Full Title: Macro periodisation of competition in international women's tennis: insights for long-term athlete development

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Abstract

Aims: This study reports the multi-year periodised international competition engagement of elite top 100 [T100] and 250 [T250] female tennis players during their youth.

Methods: Tournament data was analysed for 258 female players from 13-18y of age. Players were categorised into groups based on peak professional ranking of T100 or T250. "Fast" or "slow" achieving T100 players were further classified according to the years taken to achieve a professional T100 status. International tournament and match volumes were quantified for junior and professional categories, along with measures of competition density (i.e., time between tournaments and consecutive tournaments). Tournament quality and category was determined by ranking point offerings. A two-way analysis of variance determined the effects of age and ranking group on tournament play.

Results: Significant interaction effects for age and ranking group were observed for all junior and professional category tournaments ($p<0.05$). Significantly higher annual junior tournament volumes featured in the schedules of T100 at ages 14 and 15 ($p<0.05$) while participation in annual professional tournaments increased for all players at ages 17 and 18 ($p<0.05$). Top 100 players played more annual matches than the T250 group at 14-16y ($p<0.05$). Significant main effects for age revealed decreased days between tournaments and increased consecutive tournaments at 15y ($p<0.05$).

Conclusions: Increased volume and density of tournament-play exists from 14y in professional female tennis players. Faster achieving T100 players contest higher-quality junior and professional tournaments at earlier ages. These distinctive tournament characteristics can underpin training and competition scheduling recommendations used by national tennis federations.

Key Words: racquet sports, junior development, athlete planning, player pathways

Introduction

A central tenet of long-term athlete development in sport is striking an appropriate balance between competition and training [1]. The starting point for many sports is to chunk this development in annual cycles, and then organise the yearly calendar in blocks of training and competition [2]. Most adolescent sporting pathways are defined by structured competition activities that exist to facilitate performance milestones at key development ages (e.g., 13-18y) [3, 4], whilst ensuring appropriate training exposure and physical/psychological recovery is considered. This provides certainty for coaches and support teams to plan competition and then training stimuli in accordance with expectations for age and performance. However, in tennis classic models of periodisation are challenged given the dense competition calendar and a ranking system that incentivises frequent and international travel from young ages [5-7]. Indeed, tennis, as with many other sports, still lack empirical evidence surrounding the volume and distribution of tournament exposures to guide annual competition planning and resultant training time during the critical transition from organised junior sport to the professional or elite sporting world. Accordingly, this paper aims to report the international tournament and match volumes alongside their annual distribution during the adolescent years in future successful female tennis players.

The balance between training and competition in tennis has been inherently biased towards the 'year-round' tournament opportunities for aspiring and current professionals [8, 9]. The regular competition exposure may be compounded by geographical region, such as Europe, where a close proximity of countries allows heightened access to international-level tournaments to earn ranking points against high-quality opposition [10, 11]. Indeed, success in competition fuels the accumulation of ranking points for career progression on the junior and professional tours and forms the basis of annual periodisation in tennis [12, 13]. Drawing upon examples from the

men's game, future professional players increase their international junior tournament participation at 15-16y, with an almost exclusive involvement in professional events by 18y [14]. International tournament play has also been noted to feature prominently in the women's game at 15-16y (≈19 international-level tournaments and ≈56 matches) [15]; however, age eligibility rules - introduced in 1995 - limit professional play for female players aged <17y [16]. These regulations minimise deleterious health outcomes from high professional competition loads, which historically were more accessible for female players given their earlier physical maturation [17]. Indeed, this policy intervention has delivered fewer early retirements and improved career longevity [18], but has stopped short of providing any guidance on the recommended tournament exposures (including the volume and distribution of events) for emerging players over time. Federations have attempted to fill this void by suggesting that high-performing juniors play 22-25 tournaments and 60-100 matches during their professional transitions (i.e., 16-18y) [13]. Clearly though, these recommendations are blunt and do not consider the type, frequency, or distribution of tournament exposures as part of long-term athlete development.

The structuring of competitive opportunities alongside appropriate training time for physical and skill development is a key pillar of long-term player development [19]. In tennis, many long-term player development plans are based around the future attainment of top 100 rankings [20, 21] that are informed by age-relevant ranking benchmarks (i.e., an *outcome*) [12] but often fail to contextualise this in terms of tournament volume, type and distribution (i.e., a *process*). This becomes even more relevant in female tennis, where age eligibility constraints remain in late adolescence, yet female players still progress to the top 100 faster than in men's tennis [12]. This study addresses these gaps by quantifying the international tournament and match profiles of future T100 and T250 professionally ranked female tennis players across the adolescent

pathway (13-18y) with a view to advancing practical recommendations for periodisation in tennis.

METHODS

Participants

This study focused on historical tournament engagement characteristics of future T100 and T250 professionally ranked WTA players across their junior development pathway. Player data was analysed from their International Tennis Federation (ITF) junior tour eligibility (i.e., the day of 13th birthday to the end of their 18th birth year) in accordance with previous methods [14] and based on final highest WTA ranking. The initial sample of players obtained from the ITF included all players who competed in the main or qualifying draw at a junior or professional event from January 1st, 2000 through to December 31st, 2015. Further processing of player data was performed to remove players born prior to the year 1987, which ensured completed tournament activity from ages 13-18y could be obtained. Player ranking and tournament data was obtained from publicly available domains including the official websites of the ITF and WTA. The ranking milestones for each player included the dates of their peak junior ranking, first professional ranking and entries into the T100 and T250. This study was approved by the University Human Research Ethics Committee (ETH19-3951). Athlete consent was not provided or required for this study due to all data being on public domains.

Eligible players were those who achieved a peak professional ranking inside the T100 or from 101-250 within the years 2000-2015. Additionally, only players who existed in their 13th birth year through to their 18th birth year in the dataset were considered in the analysis. Players who were previously active on the junior or professional tours prior to the start of 2000 were removed to ensure that the entire junior pathway was analysed for all participants. To account

for the individual variability in which players obtain their peak professional ranking status, players in the T100 category were subdivided. Groupings were devised based on previous research highlighting the average time from first professional point to attainment of a ranking inside the T100 to be, on average, four years [12]. Players classified in the T250 group were determined as per previous methodologies [14] and supported by other literature that identified only three female players achieved a T100 status seven years after reaching the top 200 [22]. As a result, three groups were considered for analysis;

- T100-fast (T100-F). T100 players achieving their ranking ≤4 years from first professional ranking point (n = 86),
- T100-slow (T100-S). T100 players achieving their ranking >4 years from their first professional ranking point (n = 57),
- T250 (T250). Players achieving a T250 rank and meeting at least one of the following criteria (n = 115):
    - Are ≤8 y removed from first professional ranking and have been in T250 for >4 y
    - Are >8 y removed from first professional ranking and have been in T250 for >4 y
    - Are >8 y removed from first professional ranking and have been in T250 for ≤4 y

Data Collation

International tournaments played annually across each birth year were identified and classified according to a category for both the junior and professional circuits based on the possible ranking points earned. For the junior tour, Category 1 tournaments were inclusive of Grade A and Grade 1 junior ITF events, Category 2 tournaments included Grade 2 and Grade 3 junior

ITF events with Category 3 including Grade 4 and Grade 5 junior ITF events. For the professional tour, Category 1 tournaments were the four Grand Slams, Category 2 were WTA tour tournaments, Category 3 were ITF Series events ($100k, $80k, $60k) and Category 4 included ITF series events ($25k, $15k). Tournaments not provided in this dataset were local tournaments governed by the respective national tennis Federations for included players.

To provide further detail on annual competition engagement, descriptions of annual match volume and quality included; total matches played, total junior matches played, total professional matches played, days between each tournament and number of consecutive tournaments. Consecutive tournaments were defined as any tournament, regardless of tour or category, that started less than eight days of the previous tournament. Walkovers were noted and excluded from the match analysis. Matches played were inclusive of both singles and doubles matches. Potential instances where players were eligible to compete on the junior circuit but did not play tournaments that year (e.g., injury), they were attributed with a '0' to determine the true competition engagement of the cohort. This was only applicable to tournament and match volumes.

Statistical Analysis

All statistical analysis was performed in the R language (RStudio, 1.1.463, RStudio, Inc.). Descriptive measures of the mean and standard deviation were reported for all tournament and match variables and reported annually for each birth year. Data normality was assessed via a Shapiro-Wilk test and resulted in the log-transformation of data prior to analysis due to non-uniformity. A two-way (age x ranking group) analysis of variance (ANOVA) was used to determine the effects of respective age and ranking groups on competition engagement metrics.

178 Tukey's post-hoc test was implemented on findings of significance with a Bonferroni
179 correction to reduce risk of Type I error. Significance was set at 0.05.
180
181 **Results**
182 As a visual representation of match-play density, Figure 1 shows the average number of
183 matches played per month of future T100 and T250 players by age group. For T100 players,
184 an increase in monthly match-play exposures >7 matches exists from age 14y, with T250
185 players subject to increasing match-play density from 15y. At ages 16 and 17, T100 females
186 experience peak match loads of greater than 10 matches per month.
187
188 ***FIGURE 1 NEAR HERE***
189
190 *Annual Junior Tournaments Played*
191 Figure 2 shows the junior tournament volumes across each age for all ranking groups.
192 Significant interaction effects were observed for junior category 2 tournaments, with greater
193 tournament volumes for T100-F players compared to T250 players at ages 14 and 15 (p<0.01;
194 Figure 2A). Further, a significant main effect for age was observed and indicated that junior
195 category 1 tournament volumes increased at ages 14, 15 and 16, followed by a reduction at
196 ages 17 and 18 (p<0.05). For junior category 2 tournaments, significant interaction effects were
197 observed for age and ranking group and revealed greater tournaments played by T100-F players
198 compared to T250 players at age 14 (p<0.01; Figure 2B). However, no significant interaction
199 effect existed when comparing T100-S and T250 players at age 14 (p=0.06). A significant main
200 effect for age in junior category 2 tournaments showed a peak in volume at age 15, which was
201 followed by a significant reduction at ages 16, 17 and 18 (p<0.05). Lastly, a significant
202 interaction effect for age and ranking group existed for junior category 3 tournaments, showing

higher tournament volumes from T100-F players at age 14 compared to T250 players (p=0.02; Figure 2C). A significant main effect for age also showed reduced tournament volumes at age 16 and 17 (p<0.01).

*****FIGURE 2 NEAR HERE*****

Annual Professional Tournaments Played

Professional Grand Slam tournament volumes are presented in Figure 3. Significant interaction effects for age and ranking group existed and revealed greater tournament volumes for T100-F players at age 17 compared to T100-S and T250 players (p<0.01). Post-hoc analyses identified that T100-F and T100-S players engaged in more Grand Slam tournaments at age 18 than T250 players (p<0.01). A significant main effect for age was observed for increased tournament volumes at age 17 and 18 compared to all other ages <17y (p<0.01; Figure 3). For professional category 2 events, a similar pattern was observed, with significant interaction effects for higher tournament volumes at age 17 and 18 in T100-F players compared to T100-S and T250 players (p<0.01; Figure 3E). Further interaction effects for category 2 professional tournaments showed T100-S players engaging in greater tournament volumes at ages 17 and 18 versus T250 players (p<0.01). For this tournament category at age 16, only T100-F players competed in a significantly higher number of tournaments compared to T250 players (p=0.01; Figure 3E). A significant main effect was observed for age, with increased category 3 professional tournaments at age 16y (p<0.01; Figure 3F). Analysis of category 4 professional tournaments revealed significantly greater volumes for T250 players at ages 17 and 18 compared to T100-F players (p<0.01; Figure 3G).

*****FIGURE 3 NEAR HERE*****

228

229 *Annual Match and Tournament Distribution Variables*

230 For total matches played, a significant interaction effect showed T100-F engaged in more
231 matches at ages 14 through 16y when compared to T250 players (p<0.01; Table 1).
232 Additionally, T100-S players contested significantly more matches at age 14 compared to T250
233 players (p<0.01). Significant main effects for age showed increased total match volume at ages
234 14, 15 and 16y (p<0.01; Table 1A).

235

236 Junior match volumes showed a significant interaction effect for age and ranking group, with
237 higher match volume for T100-F players compared to T250 players at age 14 (p=0.01; Table
238 1B). Further, a significant main effect for age was observed for junior match volumes, with
239 Tukey post-hoc testing revealing higher match counts at ages 14 and 15y than ages 13-14y
240 (p=0.01 and p<0.01, respectively). Additionally, significant reductions in junior matches were
241 observed at ages 17 and 18y (p<0.01). Match volumes for professional events (Table 1C)
242 showed significant interaction effects for age and ranking group, with an increased number of
243 professional matches at age 14y in T100-S players compared to T100-F players (p=0.03).
244 Additional interaction effects for a lower volume of professional matches played by T250
245 players compared to T100-S and T100-F players at ages 15 and 16, respectively (p<0.01 and
246 p=0.04, respectively). A significant main effect for age existed, with increases in professional
247 match counts at each age from 14-18y (p<0.01).

248

249 Days between tournaments are shown in Table 1D. No significant interaction effects for age
250 and ranking group were observed (p=0.51). A significant main effect for age existed, with
251 Tukey's post-hoc testing revealing a progressive reduction in days between tournaments at
252 ages, 15, 16 and 17 (p<0.01). Further, a significant main effect for ranking group was observed

between T100-F and T250 players (p<0.01; Table 1D). Finally, counts of consecutive tournaments are reported in Table 2, with significant interaction effects observed for age and ranking group (p<0.05). Tukey's post-hoc analysis revealed T100-S players engaged in more consecutive tournaments compared to T250 players (p<0.01). Further, significant main effects existed for both age and ranking group (p<0.01), with post-hoc testing showing consecutive tournament volume increased in each age group from 14-18y (p<0.01; Table 2).

*****TABLE 1 NEAR HERE*****

*****TABLE 2 NEAR HERE*****

Discussion

This study quantified the international tournament and match profiles of future T100 and T250 professionally ranked female tennis players across the adolescent pathway (13-18y). Significantly higher annual junior tournament volumes featured from age 14, and professional tournaments from age 17, while T100 players played more annual matches than the T250 group in the formative adolescent years. As players aged, competition scheduling was also characterised by increasing the number of annual events played in a consecutive manner alongside a decreasing number of days between tournaments and likely indicates a 'block-based' approach to tournament periods as players age. Further, dense periods of match-play in January and May (Figure 1) during late adolescence likely reflects players maximising success at the Australian Open and Roland Garros. Taken together, these observations can guide age-appropriate annual periodisation for aspiring professional female players hoping to accelerate their transition to the T100 while respecting the sport's age eligibility policies.

Junior tournament engagement during early adolescence is capped by ITF regulations of 10 (13y) and 14 (14y) annual events to provide age-appropriate training time [23]. Our results show an overall progression of annual junior events (13y: 3-10, 14y: 6-14 events) that appear consistent with players capitalising on their maximum allotted tournaments; especially future T100 players (Figure 2). Interestingly, the distribution of events and matches played at 13 and 14y of age is spread throughout the year for T100 players, with no month in the tournament calendar appearing 'match-free'. Notwithstanding the sample sizes and representing nations amongst these cohorts being comparatively small, it does highlight the scheduling demands of international tennis at young ages and may prompt governing bodies to consider both the timing and volume of regulated competitive opportunities for players [24]. Such consideration would likely assist the provision of greater training exposures for developing players as well as a more balanced annual plan that offers more rest.

As players progress through to mid-adolescence, much of the focus shifts to the quality of the tournament results and how players are tracking against key competitive milestones. For example, winning a junior ITF title prior to 15y or winning a Grade A junior event before 17y [25] have been linked to future top 10 success, and appear to align with the playing behaviour observed among 14-15y T100-F players in the current study. Anecdotally, many coaches will discuss players not "skipping" levels (in other words, they should try to achieve success at each level of the tournament hierarchy), but once this is achieved, they can 'fast-track' their transition to the professional circuit. We can observe this feature in the professional match-play volumes in many of the T100-F players at age 17-18y in the current study (Table 1). However, one of the systemic risks in a focus on fast transitions, or precocious success, is that players who develop their games later are not afforded the same competitive opportunities, which represents a known challenge for the sport's policy makers.

There can be ill-effects with a disproportionate emphasis on competition play, with burn-out and compromised conditioning not uncommon [26, 27]. The present study reported days between tournaments alongside consecutive tournaments to infer competition congestion, which is known to influence recovery in other sports [28]. These additional metrics of competition density speak to the demands of the professional transition in tennis, given ≤3 weeks of recovery time typically exists between tournaments at 17-18y. Possible negative consequences of this scheduling could relate to increased risks of overuse musculoskeletal injuries given the limited physical preparation time to address all necessary physiological capacities [29]. However, this information may support strength and conditioning experts in tennis that consider this as somewhat typical training periods for professional players [30, 31] and may manifest as abbreviated strength and conditioning stimuli throughout the calendar year. Separately, coaching teams must also address the psychosocial development requirements of players during late adolescent that include education pathways alongside appropriate social outlets for a sustainable involvement in the sport as a professional [6]. The WTA policies are therefore critical in this area given tournament exposures are less dense than in the men's game [14], which further illustrates the positive role of active policy to achieve an appropriate balance of training time and competition play as well as periods for psychological rejuvenation in future elite female players [32].

The influence of intensified competition periodisation on training strategies in tennis may be prevalent as early as 14y, where playing >7 matches/month becomes commonplace throughout the calendar year (Figure 1). Indeed, greater match frequencies could pose a risk for detraining of speed and power qualities during tournament weeks given match-play exposures alone are typically insufficient in stimulating these physical capacities [8, 33]. Accordingly, specific training

interventions during tournament blocks have been used to arrest the detraining effects of competition-intensive programming in tennis [34]; however, contemporary strength and conditioning practices would still advocate for dedicated multi-week blocks of training (uninterrupted by international competition) during the calendar year. This would appear to highlight the dichotomous relationship between long-term athlete development literature that aims to maximise training exposures in adolescence and tennis's ranking paradigm that endorses considerable tournament engagement at these young ages.

Limitations

Whilst this study addressed a need for explicit reporting of competition scheduling practices of future elite female tennis, there are important limitations to acknowledge. Firstly, our study did not consider the changes in age eligibility rules throughout the years in question (i.e., 2000-2015) when reporting and classifying professional tournament engagement. As such, it is recommended that extrapolating specific professional tournament volumes at ages prior to 15y are performed with caution. Further, our study did not consider the tournament surface played, which could represent a potential limitation given the importance of clay court exposures for future T100 players [35]. Similarly, tournament success was not reported in our methods and could suggest an avenue for further research to identify distinctive tournaments or winning percentage targets for aspiring professionals. As this study focused on reporting competition engagement to inform scheduling practices and infer training availability, singles and doubles matches were combined in the reporting and could limit direct comparison to National Federation guidelines. The dataset also lacked the domestically sanctioned tournaments played and thus, overall tournament volume in the formative adolescent years may be underestimated and further influence the reported days between tournaments. Additionally, understanding the national-level tournaments played in the early adolescent years would provide greater context

as to how players start their transition on the international junior tour. It is also acknowledged that our sample could be biased towards certain global regions and thus, the tournament engagement practices may have limited transferability to other countries or regions. This sample-related limitation may also exist for maturation status that was unavailable in our dataset. Lastly, unexplained absences or injury years were not available for players in this sample and could have influenced the variability of competition engagement metrics.

Conclusions

The competition pathways of future successful female players throughout adolescence showed players undergo significant increases in junior international tournament engagement from age 14 at all grades of the junior ITF tour. Concurrently, highly successful players experience considerable density of match-play exposures through the calendar year, which presents a challenge to both players and policy makers alike. For players, they require strategically planned training exposures and rest between dedicated competition blocks. For the game's governing bodies, it may provide cause to reconsider the density of the tournament calendar, the duration of tournaments and matches as well as the ranking system.

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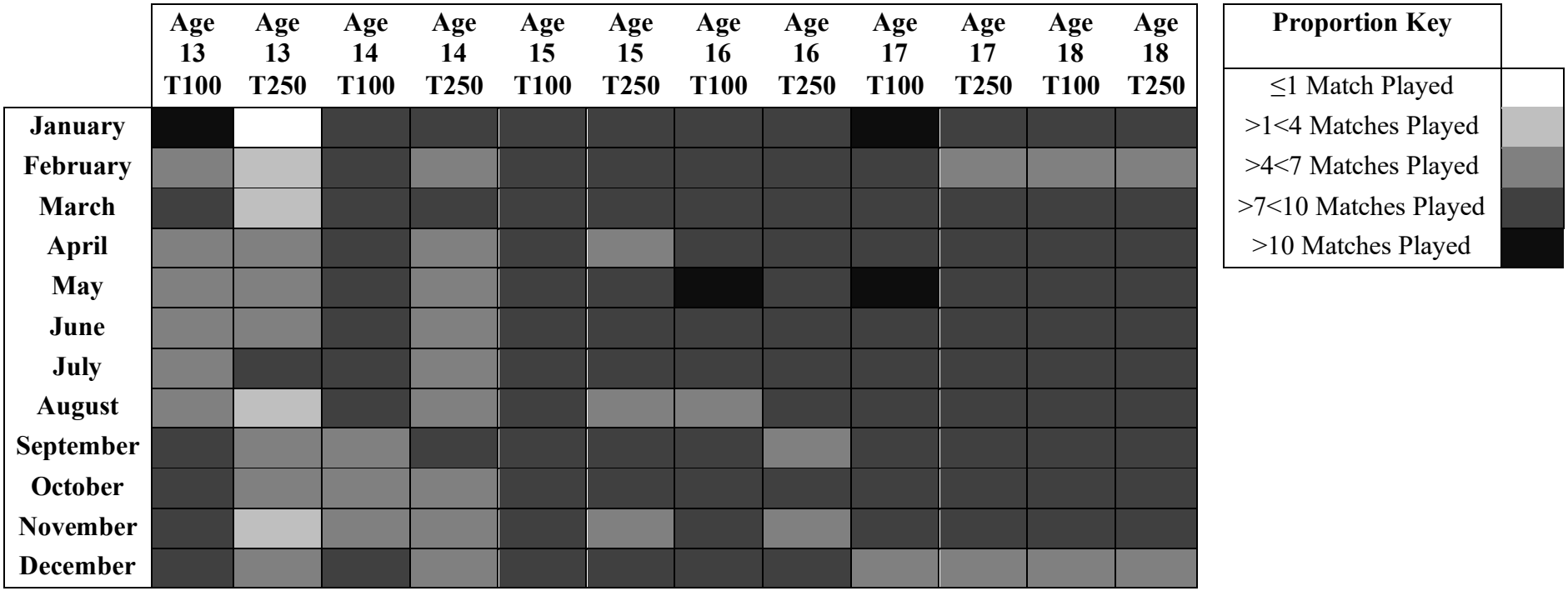

Figure 1. Average matches played per month by future top 100 (T100) and top 250 (T250) female tennis players

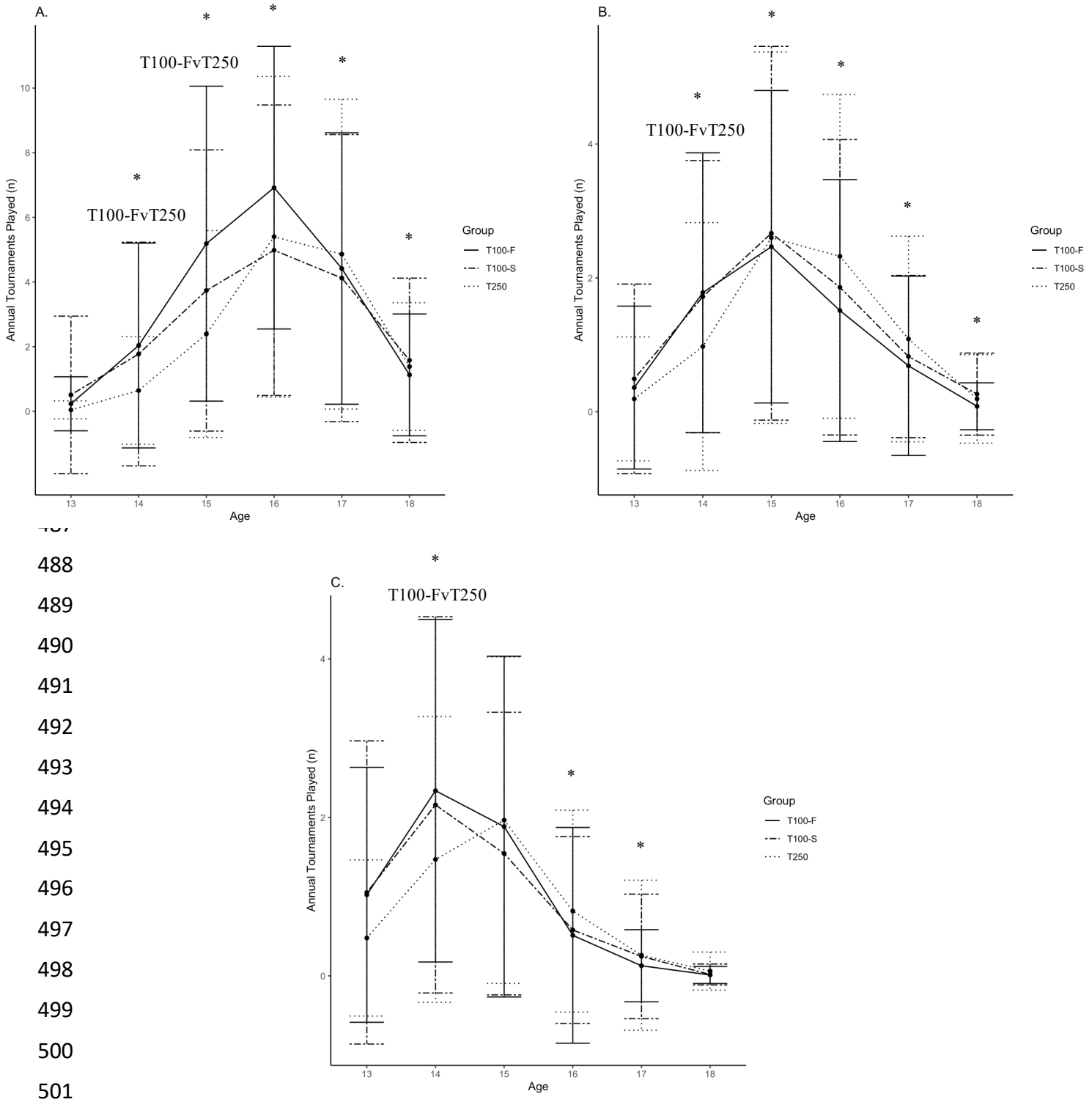

Figure 2. Annual Junior International Tennis Federation (ITF) Tournaments Played.
All data presented as mean ± standard deviation

A. Junior Category 1 (Junior ITF Grade A and Grade 1)
B. Junior Category 2 (Junior ITF Grade 2 and Grade 3)
C. Junior Category 3 (Junior ITF Grade 4 and Grade 5)

Groups
T100-F. Players who made the top 100 ≤4 years of first professional ranking point
T100-S. Players who made the top 100 more than >4 years after first professional ranking point
T250. Players who achieved a ranking inside 101-250

* significant main effect for age ($p < 0.05$)
Differences between ranking group for same age are denoted (example T100-FvT250) ($p < 0.05$)

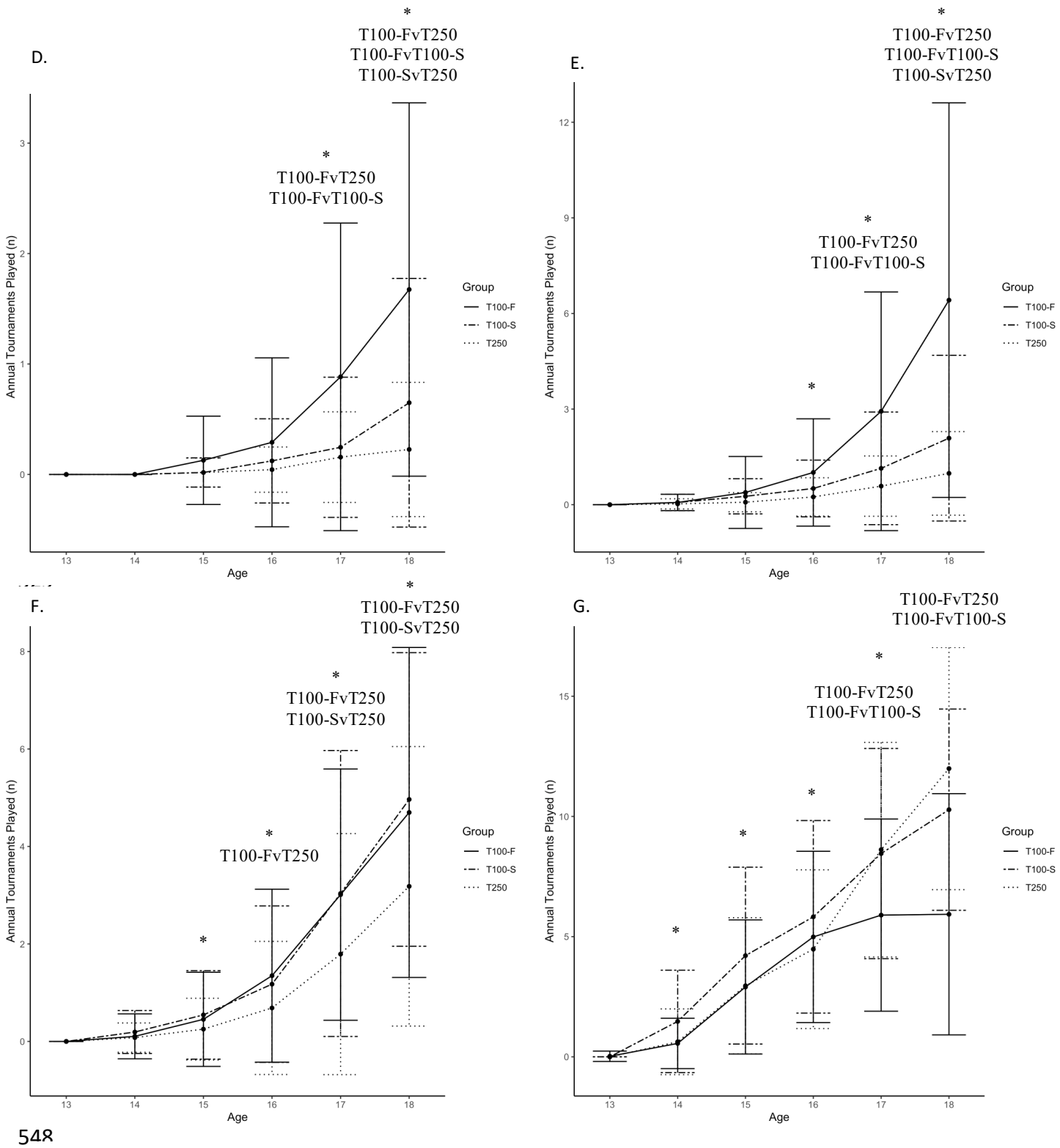

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Figure 3. Annual Women's Tennis Association (WTA) and Women's Tour International Tennis Federation (ITF) Tournaments Played.
All data presented as mean ± standard deviation

D. Professional Category 1 (Grand Slams)
E. Professional Category 2 (WTA World Tour Tournaments)
F. Professional Category 3 (ITF Series $100k, $80k, $60k)
G. Professional Category 4 (ITF Series $25k, $15k)

Groups
T100-F. Players who made the top 100 ≤4 years of first professional ranking point
T100-S. Players who made the top 100 more than >4 years after first professional ranking point
T250. Players who achieved a ranking inside 101-250

* significant main effect for age ($p < 0.05$)
Differences between ranking group for same age are denoted (example T100-FvT250) ($p < 0.05$)

Table 1. Annual Matches Played and Tournament Distribution Variables

A.

	Group		
Age	**T100-F**	**T100-S**	**T250**
13	7 ± 14	8 ± 18	2 ± 5
14*	31 ± 27$^{(T250)}$	30 ± 29$^{(T250)}$	14 ± 19
15*	63 ± 33$^{(T250)}$	53 ± 31	41 ± 30
16*	80 ± 33$^{(T250)}$	66 ± 32	60 ± 34
17	80 ± 29	75 ± 33	71 ± 30
18	76 ± 23	78 ± 31	69 ± 24

B.

	Group		
Age	**T100-F**	**T100-S**	**T250**
13	7 ± 14	8 ± 18	2 ± 5
14*	28 ± 25$^{(T250)}$	26 ± 26	13 ± 18
15*	49 ± 29	37 ± 27	32 ± 27
16	50 ± 29	38 ± 28	42 ± 31
17*	29 ± 25	27 ± 29	31 ± 28
18*	7 ± 12	10 ± 17	8 ± 12

C.

	Group		
Age	**T100-F**	**T100-S**	**T250**
13	0 ± 0	0 ± 0	0 ± 0
14*	2 ± 5$^{(T100-S)}$	5 ± 7	2 ± 5
15*	14 ± 14	16 ± 13$^{(T250)}$	10 ± 11
16*	30 ± 20$^{(T250)}$	28 ± 17	18 ± 14
17*	50 ± 21	48 ± 20	40 ± 18
18*	69 ± 22	68 ± 25	61 ± 22

D.

	Group		
Age	**T100-F$^{(T250)}$**	**T100-S**	**T250**
13	35 ± 36	34 ± 48	45 ± 61
14	38 ± 51	34 ± 60	46 ± 70
15*	27 ± 36	25 ± 37	33 ± 55
16*	23 ± 27	25 ± 37	26 ± 38
17*	20 ± 21	20 ± 27	22 ± 30
18	18 ± 19	19 ± 24	20 ± 26

All data presented as mean ± standard deviation.
(A) Annual Professional and Junior Tour Matches Played (B) Annual Junior Tour Matches Played (C) Annual Professional Tour Matches Played (D) Days Between Tournaments

Groups
T100-F. Players who made the top 100 ≤4 years of first professional ranking point
T100-S. Players who made the top 100 more than >4 years after first professional ranking point
T250. Players who achieved a ranking inside 101-250

* significantly different from previous age ($p < 0.05$)
$^{(T100-S)}$ significantly different from T100-S ($p < 0.05$)
$^{(T250)}$ significantly different from T250 ($p < 0.05$)

Table 2. Annual Consecutive^ Tournaments Played

	Group		
Age	**T100-F**	**T100-S**	**T250**
13	1 ± 1	2 ± 4	0 ± 1
14*	2 ± 3	3 ± 3$^{(T250)}$	2 ± 2
15*	5 ± 3	5 ± 3	4 ± 3
16*	6 ± 3	6 ± 3	5 ± 4
17*	6 ± 3	8 ± 4	8 ± 3
18*	9 ± 4	9 ± 4	9 ± 4

All data presented as mean ± standard deviation

^Consecutive tournament defined as those occurring less than 8 days apart of each other

Groups

T100-F. Players who made the top 100 ≤4 years of first professional ranking point

T100-S. Players who made the top 100 more than >4 years after first professional ranking point

T250. Players who achieved a ranking inside 101-250

* significantly different from previous age ($p < 0.05$)

$^{(T250)}$ significantly different from T250 ($p < 0.05$)