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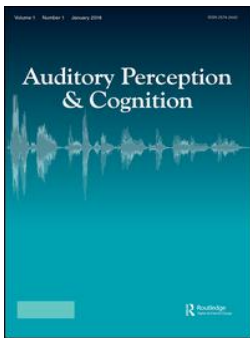
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The journey to elite success: a thirty-year longitudinal study of the career trajectories of top professional tennis players

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ABSTRACT

Learning from the career trajectories of the most successful elite players is central to informing effective strategies and long-term career planning to maximise player development and performance. This article examined the junior competition results and the performing age at major career milestones of top-level professional tennis players, utilising this information to forecast a player's career peak ranking. Thirty years of longitudinal data which included 82 top 10 professional players between 2007 and 2017, were analysed. Gender and generational differences were compared. The results revealed that good performances at the highest junior level of competition was shown to be a critical precursor to eventual top-level professional success. It was revealed, however, that top 10 professional tennis players spent nearly 10 years from starting age to reaching an international junior level and another 10 years on average to achieve career peak ranking. Additionally, age at major career milestones was shown to be moderately correlated with a player's career peak ranking, with 61% of the top one players correctly "predicted" to be top one players. The practical implications arising from these findings, specific to informing the career planning, prediction of professional success, monitoring and assessment of emerging tennis players, is discussed.

ARTICLE HISTORY

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KEYWORDS

Elite success; talent identification and development; performance analysis; player development; peak ranking

1. Introduction

Over the past few years, there has been an increasing amount of research focusing on the relationship between junior performance and senior competitive success within different sports (e.g. Barreiros, Côté, & Fonseca, 2014; Güllich & Emrich, 2014). Specific to the sport of tennis, several authors have examined the developmental trajectories and transitional experiences of successful junior players and highly ranked professional players (Brouwers, De Bosscher, & Sotiriadou, 2012; Mathews, Farrow, MacMahon, & Weissensteiner, 2012; McCraw, 2009; Reid & Morris, 2013). The findings of Brouwers et al. and Reid and Morris failed to reach consensus regarding the required conversion rate of junior to senior tennis players. For instance, Brouwers et al. (2012) found that a mere 16.8% of male and 11.4% of female junior top 20 tennis players reached a top 20

professional ranking at a later age. In contrast, Reid and Morris (2013) reported that 91% of top 100 professionals earned a junior ranking. According to McCraw (2009), however, 72% of the junior top 10 girls and 48% of the top 10 boys achieved a top 100 WTA/ATP ranking. Regardless of an uncertain relationship between junior success and senior success, in practise, federations and their coaches still largely rely on junior ranking or competition results as an indicator of later senior level competitive success. In an attempt to fill this void in knowledge, this study utilised retrospective longitudinal data of top 10 professional players to ascertain what performance level did top ranked professional players reach, when they were at a junior competitive level. It is envisaged that the outcome of this analysis will help federations and coaches to establish a range of statistical benchmarks that will in turn inform the career planning, monitoring and support of emerging players to maximise their development and eventual performance at a senior professional level.

Age has been attributed as a major factor that influences performance in different sports (Gallo-Salazar, Salinero, Sanz, Areces, & Del Coso, 2015; Malcata, Hopkins, & Pearson, 2014). Driven by a global sporting arms race, national governing bodies are facing an increasing pressure to deliver collective success, resulting in the implementation of elite athlete development programmes at an increasingly younger age (Cooke, Coble, Till, & Wattie, 2010; Green, 2005). Recently, a range of studies have attempted to reveal the age at which specific ranking benchmarks are attained by top ranked tennis players and the potential of these ranking benchmarks in predicting professional success (Kovalchik, Bane, & Reid, 2016; Reid, Morgan, Churchill, & Bane, 2014; Reid & Morris, 2013). These results, however, were restricted to a descriptive level. The use of more advanced statistics to evaluate or forecast outcomes has been embraced by a majority of professional sports (Ergül, Yavuz, & Yavuz, 2014; Li, De Bosscher, Pion, Weissensteiner, & Vertonghen, 2018; Sgro, Barresi, & Lipoma, 2015). Inspired by the research of Reid and Morris (2013), which suggested that the ages associated with ranking milestones may have some forecasting potential in player's career peak ranking, the current study utilised regression and discriminant analyses to further explore the value of the age at different career milestones in predicting career peak ranking.

Recently, speculation regarding the impact of generational differences on a player's developmental trajectory has attracted great interest in both practise and the academic field (Gallo-Salazar et al., 2015; Guillaume et al., 2011). The central question guiding this debate is: "Is it becoming more difficult for players of the young generation (e.g., born after 1990) to break into top rankings?" The study from Guillaume et al. (2011) revealed that the attainment of peak performance of the current generation tended towards a younger age than that of older generation players. However, methodologically the researchers categorised the two generations of players by whether their first professional match was played before or after 1985. In essence, they compared players that were born before and after 1970. As new players are emerging, the separation of top 10 players merely by the year of 1970, does not allow true exploration of how trends in players' performing age, has changed overtime (i.e. the last 30 years).

In summary, to fill these gaps in the literature, the primary aim of this research was to examine the junior performance and the age at different career milestones of top ranked professional tennis players, and to establish a range of statistical benchmarks

that coaches and federations can use for assessing and monitoring player development. Specifically, the following questions will be addressed:

- (i) What is the common age of top professional tennis players (specific to gender and generation) when they achieved their underpinning career milestones?
- (ii) To what extent can we predict future career peak ranking by age at different career milestones?
- (iii) How critical are junior competition results and age at ranking milestones to attaining a top world ranking?

2. Method

Quantitative biographical data were obtained from the International Tennis Federation (ITF, www.itftennis.com), Association Tennis Professionals (ATP, www.atptennis.com) and Women Tennis Association (WTA, www.wtatennis.com). Written Permission specific to utilising these data was obtained separately from officials affiliated with these websites. The names and birthdates of all professional players that achieved a top 10 year-end ranking between 2007 and 2017 were recorded. Duplicate names were removed from the data set, resulting in a total of 82 players, including 44 female and 38 male players with 53 players born before 1990 and 29 players after 1990.

Player career trajectories were examined in detail and included three distinguishable career stages, i.e. 1) ITF Junior-circuit 2) ITF Pro-circuit and 3) WTA/ATP Tour. A player's first participation within these three stages and other key professional ranking benchmarks, were defined as career milestones. These included in chronological order:

- Age started playing tennis
- Date of the first participation in the ITF junior circuit
- Date of the first participation in the ITF pro-circuit
- Date of the first participation in WTA/ATP Tour
- Date of achieving the highest junior ranking
- Date of the first professional ranking (i.e. when the first professional ranking point was made)
- Date of achieving the first Top 500 professional ranking
- Date of achieving the first Top 400 professional ranking
- Date of achieving the first Top 300 professional ranking
- Date of achieving the first Top 200 professional ranking
- Date of achieving the first Top 100 professional ranking
- Date of achieving the first Top 50 professional ranking
- Date of achieving the first Top 20 professional ranking
- Date of achieving the first Top 10 professional ranking
- Date of achieving their career peak ranking

The dates of these career milestones were then converted to age based on a player's birthdate. Each player's competition results and their respective age whilst participating in the ITF junior circuit (age < 18), were examined to explore and quantify their junior competitive success, preceding their senior professional success. Comparative analyses

were then performed specific to gender, player generation (i.e. year of birth prior to, or after 1990) and specific to age, for each career milestone.

3. Statistical analyses

Descriptive statistical methods were firstly used to analyse the age features of the top world ranked players at each respective career milestone and the length of time required to progress from one career milestone to the next. Independent *t*-test were then carried out to analyse differences in age within the cohort for each career milestone considering gender and player generation.

Secondly, the ages at different career milestones were further examined with Pearson correlation coefficient to determine whether they were related to a player's career peak ranking. Players are known to reach their career peak ranking at approximately 25 years of age (Reid, Crespo, Santilli, Miley, & Dimmock, 2007). For this analysis, players who were born after 1993 were excluded, resulting in 69 players meeting this criterion. The identified variables (i.e. age at the ranking milestones that related to the career peak ranking) were then entered into a multiple regression model to explore to what extent these variables can predict career peak ranking. Additionally, a discriminant analysis was applied to further explore whether or not players who reached a top one ranking would differ from their top 10 player counterparts. Leave-one-out classification was adopted for cross validation. In cross validation, each case is classified by the functions derived from all cases other than that case. Several assumptions were tested before proceeding with the regression and discriminant analyses. The correlation of the variables from Pearson correlation were shown to be within the violation ($r < 0.8$) of multicollinearity (Field, 2005). The normality of the variables was checked through Kolmogorov-Smirnov's tests, with the results revealing a non-significant *p* value ($p > 0.05$), indicating that the normal distribution appeared to be a good fit to the data.

All statistical analyses were performed with SPSS software Version 24. Results were considered significant when $p < 0.05$. Ethical approval to undertake the study was obtained by the relevant committee at the Vrije Universiteit Brussel.

4. Results

4.1. The age features of top professional players at each career milestone and the progression time between major milestones

Table 1 presents the average age of top 10 professional players at each major career milestone. Specific to female top 10 ranked players, on average they commenced their participation within the ITF junior circuit at a mean age of 13.8 years, whereas male top 10 players were about one year older at 14.7 years. It takes nearly one year on average for players of both genders to progress from a junior to pro-circuit level. Attainment of their first professional ranking was achieved by female top 10 players at a mean age of 15.4 years whilst male top 10 player achieved this milestone at a mean age of 16.5 years. Interestingly, the results further revealed that, by the time female players achieved their junior peak ranking, they were concurrently ranked between the top 400 and 300 of the

Table 1. The average age of Top 10 professional tennis players at major career milestones (n = 82).

Career milestones	Female (Mean \pm SD)	Male (Mean \pm SD)
Starting age	5.6 \pm 1.9	5.5 \pm 1.6
First participation in ITF junior-circuit	13.8 \pm 0.7	14.7 \pm 1.2
First participation in ITF pro-circuit	14.6 \pm 0.6	15.6 \pm 1.0
First participation in WTA/ATP Tour	16.2 \pm 1.3	17.8 \pm 1.3
First WTA/ATP ranking	15.4 \pm 0.7	16.6 \pm 0.9
Highest ITF junior ranking	16.6 \pm 0.9	17.4 \pm 0.7
Top 100 professional ranking	18.4 \pm 1.7	19.4 \pm 1.3
Top 10 professional ranking	22.1 \pm 3.5	23.1 \pm 2.6

WTA professional ranking. In contrast, by the time the male players achieved their junior peak ranking, they were ranked lower than top 500 ATP professional ranking.

Further analyses specific to the time required to progress between major career milestones, demonstrated that top 10 players spent on average two years from their initial participation on the ITF junior circuit to achieving their first professional ranking. A further three years on average was required to achieve a top 100 ranking, and another four years on average to reach a top 10 ranking. No significant statistical differences were found specific to these time-spans between male and female players. However, the time from starting age to entering the ITF junior circuit was found to be significantly different between female (M = 7.8, SE = 2.0) and male (M = 9.2, SE = 2.0) top 10 players ($t(80) = -2.7, p < 0.01$). Specific to player generations, no statistical differences were found for the female cohort. Interestingly, for the male cohort, the results showed that top 10 male players who were born before 1990 spent significantly longer time (M = 9.5, SE = 0.38) progressing from starting age to entering the ITF junior circuit than players who were born after 1990 (M = 7.9, SE = 0.53; $t(19) = 2.3, p < 0.05$).

Figure 1 depicts the age distribution of top 10 professional tennis players at each major career milestone. The results show that 50% of the top 10 female players broke into the top 100 and top 10 rankings at 18.2 and 22.0 years, respectively, while top 10 male players were 19.4 and 23.7 years, respectively. The figure also illustrates that nearly 95% of female top 10 players had reached the top 500 professional ranking before the age of 18 years and the top 100 before 20 years of age; while almost all male top 10 players had reached a top 500 ranking before they were 20 years, and a top 100 ranking before they were 22 years. A fast ascent towards peak ranking is apparent during the early years for both genders. From a top 500 to top 100 ranking, players required less than half a calendar year to break into every hundred-ranking band. Additionally, significant age differences were found between genders ($p < 0.01$). Top 10 male players were nearly 1.5 years younger on average than their female player counterparts at each milestone. Interestingly, there were no significant age differences between the two player generations and between number one female and male players at each career milestone.

4.2. The performing age and competition results in the junior circuit of top professional players

The analyses of the ITF junior performances of the top 10 players revealed that 95% of the top female players and 92% of male players had won at least one single or double title within the

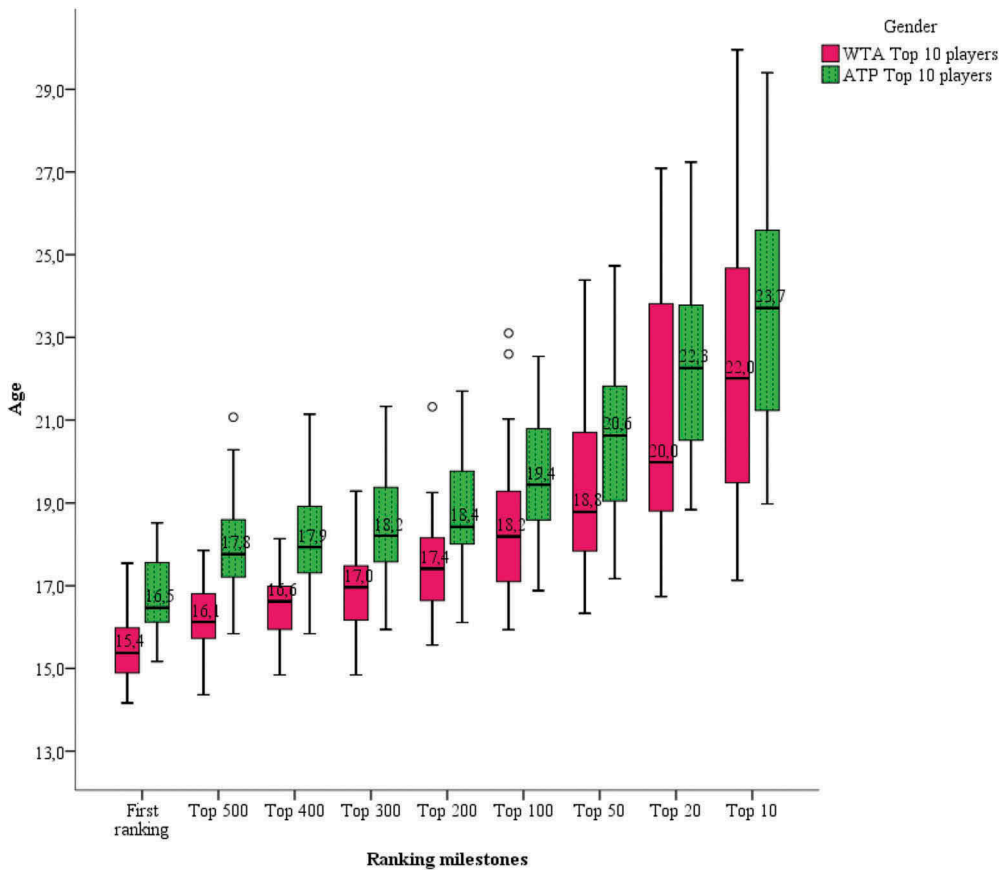


Figure 1. The minimal, 25%, 50% and 75%, maximal quartiles of age at each major ranking milestone of top 10 professional male and female tennis players.

ITF junior circuits. Further scrutiny of the results revealed that 75% of the top 10 ranked players had won their first ITF junior title before 15.3 years of age for girls and 16 years of age for boys. Additionally, Figure 2 presents the competition results of these top 10 ranked players within the highest junior events (ITF junior Grade A events). As demonstrated within the figure, more than 90% of the top 10 professional players had reached at least a quarter final in Grade A events. Seventy-eight percent of female players and 70% of male players reached at least one final with nearly two thirds, winning at least one title in Grade A events. Notably, 75% of the winners for both genders won their Grade A title before the age of 17 years.

4.3. The potential of utilising age at career milestones to forecasting career peak ranking

The results revealed that the age at which a player first participated in the pro-circuit and their age at each ranking milestone were significantly related to their career peak ranking. The correlations were revealed at a medium level (see Table 2). This finding suggests that the younger a player is when achieving these career milestones, the higher the ranking they may reach in the professional rankings.

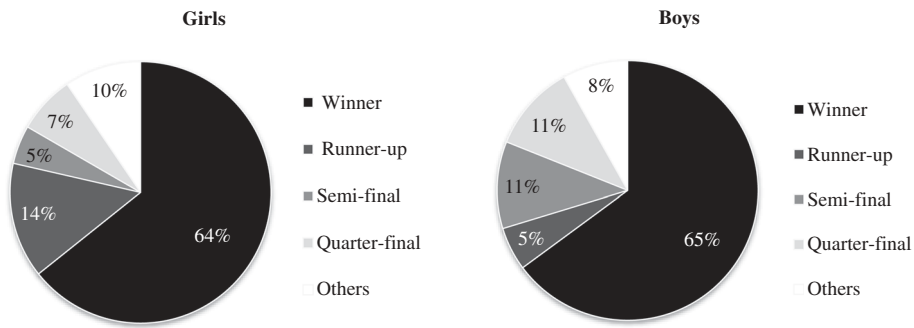


Figure 2. The junior performances of top 10 professional male and female players at the highest junior competitions (ITF junior Grade A events).

Table 2. Correlational analyses of the relationship between career peak ranking and the age specific to each career milestone.

Variables	Starting age	First Junior circuit	First Pro-circuit	First WTA/ATP	First Pro-ranking	Top 500	Top 400	Top 300	Top 200	Top 100
Career peak rank	0.14	0.20	0.29 ^b	0.15	0.28 ^b	0.36 ^a	0.31 ^a	0.31 ^a	0.40 ^a	0.38 ^a

^aCorrelation is significant at the 0.01 level.

^bCorrelation is significant at the 0.05 level.

Table 3. The discriminant classification (cross-validated) results of the top one players and the rest of the top 10 players based on their age at career milestones.

	Predicted Group Membership		Correctly predicted (%)
	Top 1 ranked players	Rest of top 10 ranked players	
Top 1	11	7	61.1
Rest of top 10	5	46	90.2
Overall (%)			82.6

The multiple regression model revealed a significant equation, $F(7, 60) = 3.4$, $p < 0.001$, $R^2 = 0.32$, showing that the extracted function accounted for a moderate of 32% of the variance in predicting a player's career peak ranking based on the ages across these ranking milestones, i.e., the performing age at top 500, 400, 300, 200, 100 ranking. To further determine the forecasting potential regarding top one ranked players, results from the discriminant analysis showed that the overall Chi-square test was statistically significant (Wilks $\lambda = .62$, Chi-square = 30.9, $df = 6$, $p < 0.001$). The discriminant classification results, shown as in Table 3, suggest that 82.6% of the top 10 players were correctly classified into their original ranking categories based on the canonical variables and, a further 61.1% of the top one players were correctly classified to their original top one ranking.

5. Discussion

Legendary American tennis player Arthur Ashe once said, "success is a journey not a destination" (Ashe, 1980). The learnings obtained from this study regarding the career

trajectories of the world's finest male and female tennis players certainly support this notion. Such critical information on the relative time course of this journey across multiple, progressive career transition stages is critical to informing associated strategy and policy specific to maximising player performance and player development across the tennis pathway inclusive of its foundational, pre-elite and elite components (Gulbin, Croser, Morley, & Weissensteiner, 2013).

By analysing retrospectively, the longitudinal data of the top professional tennis players, the current investigation has provided great insight regarding as to what age top ranked players achieved each of their underpinning career milestones in order to achieve eventual professional success. The results showed that being able to reach a quarter-final level at the highest level of junior competition was a commonality of the top professional players regardless of gender and generation. This finding suggests that showing promise at a high junior level of competition plays a critical role and is a springboard for later achieving the pinnacle of success in professional tennis. According to the literature, however, due to a notable number of top-ranked junior players who drop out or do not progress to achieve a top 100 professional ranking, some authors (Brouwers et al., 2012; Güllich & Emrich, 2014) questioned the role of junior success and argued that junior success is not a prerequisite for later senior success. The possible explanation for the paradoxical finding might be that, previous research mainly used junior ranking to represent the success level of a player. Utilising junior ranking may be inaccurate in capturing the competence of a player, as players may stay longer in the lower-tier junior circuit chasing after ranking points instead of challenging themselves in higher level competitions to develop their overall competence and prepare them adequately for their professional career. The commonality of the top 10 players specific to the importance of succeeding at a high level of junior competition (e.g. ITF Grade A events) suggests that players and their respective coaches and federations should map these critical competitions into an aspiring player's developmental plan and calendar.

The current study revealed several features regarding the career trajectory of both male and female top 10 ranked professional players. A fast ascent characterised by transitioning up the ranking tiers within their early years on tour before achieving a top 100 ranking, was identified. This feature is supported by previous investigations which also revealed that higher ranked players presented a faster progression speed and appeared to achieve ranking bands younger (Reid et al., 2014). The current investigation revealed that top one players were also significantly younger at achieving each ranking milestone and ascended to their peak ranking faster than the rest of the top 10 ranked players. Current results also suggest that although the age at different milestones varies from player to player, the time that top professional players progress from one milestone to another tends to be similar. The direct implication of this finding is that the progression time between career milestones tends to be more reliable than the age at career milestones in assessing and monitoring player development. Additionally, the current results like those demonstrated by Gulbin, Weissensteiner, Oldenzel and Gagne (2013), showed that the top professional players commenced their participation in professional events shortly after their first junior events and invested in both junior and professional events within the same calendar year. This finding regarding the criticality of junior and senior concurrent competitive experiences to latter expertise and success, is critical to informing athlete, parent and coach

education, competition scheduling and most importantly, informing effective, appropriate and individualised player management and support.

To our surprise, we found that the younger generation of male top 10 players spent less time from their starting age to their first participation in international junior competition than players from the older generation. This finding indicates that players who were born after 1990, spent less time in their developmental preparation and started international junior circuit earlier compared to the top 10 players who were born before 1990. However, no age differences were found between the two generations amongst the female top professional players.

Meanwhile, gender differences specific to the age of the top professional players were apparent in the results, implying that the developmental experiences and trajectories of the sexes are not one and the same. This nuance provides an objective basis for informing suitable player programming and career goal setting specific to gender. For example, the results showed that 54% of female top 10 players participated in their first WTA Tour before reaching their ITF junior peak ranking, while 66% of male players participated in their first ATP Tour after reaching their ITF junior peak ranking. Interestingly, the results also showed that male players typically spent double the time than females to break into top 500 ranking from achieving their first professional ranking. After breaking into the top 500 ranking, however, male top 10 players ascended up the ranking tiers significantly faster than their top 10 ranked female counterparts.

A key finding of the present work is that the age of which players reach at major ranking milestones is moderately related to a player's career peak ranking, explaining 32% of the variance. This finding provides statistical support for the previous hypothesis and explorative suggestion that the age associated with ranking milestones may have some forecasting potential in player's career peak ranking (Reid & Morris, 2013). However, this variance is only moderate, which is in accordance with the fact that forecasting future professional success of young players is difficult, because athlete development is a complex process that is influenced by a dynamic interplay of athlete, environmental, system and chance factors (Gulbin & Weissensteiner, 2013; Weissensteiner, 2017). In practise, although age and ranking cannot accurately measure a tennis player's future success, they have been often used by federations as the most common way to indicate player career development and serve as an important criterion for critical funding. The results emerging from this research thus provide an evidence-based reference for federations regarding the contribution of age and performance results at important competitions when making decisions specific to athlete support.

Additionally, top professional players' age distribution at each career milestone revealed within this study, serves as another evidence-based guide for coaches and federations when considering and mapping out the developmental plan of an aspiring player, detailing key objective goals required to reach the pinnacle of tennis on the world stage. For example, players who aim to reach a top 10 ranking should attain a top 500 ranking no later than 18 years for girls and no later than 20 years for boys and should expect to break into the top 100 before the age of 21 for women and 23 for men.

Lastly, the analyses of the progression time between major career milestones highlights that the top 10 players of both genders spent approximately two years on average, from their first appearance on the ITF junior circuit to their first professional ranking, then three years to achieve a top 100 ranking, and further four years to attain a top 10 world

ranking. In summary, this indicates that top 10 players spent nearly 10 years from starting age to reaching an interantional junior level and another 10 years to reach their best career peak ranking. These findings provide unique insight into the reality of the developmental time course and career trajectory of top-level players in professional tennis.

6. Limitation

Considering the level of junior competitions, this study did not include other competitions other than the international ITF junior circuits for the analysis of junior performance of the top 10 professional players. Other local and regional junior competitions may also provide relevant information in understanding the age features and performances of top 10 players at relevant junior career milestones. Secondly, the age at which each career milestones was achieved is reliant on multiple concurrent developmental factors. Utilising solely a quantitative approach, the findings of the current study are limited in its relative understanding of what athlete, environmental and system-level contextual factors contributed to these favourable outcomes (see Gulbin & Weissensteiner, 2013). Further qualitative research is required to explore the interplay and relative contribution of these factors to further explain the similarities and differences regarding the career trajectory of the top ranked players. Such detailed contextual information is critical to informing reliably and practically how national governing bodies can better identify, develop and support players at a young age. Despite this limitation, the findings of the current study were very promising, revealing a moderate correlation (i.e., 32% variance) whereby professional peak ranking could be effectively attributed to the respective age of a player when they reached different career milestones. Apart from age and performance, future research that considers other athlete-centric factors and attributes such as technical, physical, physiological, psychological and sociological variables and the required contextual support, is needed to build a more comprehensive model in predicting a player's future professional peak ranking.

Disclosure statement

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