigations analyze settings that are far removed from elite competition and fail to account for all playing surfaces and categories, creating gaps in our understanding of the game at these stages [15,17,18].

With regard to total match duration in formative stages, similar values have been reported across categories and genders at both the international and U-18 international competitive levels (77.2–85.0 minutes for males and 77.9–80.6 minutes for females) [18–24]. In comparison, other studies conducted at the national competitive level have found lower durations in the U-14 (65.4 minutes for males and 59.8 minutes for females) and higher durations in the U-16 (108.0 minutes for males and 99.7 minutes for females) [21–23].

Regarding average set and game duration—two parameters that have received relatively little attention in the literature—similarities have been observed for professionals (41.2 min for males and 43.5 min for females) and U-18 (34.6 min for males and 34.2 min for females) at the set level, and for games (174.2–178.6 s for males and 183.8 s for females) [18,25,26].

In terms of point duration, differences have been observed between the U-12 category and other developmental stages (12.1 s in U-12 males; 7.3 s and 6.3 s in U-14; 9.1 s and 9.0 s in U-16; 7.2 s and 8.2 s in U-18) [20–23,27–29]. With respect to gender, similarities have been identified in the U-14 and U-16 categories [21,22], whereas at the professional level, men's point duration was shorter (4.4–7.1 s in men vs. 7.0–7.2 s in women) [21,26–28,30–33].

Concerning the percentage of active time, differences have been reported between categories in males (26.3% in U-12, 27.6% in U-14, 33.6% in U-16, and 21.9% in U-18) [19–22]. Gender-based analysis has not confirmed any differences by category [19,20,22,23,34,35] or by competitive level [21,26,32,36–38].

With regard to the number of sets per match, differences have been found in the U-18 category (2.2 in males and 2.3 in females) and at the professional level in best-of-three matches (2.3–2.6). However, gender-based analyses revealed no differences [18,24,39].

Regarding the number of games per set, this variable has only been investigated in professional players, revealing differences at the general level (9.8 in males and 9.3 in females) as well as specifically on hard courts (9.6–9.9 in males and 9.2–9.3 in females), grass (10.1 in males and 9.6 in females), and clay (9.6 in males and 9.1 in females). Additional discrepancies emerged between male professional matches at sea level (10.1 on hard and 9.9 on clay) versus high-altitude conditions (9.9 on hard and 10.1 on clay) [39,40].

As for the number of points per game, professional males have shown similar values on clay (6.3), grass (6.0), and hard courts (6.2) [41]. In terms of gender, differences have been observed at the general level (6.3 in males and 6.5 in females), on hard courts (6.3–6.4 in males vs. 6.5–6.6 in females), on clay (6.4 in males vs. 6.6 in females), and on grass (6.1 in males vs. 6.4 in females) [40].

Concerning the number of shots per point, general averages ranging from 2.5 to 5.9 have been reported in formative stages [19,20,22,23,34,42]. A comparative study on hard courts between professional and U-18 players found no significant differences for either males (5.0 in professionals vs. 4.8 in U-18) or females (4.6 in professionals vs. 4.4 in U-18) [42]. U-18 females showed similar values on hard courts (2.7) and clay (2.5) [19,34], both of which were lower than the 4.4 reported on hard courts [42]. By gender, similar values have been found on hard courts in U-16 players (5.4 in males vs. 5.9 in females) [22] and U-14 players (4.8–5.3 in males vs. 4.3 in females) [21,29], contrasting with U-12 males (5.7) [20].

With regard to hitting frequency (strokes/min), this variable has been examined in professional players, where significant differences have been observed based on gender and playing surface. Specifically, male players recorded higher values (44.5) compared to female players (42.9). As for the playing surface, hitting frequency was higher on grass courts (45.1 for males and 44.1 for females) than on hard courts (44.0 for males and 42.2 for females) [26].

By age group and gender, U-14 male players exhibit indicators of higher gameplay demands. This aligns with the early and intermediate stages of pubertal development (ages 12–16 for males and 10–14 for females), which directly affect physiological parameters [43] and the physical-motor performance levels of both the upper and lower extremities—key determinants of match success [44]. In this regard, studies analyzing the physical condition of players transitioning from U-12 to U-14 indicate increases in strength, speed, and agility as players grow older. However, while males and females display similar values during the early and intermediate stages of puberty, males experience a marked performance increase relative to females once these stages are completed [45–53].

Based on this review of previous studies examining different variables by gender and category during formative stages, a clear lack of research on younger age groups becomes apparent. Therefore, the aim of this study was to analyze the temporal and formal structures of the game according to gender in the U-12 and U-14 categories.

2. Materials and Methods

Using notational analysis, we investigated the technical-tactical variables pertaining to the temporal and formal structure in a sample of 24 semifinal and final matches—both male and female—held at the “Open Super 12 Auray” (U-12 category) and “Les Petits As” (U-14 category) international tournaments. These two championships are widely recognized as premier global references for competitive development at these stages, requiring participants to either meet the requisite performance criteria or advance through a preliminary qualifying phase. All matches were contested on indoor hard courts under controlled conditions, ensuring identical climatic factors across all encounters.

Participant selection was based on expert judgment and a purposive sampling approach aimed at compiling an elite group of players. The requirement to include only right-handed players competing in semifinal and final rounds from 2017 to 2019 resulted in a total of 35 participants. All matches were played in a best-of-three format with a tie-break in every set. The courts were Category 3 (high-speed) indoor hard surfaces, as classified by the ITF CS 01/02 guidelines.

The study variables are grouped into independent (see Table 1) and dependent variables (see Table 2).

Table 1. Independent variables in the Study.

Independent variable	Groups
Category	U-12
	U-14
Gender	Male
	Female

Table 2. Dependent Variables and their relationship to the game.

Variable Dependiente	Registra
Total match time (min)	Time from the first action of the match until the last
Total set time (min)	Time from the first action of a set until the last
Total game time (s)	Time from the first action of a game until the last
Point duration (s)	Time from the start of a point until its conclusion
Percentage of active match time	The proportion of point-play duration to the total match time
Number of sets per match	Total sets played in the match
Number of games per set	Total games played in each set

Number of points per game	Total points played in each game
Number of shots per point	Total shots executed during a point
Frequency	The ratio of the number of shots to the total active playing time

The match structure was analyzed using VirtualHub 1.10.4 software, which offered a precision of 0.04 s between frames. All variables were recorded upon completion of each point through a sequential notational system (Hughes & Barlett, 2007) specifically developed in Microsoft Excel version 16.16.7 (Microsoft, Redmond, USA).

Regarding intra-observer reliability, the coding of a complete match was repeated one month later, and a Bivariate Correlation was calculated (O'Donoghue, 2010). Table 3 presents the results of the Cohen's Kappa and Bivariate Correlation tests, which indicated a very high level of reliability.

Table 3. Reliability test results.

Variable	Value	Stenght of agreement
Number of sets	1.000	Very good
Number of games	1.000	Very good
Number of points	1.000	Very good
Number of shots per point	0.980	Very good
Point start time	1.00	Very good
Point end time	1.00	Very good

Data obtained from the Excel registration system were exported to SPSS version 26 (SPSS Inc., Chicago, IL, USA). First, we examined the data distribution to check for normality. Depending on the sample size (n) for each variable, we applied either the Kolmogorov-Smirnov test ($n > 30$) or the Shapiro-Wilk test ($n < 30$). Second, to compare the variable data, we employed tests for independent samples.

For variables with a normal distribution, a one-way between-subjects ANOVA was performed, followed by Bonferroni post-hoc pairwise comparisons. We used Levene's test to assess homogeneity of variances. When homogeneity was not met (e.g., in point duration), we carried out pairwise comparisons with Student's t-tests, applying the results corresponding to unequal variances. For variables that did not follow a normal distribution (number of sets per match, number of points per game, and number of shots per point), we used the nonparametric Kruskal-Wallis test. Whenever we found significant differences ($p < 0.05$) in any statistical test, we calculated effect size via Cramer's V, Cohen's d, or partial eta-squared.

3. Results

The results for the temporal structure revealed significant differences in point duration, with higher values in the U-12 category than in U-14 for both male players ($t_{1706}=10.37$; $p<0.001$; $d=0.497$) and female players ($t_{1685}=7.216$, $p<0.001$; $d=0.344$). Significant differences were also found for hitting frequency ($F_3=7.643$; $p=0.001$; $\eta^2=0.534$), as the post hoc comparison indicated a lower mean for U-12 male players (42.20) compared to U-14 male players (46.44).

The results of the formal structure analysis showed significant differences in the number of shots per point ($H_3=98.705$; $p<0.001$), in both male (6.76 in U-12 vs. 4.92 in U-14) and female players (6.14 in U-12 vs. 5.16 in U-14) (see Table 4). With regard to hitting frequency, the one-way between-subjects ANOVA also revealed significant differences ($F_3=7.643$; $p=0.001$; $\eta^2=0.534$). Post hoc comparisons again showed a lower mean for U-12 male players (42.20) relative to U-14 male players (46.44).

Table 4. Results from the analysis of the variables.

	U-12	U-12	U-14	U-14	Gender	Gender	Category	Category
	Male (a)	Female (b)	Male (c)	Female (d)	Effect	Effect	Effect	Effect
	M (DT)	M (DT)	M (DT)	M (DT)	U-12	U-14	Males	Females
					p	p	p	p
Total match time (min)	97.38 (23.44)	94.01 (36.60)	75.85 (19.17)	77.90 (31.06)	1.00	1.00	1.00	1.00
Total set time (min)	37.41 (12.72)	35.67 (11.98)	33.76 (7.81)	31.92 (8.10)	1.00	1.00	1.00	1.00
Total game time (s)	189.66 (91.89)	171.27 (98.68)	163.36 (95.45)	162.07 (94.73)	0.612	1.00	0.149	1.00
Point duration (s)	9.48 (6.98)c	8.76 (6.57)a,d	6.13 (6.49)a	6.41 (7.06)b	0.030	0.275	< 0.001	< 0.001
Percentage of active match time	26.33 (3.99)	25.03 (2.86)	18.59 (4.52)	20.15 (4.52)	1.00	1.00	0.021	0.296
Number of sets per match	2.50 (0.55)	2.50 (0.55)	2.17 (0.41)	2.33 (0.52)	1.00	0.523	0.241	0.575
Number of games per set	9.53 (2.10)	9.67 (2.32)	9.54 (2.11)	8.93 (1.69)	1.00	1.00	1.00	1.00
Number of points per game	6.77 (2.64)	6.66 (2.80)	6.25 (2.70)	6.54 (2.87)	0.588	0.508	0.508	0.508
Number of stroke per point	6.75 (5.15)b, c	6.14 (4.42)a, d	4.94 (3.67)a	5.12 (3.87)b	0.025	0.497	< 0.001	< 0.001
Frequency	42.20 (2.12)c	42.09 (0.91)	46.44 (2.02)a	44.02 (2.67)	1.00	1.00	0.008	0.056

a= significative differences with U-12 male; b= significative differences with U-12 female; c= significative differences with with U-14 male; d= significative differences with U-14 female.

4. Discussion

Average match time

In general terms, the total match duration observed in the U-12 and U-14 categories was consistent with the 90 minute reference for three-set matches in formative stages [18–24,34].

When compared to other research at the international competitive level, the similarities observed in total match duration between categories align with reported values for U-12 male players (77.2 min) and U-18 (77.2–85.0 min for males and 77.9–80.6 min for females) [18–20,24]. By contrast, these findings differ from national and regional-level competitions, where shorter match durations were reported in the U-14 category (62.6 min overall; 65.4 min for males; 59.8 min for females) and longer durations in the U-16 category (103.9 min overall; 108.0 min for males; 99.7 min for females) [21,22].

Focusing on playing surface, the total match duration observed for U-12 male players on clay courts (77.2 min) [20] was lower than anticipated, indicating that the effect of surface type on total match duration may be less pronounced at these stages. Since clay courts are typically slower, one would expect longer matches. In terms of gender comparisons, the observed similarity in total match duration aligns with other studies of formative stages, both internationally and nationally [18–24].

Average set and game time

Regarding total set time, the similarity found between males and females corresponds with data from international competitions at the U-18 level (34.6 min in males and 34.2 min in females) and the professional level (41.2 min in males and 43.5 min in females) [18]. Comparing total game time with other professional-level data (174.2–178.6 s for men and 183.8 s for women) [25,26], our results likewise showed gender similarities. However, by category, game durations were higher in U-12 and lower in U-14, reflecting differences in point-by-point gameplay dynamics.

Point duration

Point duration in both categories followed a decreasing trend as players advanced from the U-12 stage to higher formative levels, likely influenced by a more offensive style of play [38,54]. By gender, the durations for male and female players remained similar (12.1 s in U-12 males; 7.3 s and 6.3 s in U-14; 9.1 s and 9.0 s in U-16; 7.2 s and 8.2 s in U-18) [20–23,28,29,31,56], contrasting with the differences found at the professional level (4.4–7.1 s for men vs. 7.0–7.2 s for women) [21,26,32,33,55].

Regarding surface effects, point duration among U-12 male players on hard courts was lower than the value observed for the same category and gender on clay courts in international tournaments (12.1 s) [20]. In this sense, surface-related differences mirrored those documented at the professional level [21,26,28,30–33,56].

Percentage of active time

Regarding the percentage of active time, U-14 males (18.6%) showed a trend toward significance compared with U-12 males (26.3%), confirming that active time tends to decrease in the male categories as level increases (26.3% in U-12, 27.6% in U-14, 33.6% in U-16, and 21.9% in U-18) [19–22]. When compared with the 20–30% range for active time [17], the findings align with the values for females in both categories and U-12 males, whereas U-14 males fell below this range. In formative stages, variability in the percentage of active time was observed according to competitive level. At the national and regional levels, the U-16 categories (30.1% for males and 31.1% for females) [22] and U-14 categories (27.6% for males and 23.5% for females) [21] exceeded the values for the U-14 category in both genders. Conversely, at the international level, the results for U-18 females (21.6–21.9%) [19,34] were similar to those for U-14 females. Likewise, the U-12 category on clay courts (26.3%) [20] closely matched the same category on hard courts, suggesting that surface type has a smaller impact at these levels than what has been documented in professional competitions [21,26,31,32,36,37].

Number of sets per match

In terms of the number of sets per match, the similarity between categories was consistent with findings for the U-18 category (2.2 in males and 2–3 in females) and professional best-of-three matches (2.3–2.6), yet lower than those in five-set professional men's matches (3.7) [18,24,39]. This indicates that neither category nor gender produced notable differences, whether in comparison with other formative stages or with three-set matches at the professional level.

Number of games per set

As for the number of games per set, the similarity between genders contrasts with the significant differences reported in professional tennis by Carboch (2017) [40], both at the overall level (9.8 in males and 9.3 in females) and specifically on hard courts (9.6–9.9 for males vs. 9.2–9.3 for females), grass (10.1 for males vs. 9.6 for females), and clay (9.6 for males vs. 9.1 for females), as well as with the values for professional men playing at sea level (10.1 on hard courts and 9.9 on clay) versus high altitude (9.9 on hard courts and 10.1 on clay) [39]. Notably, the data for U-12 and U-14 males followed the stable trend reported between 1991 and 2009 on hard courts in professional men's matches (9.5–9.8), as documented by Cross and Pollard (2009) [41].

Number of points per game

With respect to the number of points per game, a longitudinal study on hard courts (6.2) by Cross and Pollard (2009) [41] reported lower values in professional men's tennis than those found for U-12, and values similar to those for U-14. However, another study showed a reduced difference in both men's (6.3–6.4) and women's tennis (6.5–6.6) [40]. By gender, the observed similarities contrast with the significant differences noted in professional tennis between men (6.3) and women (6.5) [40], indicating a shift in how gender influences the early formative stages compared to the professional level.

Number of shots per point

With respect to the number of shots per point, the observed differences aligned with the trend of these values decreasing as players move up to higher categories. Thus, U-12 males (5.7) showed higher values than U-14 males (4.8–5.3) and females (4.3), U-16 males (3.7–5.4) and females (5.4), U-18 females (2.8), and professionals (2.7–4.8 in men and 2.5–2.7 in women) [19–23,28,29,31–34,42,56]. In terms of gender, the values obtained were similar to those reported in other studies at the national competitive level for formative stages (4.8–5.3 in males and 4.3 in females in the U-14 category, and 5.4 in males and 5.9 in females in U-16) [21,22]. Regarding the playing surface, it is noteworthy that the value recorded for U-12 males on clay courts (5.7) [20]—despite clay being a slower surface that

tends to generate more shots—was lower than that observed on hard courts for the same category and gender.

Frequency

Concerning hitting frequency, differences by category and category-gender are consistent with Smekal et al. (2001) [38], who noted that an offensive playing style yielded higher values than a defensive style. When compared with professional players (44.0 for men and 45.1 for women) [26], the values for U-12 players of both genders and U-14 females were lower, whereas U-14 males recorded higher values. This may be explained by the current increase in game intensity. In terms of gender, the similarities observed contrast with the differences reported in professional tennis [26], indicating a change in how gender influences the earlier formative stages relative to the professional level.

5. Conclusions

The total match times in the U-12 and U-14 categories align with the reference of 90 minutes for three-set matches at formative stages, coinciding in part with international-level research. However, discrepancies arise when compared with national and regional studies: match durations in U-14 tend to be shorter, while those in the U-16 category are typically longer. Additionally, surface type does not seem to exert as strong an influence on match duration in these categories, in contrast with what occurs in professional tennis.

Point duration decreases as players move up through the categories (from U-12 to U-18), consistent with the progressive adoption of more offensive styles of play. Regarding the percentage of active time, it tends to drop in the male category as age increases, falling below the reference range (20–30%) in U-14 male players, whereas U-12 male and female players remain within this interval. This progression shows that moving up to a higher category changes the game's dynamics, impacting both playing time and rally intensity.

The number of sets per match is quite similar across categories and genders, mirroring findings for the U-18 category and professional three-set matches; this pattern differs from men's professional tennis played best-of-five. Concerning the number of games per set and points per game, fewer differences are observed between boys and girls at formative stages compared to the professional level. Additionally, the values recorded in U-12 and U-14 may be higher than in professional tennis, although they tend to approach the levels observed in U-14 male players.

The number of shots per point progressively decreases as players move up in category, meaning the highest values appear in U-12 and gradually drop in U-14, U-16, U-18, and eventually professional tennis. This trend supports previous evidence linking competitive maturity to a more direct style of play. Regarding hitting frequency, similar values are noted during formative stages, contrasting with the pronounced gender differences observed on the professional circuit, suggesting that gender has a lesser influence in early stages of athletic development.

Although the sample in this study comes from internationally renowned tournaments (Open Super 12 Auray and Les Petits As), the total number of matches analyzed (24) is limited for extrapolating results to other U-12 or U-14 events, primarily because the research focused exclusively on semifinal and final rounds under specific indoor hard-court conditions. Thus, the findings may offer only a partial perspective on competitive dynamics in earlier stages of play. Future research should consider including preliminary rounds and additional international tournaments on different surfaces and in outdoor conditions to encompass various player profiles and playing styles. Moreover, a longitudinal approach tracking the same cohorts of players over multiple seasons would help identify developmental patterns and sporting progression.

These findings can inform coaches, physical trainers, and talent-development specialists on training-planning and tactical decision-making, particularly concerning how to integrate competition into training sessions and how to apply exercise intensities and loads that are specific to each category

and gender. This approach maximizes learning experiences and facilitates holistic growth among young athletes, helping them progress toward higher categories.

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Abbreviations

The following abbreviations are used in this manuscript:

MDPI	Multidisciplinary Digital Publishing Institute
DOAJ	Directory of open access journals
TLA	Three letter acronym
LD	Linear dichroism

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