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Getting to the top: an analysis of 25 years of career rankings trajectories for professional women's tennis

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ABSTRACT

Official rankings are the most common measure of success in professional women's tennis. Despite their importance for earning potential and tournament seeding, little is known about ranking trajectories of female players and their influence on career success. Our objective was to conduct a comprehensive study of the career progression of elite female tennis talent. The study examined the ranking trajectories of the top 250 female professionals between 1990 and 2015. Using regression modelling of yearly peak rankings, we found a strong association between the shape of the ranking trajectory and the highest career ranking earned. Players with the highest career peak ranking were the youngest when first ranked. For example, top 10 players were first ranked at age 15.5 years (99% CI = 14.8–15.9), 1.2 years (99% CI = 0.8–1.5) earlier than top 51–100 players. Top 10 players were also ranked in the top 100 longer than other players, holding a top 100 ranking until a mean age of 29.0 years (99% CI = 27.8–30.3) compared with age 24.4 years (99% CI = 23.7–25.2) for top 51–100 players. Ranking trajectories were more distinct with respect to player age than years from first ranking. The present study's findings will be instructive for players, coaches, and administrators in setting goals and assessing athlete development in women's tennis.

Introduction

Every professional tennis athlete wants to fulfil their potential. Players and other stakeholders invest considerable resources to maximise the likelihood of career success. Success in tennis is often linked to the attainment of a top 100 ranking as this secures main entry into Grand Slam competition, the 4 most prestigious and lucrative tournaments of the season. Regular involvement in Grand Slam competition has taken on additional importance for female professionals since the introduction of equal prize money in the mid-2000s.

Although attaining a top 100 ranking is a critical milestone for aspiring female tennis players, little is known about the typical paths taken to reach the top 100. Only 1 study by Kovacs et al. (2015b) has examined this question in depth. However, that study was limited to players ranked in the top 100 in 2014, so it was unable to determine how trends in career progression have changed over time. Other studies that have spanned more years of rankings data have focused almost exclusively on the most highly ranked players, which limit the generalisability of the findings to the career progressions of the majority of aspirant professional players. As a consequence, athlete development guides that have been developed by tennis federations rely on untested beliefs about the defining characteristics of an elite tennis athlete's career progression (Tennis Australia, 2013). This raises concerns about the validity of these resources and their ability to assist stakeholders to set achievable goals for their players

(Brouwers, Sotiriadou & De Bosscher, 2015; Dormehl, Robertson & Williams, 2016; Pyne, Trewin & Hopkins, 2004; Reid, Morgan, Churchill, & Bane, 2014).

Literature on the career progression of professional tennis athletes indicates that the careers of male tennis players have received greater study than those of female players. Reid and Morris (2011) generated year-on-year ranking benchmarks between the ages of 16 and 25 years for the professional top 100 male players to describe a male player's progress through the professional ranks. More recent work has advanced these basic initial insights by evaluating differences in these benchmarks according to the highest career ranking a player earned (Reid et al., 2014). Significant changes in the time taken for male athletes to earn their first ranking points and enter the professional top 100 (Bane, Reid, & Morgan, 2014) have also been unearthed. These findings have shaped stakeholder attitudes towards the transition of young male players into the professional game, effectively creating space for "development" to take place. It has been suggested that similar trends have infiltrated the women's game (Perrotta, 2015), but this has yet to be confirmed.

Studies that have addressed athlete development in women's tennis have largely focused on the transition from the junior to elite level. For example, the professional ranking progress of the year-end International Tennis Federation (ITF) top 20 ranked junior female players were analysed from 1995 to 2002 to reveal that peak junior ranking as well as the age

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that players reached that peak explained a significant (but very small) amount of the variance in the players' subsequent ranking success in the professional game (Reid, Crespo, & Santilli, 2009). In a similar vein, Brouwers, De Bosscher, and Sotiriadou (2012) explored various associations between success in both male and female junior and professional competition, revealing that performances or rankings in 18/U junior competition were more informative than 14/U competition. These findings, although unremarkable, were confounded to some extent by likely variation in the calibre of the respective samples. That is, the 18/U competition was international, while the 14/U competition was predominantly European. Other researchers have examined relationships between socio-economic (De Bosscher, Bingham, Shibli, Van Bottenburg, & De Knop, 2008) or policy decisions (i.e., tournament structures, Reid, Crespo, Atienza, & Dimmock, 2007) and a nation's success in women's tennis.

While prior work has provided insights into the role of the junior game for establishing a professional career in women's tennis, many questions remain about an athlete's progression at the professional level. In particular, because male careers have generally received more research attention than the careers of female tennis players, it is not known whether the characteristics of men's careers can be generalised to women. Differences in men's and women's ages of peak performance (Ericsson, 1990; Maquirriain & Cerúndolo, 2009) as well as differences in the policy and structure of the men's and women's tours (King & Starr, 1988) – which operate independent of each other – suggest that the paths to success in women's tennis are likely to be distinct from those in the men's game. The women's game has a separate calendar, separate match format at major events (Kovalchik, 2015), and distinct age eligibility rules (Otis et al., 2006), any one of which could influence career progression.

The primary aim of the present paper was to conduct a comprehensive study of the career progression of elite female tennis talent. To address the identified gaps in prior work and therefore to inform an improved understanding of ranking trajectories in the professional women's game, 25 years of ranking data for all professional tennis players, including both female tennis players who did and did not reach the top of the game, will be interrogated. Specifically, this article (a) examines the change in career milestones of top 100 players over time and (b) identifies the distinguishing features of the ranking signatures of top 100 players as compared to lower ranked players.

Method

The study focused on female players who entered the Women's Tennis Association (WTA) rankings between January 1989 and January 2016. All player and rankings data were obtained from websites in the public domain (Sackmann, 2016; Women's Tennis Association, 2016).

In this paper, "WTA rankings" refer to the official computerised rankings used by the WTA tour. Rankings are updated weekly and each week reflects the cumulative sum of points earned at 16 tournaments in the previous 52 weeks. Players receive a ranking if they are age eligible and meet minimum

competitive requirements. The specific age-eligibility rules, which were introduced in 1995 with the intention of preventing burnout of young players (Rodenberg, 2000), prohibit girls under 14 from competing in sanctioned professional events while allowing phased participation up to the age of 18. Further details of the ranking system can be found in the WTA Official Rulebook (2016).

Weekly professional rankings were captured from the age and the date that they obtained their first WTA ranking. Rankings were expressed in absolute terms, with the No. 1 ranking reflecting the best player on the tour. Peak ranks were defined as a players' best (or numerically lowest) WTA ranking. The career peak ranking was the best ranking players received during their years of playing activity. The peak ranks for each athlete by chronological age as well as for each year from their first point were identified. Years were calculated in 12-month intervals from the player's birthdate or the date of first ranking (ranking years) for each athlete. For years prior to 1995, weekly rankings were not available for 498 lower ranked players out of 7544 players ranked between 1990 and 2015 (6.6%). In these cases, a year-end ranking was used.

The first set of analyses was aimed at establishing benchmarks for the career trajectories of top 100 players. A career benchmark is the timing of a major career milestone. Following the approach adopted by Bane et al. (2014), the milestones investigated included the age and years to achieve a first ranking, a first top 100 ranking, and last top 100 ranking. Benchmarks were summarised by the mean across top 100 players. To allow sufficient time to observe each career milestone, only players who received their first ranking on or before 2005 were considered. By definition, players who never earned a top 100 ranking were excluded from the benchmark estimates.

We further evaluated whether the characteristics of career benchmarks for the top 100 differed by peak career ranking. Players were grouped into 4 ranking bands according to the career peak ranking, 1–10, 11–20, 21–50, and 51–100. Estimates for every career benchmark were obtained for each ranking band by including band as a categorical variable in a linear regression model. We also assessed the change in milestones over time by including an interaction term between the ranking band and age in the regression model.

Additional analyses were conducted to determine the distinguishing features of the career progression of top 100 players compared with lower ranked players. In these analyses, athletes were categorised into a broader range of career peak ranking bands: top 10, 11–20, 21–50, 51–100, 101–175, 176–250. Yearly peak rankings were calculated for each player for 2 different timescales: in ranking years (the year analysis) and in terms of age (the age analysis). Since the focus of these analyses was on the years up to the establishment of the career peak ranking, the year analysis included peak rankings for the first 10 years on tour and the age analysis included peak rankings from age 16 to 25. Athletes who were active professionals prior to 1990 (who were identified by the 1989 ranking list) were excluded. Players who were still ranked in 2016 and had been active for less than 10 years were excluded so as to reduce the likelihood of erroneously including players who had not yet achieved their career peak ranking

(Reid, Crespo, Atienza, et al., 2007). Athletes whose career peak rank was greater than 250 were also excluded, leaving 877 player trajectories eligible for inclusion in the study.

Differences in career progression according to the peak career rank were determined with non-parametric regression techniques to allow for non-linearity in how yearly peak rankings changed over the course of a player's career. Accordingly, cubic splines were used to model the relationship between peak rankings with time as these allow sufficient flexibility to capture the potentially complex, non-linear patterns in multiple years of peak rankings data. The career peak ranking categories were interacted with the cubic splines to allow each group to have its own progression trajectory.

For each career peak ranking group, we estimated several specific characteristics of the rankings trajectories. These were (1) the mean peak ranking in the first ranking year, (2) the number of years during which the majority of progression occurred (the progression stage), and (3) the rate of rankings gained during the progression stage. The first year's peak ranking was estimated from the intercept term of the regression model. The progression stage was measured from the date of the first ranking to the time when the progression curved reached a steady state, which was defined as the first year in which the gain in ranking from the previous year was less than 2 ranking positions. The rate of change in rankings during the progression stage was estimated by the best linear fit, and characteristics were examined in years from first ranking and age.

Inferences for all presented statistics were based on confidence intervals at a stringent 99% confidence level. Statistical significance was judged by non-overlapping regions in these confidence intervals and the magnitude of effect sizes were measured with Cohen's d statistic. All analyses were performed in the R programming environment (R Core Team, 2012). Ethics approvals to undertake the study were obtained by the relevant committee at the University of Western Australia.

Results

Career benchmarks for the top 100

For players entering the WTA tour between 1990 and 2005, the mean age of the first ranking for players who attained a top 100 ranking in their career was 16.2 (99% CI = 16.0–16.4). The age that a top 100 ranking was achieved was 20.5 (99% CI = 20.1–20.8), implying a mean of 4.3 years from first ranking to a top 100 ranking. Players typically dropped out of the top 100 ranking at age 26.3 years (99% CI = 25.8–26.8), suggesting a top 100 longevity of 5.8 years.

The characteristics of career milestones differed significantly according to the career peak ranking achieved among top 100 players. The patterns found suggested that the age of first ranking and attainment of top 100 ranking was youngest for players who achieved the highest career ranking (Table 1). Career top 10 players were a mean of 15.4 years old when they were first ranked, whereas top 11–20 players were 0.4 years older (99% CI = −0.3–1.0; d = 0.3), 21–50 players were 0.8 years older (99% CI = 0.3–1.3; d = 0.5), and top

Table 1. Career benchmarks for WTA players who attained a career peak ranking in the top 100.

Career peak ranking	First ranking	First top 100 ranking	Last top 100 ranking
1–10	15.4 (14.8–15.9)	17.7 (16.8–18.6)	29.0 (27.8–30.3)
11–20	15.8 (15.2–16.3)	19.2 (18.2–20.2)	28.0 (26.7–29.3)
21–50	16.2 (15.9–16.5)	20.3 (19.8–20.8)	26.7 (26.0–27.4)
51–100	16.7 (16.3–17.0)	21.9 (21.4–22.4)	24.4 (23.7–25.2)

Numbers in parentheses indicate the 99% confidence interval.

51–100 ranked players were 1.3 years older (99% CI = 0.8–1.8; d = 0.9). Age differences were most notable for the milestone of a top 100 ranking, with top 10 players having an age of 17.7 years, top 11–20 players being 1.5 years older (99% CI = 0.1–2.9; d = 0.6), top 21–50 players being 2.6 years older (99% CI = 1.5–3.7; d = 1.0), and top 51–100 players being 4.2 years older (99% CI = 3.1–5.3; d = 1.7) at this milestone. These ages imply that the years taken to break into the top 100 ("development time" as in Bane et al., 2014) were 2.3, 3.4, 4.1, and 5.2 for top 10, top 11–20, top 21–50, and top 51–100 players, respectively (Figure 1). In a separate analysis, we found that the times to break into the top 100 were statistically equivalent to the tennis evolution time, defined by Kovacs et al. (2015a) as the transition time from a ranking of 1000 to 100.

Patterns reversed for the longevity of the top 100 ranking, as players with the highest career ranking tended to hold on to the top 100 ranking the longest (Table 1). The age when a top 100 ranking was last held was 29.0 years for the top 10, 1 year younger for top 11–20 (99% CI = −2.9 to 0.9; d = 0.3), 2.3 years younger for top 21–50 (99% CI = −3.8 to −0.8; d = 0.7), and 4.6 years younger for top 51–100 players (99% CI = −6.1 to −3.1; d = 1.4). These ages imply the corresponding mean lengths of top 100 longevity of 11.3, 8.8, 6.4, and 2.5 years.

The characteristics of the career milestones for the age of first ranking and age of breaking into the top 100 were stable for eventual top 100 players entering the tour between 1990 and 2005. There was modest evidence that the time inside the top 100 decreased over time for players in the top 20 (linear slope = −0.22 years 99% CI −0.51 to 0.06), which could be explained by the truncation of very long careers for more recent cohorts.

Career progression for top 250 by age

The first 10 years of the peak ranking progression of WTA players showed a similar pattern across all ranking bands. The observed pattern was characterised by initial steep gains lasting for several years then a levelling off in ranking positions gained (Figures 2 and 3). Although this pattern was found for all career peak ranking groups, there were notable differences in first peak ranking and the length of the progression stage between ranking groups. At age 16, players who went on to achieve the highest career peak ranking began with the highest first ranking (Table 2). The mean first peak ranking for players with a top 10 career peak ranking was 225, which was approximately 175 positions better than the first peak ranking for players in the 21–50 career peak ranking band, 325 positions better than those in the 51–175 career peak ranking band, and 425 positions better than those in the
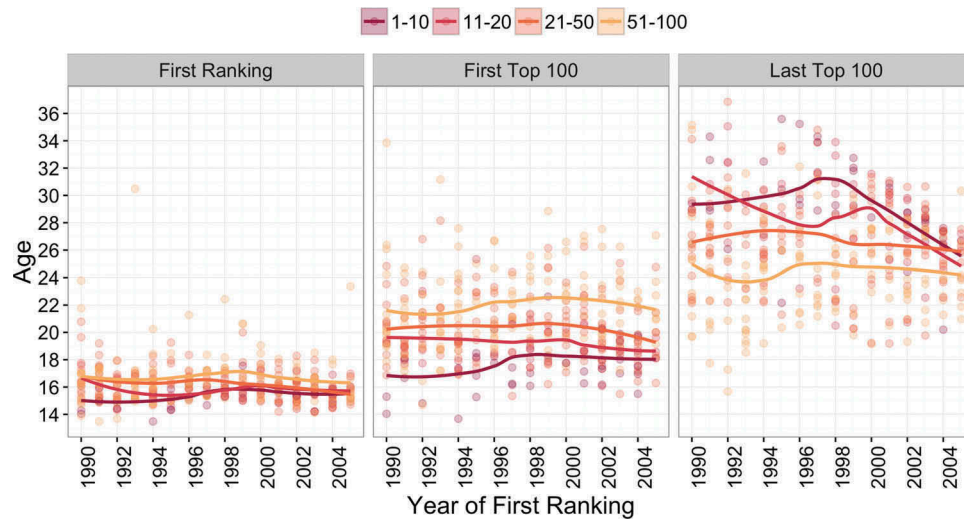
Figure 1. Trends in top 100 career milestones for players (*n* = 679) who entered the tour between 1990 and 2005 according to career peak ranking.
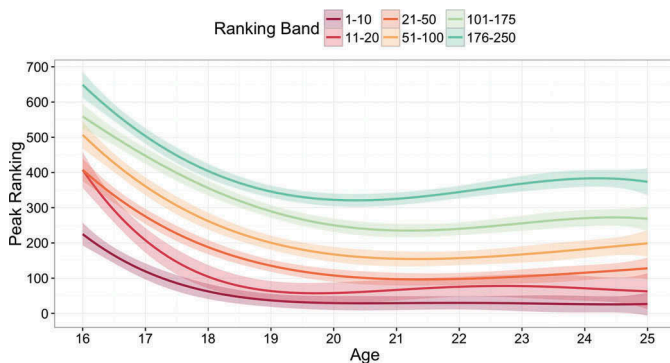

Figure 2. Peak rank trajectories by age using non-parametric regression. The shaded regions reflect the 99% confidence interval for the peak ranking.
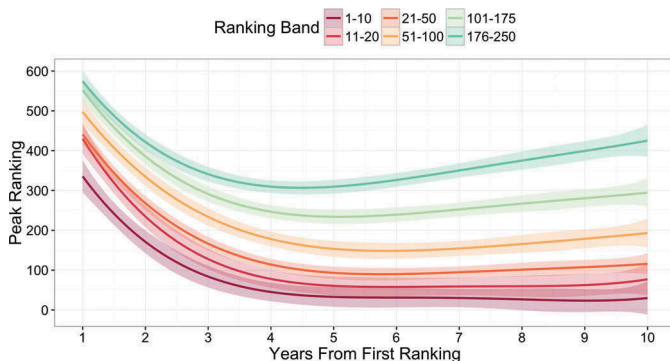

Figure 3. Peak rank trajectories by year from first ranking using non-parametric. The shaded regions reflect the 99% confidence interval for the peak ranking.

Table 2. Age characteristics of the career ranking progression of WTA players who attained a top 250 career ranking or better.

Career peak ranking	First peak ranking at age 16	Progression phase	Yearly ranking progression during development from age 16
1–10	225 (167–283)	19.5 (17.7–21.3)	61 (46–76)
11–20	407 (343–471)	19.0 (15.9–22.1)	112 (90–134)
21–50	408 (371–444)	20.5 (19.5–21.5)	93 (80–106)
51–100	507 (467–546)	20.5 (19.3–21.7)	100 (85–116)
101–175	559 (526–592)	20.5 (18.4–22.6)	92 (78–105)
176–250	649 (616–682)	19.5 (15.4–23.6)	101 (89–113)

Numbers in parentheses indicate the 99% confidence interval.

a tendency for the steady state to be reached sooner for the highest and lowest ranked groups, while players with a career peak in the middle of the ranking spectrum tended to have a progression period that was approximately 1 year longer.

The rate of ranking positions gained during the progression stage from age 16 was found to be significantly less for players who attained a top 10 career ranking compared with all other career ranking groups. Whereas the 10 most highly ranked players progressed at a rate of 60 positions gained per year on mean from age 16, the lower ranked groups progress at a rate of 90–100 ranking positions per year (Table 2).

Career progression for top 250 by ranking year

When progression in rankings was described in terms of years from first ranking rather than age, we observed a similar early separation in the peak ranking level (Figure 3). Characteristics of the first peak ranking by career peak group were in good correspondence with the levels at age 16 with the exception of top 10 players where they reported lower first peak rankings (335 vs. 225 at age 16).

The period of the progression stage was 4.5–5.0 years for the majority of players and did not vary significantly according to the career peak ranking. Players were also found to experience a similar rate of ranking positions gained in the first year

176–250 ranking band. First peak rankings at age 16 did not differ significantly between players with a 11–20 and 21–50 career peak ranking or between players with a 51–100 and 101–175 career peak ranking.

There was a similar period of progression across ranking bands, with all groups reaching a steady state in their ranking progression by ages 19–20.5 years of age (Table 2). There was

Table 3. Year from first ranking characteristics of the career ranking progression of WTA players who attained a top 250 career ranking or better.

Career peak ranking	First peak ranking in first year ranked	Progression phase	Yearly ranking progression during development from first year ranked
1–10	335 (281–390)	4.5 (3.3–5.7)	93 (72–114)
11–20	430 (372–489)	4.5 (3.2–5.8)	117 (99–135)
21–50	405 (410–472)	5.0 (4.3–5.7)	86 (79–93)
51–100	497 (466–529)	5.0 (4.3–5.7)	84 (75–93)
101–175	551 (526–577)	4.5 (3.9–5.1)	100 (89–110)
176–250	574 (551–597)	3.5 (1.2–5.8)	117 (101–133)

Numbers in parentheses indicate the 99% confidence interval.

of progression, with the mean rate being between 90 and 110 positions gained per year (Table 3).

Discussion

We have advanced the quantitative study of the career progression of women's professional tennis players using 25 years of ranking data. Our findings revealed several distinguishing features in the trajectories of player rankings according to the highest career ranking that players earned. The players with the highest career peak rankings tended to attain a first ranking at younger ages were more highly ranked by age 16 and maintained a top 100 ranking for longer than players with lower career peak rankings. Differences in the timing of the career milestones of top 10 players were particularly distinct. Compared with players who peaked in the top 100 but never broke through a top 50 ranking, top 10 players earned a first ranking 1.3 years earlier, a top 100 ranking 4.2 years earlier, and maintained a top 100 ranking 8.8 years longer. Current evidence indicates that these characteristics of player ranking trajectories have been stable since 1990.

The results of this study provide empirically driven career benchmarks that can help coaches and players assess progress and establish ranking goals. Importantly, these benchmarks provide a more comprehensive summary of pathways in women's tennis than prior studies that have focused only on top 100 players (or more highly ranked players) and, in doing so, have not been able to compare the career outcomes of players who never attain a top ranking to those who did. Our broadened analysis found that players who intend to attain a top 100 ranking should aim to have a ranking of 500 or better by age 16 and expect to break into the top 100 by age 22. Players who aspire to top 10 status should aim to be ranked inside 225 by age 16 and break into the top 100 by age 18. Somewhat surprisingly, we observed that the later a top 100 ranking was first achieved, the earlier a player tended to drop out of the top 100, which has direct implications for sustainable career longevity.

A key finding of the present work was a "right out the gate" effect for the players with the highest career ranking potential. By age 16, top 10 players, top 11–50, top 51–175, and top 176–250 were distinguishable based on their peak yearly ranking. This provides statistical support for the popular and previously anecdotal suggestion that rankings from a young age are indicative of later success (Reid, Crespo, Santilli, et al. 2007). Indeed, players who went on to achieve a top 10 ranking were ranked 200 positions or more higher at age 16

than players with lower career ranking potential. Thus, a strong start on the tour appears to be an important ingredient of later career success.

Previous work on the career progression of male tennis players also highlighted the importance of players distinguishing themselves among their age groups early on Bane et al. (2014). In contrast with findings in the men's game, we have shown that the characteristics of the ranking trajectories for female players were more distinct when described as a function of age rather than ranking year (Reid et al., 2014). This suggests that player ability on the women's side might be more closely tied to their calendar age than the years of experience on the WTA, whereas years on tour is a stronger indicator of ranking progression for the men. Differing rates and processes underlying the physical and psychological maturation of male and female players could both contribute to this finding (Durand-Bush & Salmela, 2001), though further research is needed to delineate these relationships. The depth of lower-tiered tournaments could also be a factor, since these tournaments are where most players earn their first ranking points (International Tennis Federation, 2014). If the strength of opponents across the lower-tiered tournaments is more variable for 1 tour, one would expect that the rankings in the first year on tour would be less strongly correlated with career potential.

Although a number of the characteristics of career trajectories were similar for both the men's and women's tours – each showing initial years of rapid progression followed by a stabilisation period and the early separation of players with the highest ranking potential from those with lower ranking potential – women tended to achieve a top 100 ranking at younger ages and hold on to a top 100 ranking into older ages. For example, the mean top 10 female player earned a top 100 ranking at age 17.7 years, whereas top 10 men earned this milestone at age 19.7 years. Yet, top 10 female players were typically 29 years old when they last were in the top 100 but top 10 men were only 27.4 years.

These findings support previous work of the most highly ranked players. A study of top 10 players found that top female players achieved their peak ranking at age 21.5 years, whereas male players peaked at 24.1 years (Maquirriain & Cerúndolo, 2009). Further work by Maquirriain (2014), which explored the ranking trajectories of world No. 1 ranked male and female players, found that females achieved significantly higher rankings 2 years before than their male counterparts. The present work has confirmed these trends among top players and found that similar gender differences exist for lower ranked players.

It was a surprise to observe that the rate of ranking progression in the first years as a professional were quite similar. That is, we found that most players, regardless of their career peak ranking band, progressed rapidly and at a similar rate up to ages 19–20. In interpreting these findings, it is important to keep in mind that, owing to the point-based system that underlies WTA official rankings, moving the same number of ranks up requires a very different number of earned points depending on where a player is initially ranked (e.g., moving 10–5 vs. 100–95). Thus, similarity in ranking positions gained does not imply similar performance achievements.

Ranking benchmarks can be useful tools for gauging the financial sustainability of a tennis player's career. A recent report found that in order for an athlete to break-even financially on tour, that is, for them to earn enough prize money to cover their costs, they need to be ranked among the top 150 earners globally (Bane, 2015; Bane et al., 2014; International Tennis Federation, 2014; Stosur, 2013). Our study shows that the time at which a player is likely to reach a 150 ranking and the number of years she will maintain that ranking are closely tied to her peak career ranking potential. Players who can expect at least 5 or more years within the top 100 should expect to earn a WTA ranking by age 16 years and a first top 100 ranking by age 20 years. These and other findings can be used to inform more objective cost-benefit assessments as part of a female tennis professional's career plan.

Although the study has made important contributions to understanding the career progression of female professional tennis players, it has several limitations. Due to the number of years needed to observe a career, we were not able to assess career benchmarks for cohorts who were first ranked after 2005. Consequently, it remains unclear whether trends in benchmarks have changed in the past decade. Further, our analyses present norms for the careers of a large cohort of WTA players, which suggest what is typical for the mean player. This information is not the same as a prediction for an individual player, given her characteristics at a particular point in her career. A valid prediction model would be required for this purpose. Activity on the junior circuit, including practice history information, and its role in tennis athlete progression was not included in the present study, as publicly available historical data on junior players are less complete than at the professional game. Also, we have focused on official rankings as the measure of progress as it is the most common measure of strength used by coaches, players, and tournaments. Nonetheless, alternative measures of strength in professional tennis (Dingle, Knottenbelt, & Spanias, 2012) have been proposed that more accurately reflect player ability and might also be able to better distinguish the career paths of the best players from mean players.

Finally, a major policy distinction between the men's and women's tours that introduces the potential for disparate ranking progressions is age eligibility. As noted earlier, the WTA age-eligibility rule (Women's Tennis Association, 2013), instituted in 1995, restricts the number of tournaments in which female tennis players under the age of 18 can compete. Two studies have investigated the effect that this rule has had on the careers of athletes. Rodenberg and Stone (2011) illustrated that the introduction of the rule did not significantly effect the duration of time that players spend within top 10 and/or top 50, while Otis et al. (2006) suggested that the rule had significantly increased the median career length of tennis players. Our assessment of trends in top 100 career milestones did not observe any effect of the 1995 rule change and, in this way, is in agreement with the conclusions of Rodenberg and Stone (2011). It remains to be determined whether long-term effects of the rule will have had an influence on the longevity and milestone attainment of currently active players.

Conclusion

This study presents the ranking signatures of 25 years of ranking data for WTA Top 250 athletes. The resulting analysis identified precise points where players with the highest career peak ranking potential statistically distinguish themselves from those with less potential. Specifically, it was found that comparing the ranking progression of female athletes by age was more informative than by year on tour and by age 16, the best players have generally distinguished themselves from the rest of the field. We also highlighted a number of features that differ from what has previously been reported for the ranking progression of the men's tour, which reinforces a need for sex-specific progression analysis and policy in the sport. The insights presented can help to support more objective investment decisions and goal setting for developing female tennis athletes.

Disclosure statement

No potential conflict of interest was reported by the authors.

References

Bane, M. K. (2015). The cost of competing. Retrieved from http://mpegmedia.abc.net.au/news/video/201501/NBKm_TennisEarningsIV_1901_512k.mp4

Bane, M. K., Reid, M., & Morgan, S. (2014). Has men's tennis really changed? An historical rankings perspective. *Journal of Sports Sciences*, 32(15), 1477–1484.

Brouwers, J., De Bosscher, V., & Sotiriadou, P. (2012). An examination of the importance of performances in youth and junior competition as an indicator of later success in tennis. *Sport Management Review*, 15(4), 461–475. doi:10.1016/j.smr.2012.05.002

Brouwers, J., Sotiriadou, P., & De Bosscher, V. (2015). An examination of the stakeholders and elite athlete development pathways in tennis. *European Sport Management Quarterly*, 15(4), 454–477. doi:10.1080/16184742.2015.1067239

De Bosscher, V., Bingham, J., Shibli, S., Van Bottenburg, M., & De Knop, P. (2008). *The global sporting arms race. An international comparative study on sports policy factors leading to international sporting success*. Aachen: Meyer & Meyer.

Dingle, N., Knottenbelt, W., & Spanias, D. (2012). On the (page) ranking of professional tennis players. In M. Tribastone & S. Gilmore (Ed.), *Computer Performance Engineering* (pp. 237–247). Berlin: Springer.

Dormehl, S. J., Robertson, S. J., & Williams, C. A. (2016). How confident can we be in modelling female swimming performance in adolescence? *Sports*, 4(1), 16. doi:10.3390/sports4010016

Durand-Bush, N., & Salmela, J. H. (2001). The development of talent in sport. *Handbook of Sport Psychology*, 2, 269–289.

Ericsson, K. A. (1990). Peak performance and age: An examination of peak performance in sports. In P. B. Baltes & M. M. Baltes (Ed.), *Successful Aging: Perspectives from the Behavioral Sciences* (pp. 164–196). Cambridge: Cambridge University Press.

International Tennis Federations. (2014). Pro-Circuit Review. Retrieved from http://www.itftennis.com/procircuit/about-pro-circuit/pro-circuit-review.aspx

King, B. J., & Starr, C. (1988). *We have come a long way: The story of women's tennis*. NewYork, NY: McGraw-Hill Companies.

Kovacs, M., Mundie, E., Eng, D., Bramblett, J., Kovacs, M. J., & Hosek, R. (2015a). How did the Top 100 Professional Tennis Players (ATP) succeed: An analysis of ranking milestones. *Journal of Medical and Science in Tennis*, 20(2), 50–57.

Kovacs, M., Mundie, E., Eng, D., Bramblett, J., Kovacs, M. J., & Hosek, R. (2015b). How did the top 100 Women's Tennis Association (WTA)

players succeed: An analysis of ranking rankings. *Journal of Medical and Science in Tennis*, 20(3), 122–128.

Kovalchik, S. (2015). Grand Slams are short-changing women's tennis. *Significance*, 12(5), 12–17. doi:10.1111/j.1740-9713.2015.00852.x

Maquirriain, J. (2014). Analysis of tennis champions' career: How did top-ranked players perform the previous years? *SpringerPlus*, 3(1), 504–505. doi:10.1186/2193-1801-3-504

Maquirriain, J., & Cerúndolo, A. (2009). Age trends in professional tennis players: 1655: Board# 5 May 27 3: 30PM-5:00PM. *Medicine & Science in Sports & Exercise*, 41(5), 85. doi:10.1249/01.MSS.0000354820.51259.6c

Otis, C. L., Crespo, M., Flygare, C. T., Johnston, P. R., Keber, A., Lloyd-Kolkin, D., ... Terry, P. C. (2006). The Sony Ericsson WTA Tour 10 year age eligibility and professional development review. *British Journal of Sports Medicine*, 40(5), 464–468. doi:10.1136/bjsm.2005.023366

Perrotta, T. (2015, June 29). Why your child shouldn't be a tennis prodigy. *Wall Street Journal*. Retrieved from http://www.wsj.com/articles/why-your-child-shouldnt-be-a-tennis-prodigy-1435601399

Pyne, D. B., Trewin, C. B., & Hopkins, W. G. (2004). Progression and variability of competitive performance of olympic swimmers. *Journal of Sports Sciences*, 22(7), 613–620. doi:10.1080/02640410310001655822

R Core Team. (2012). R: A language and environment for statistical computing: R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0. Retrieved from http://www.R-project.org/

Reid, M., Crespo, M., Atienza, F., & Dimmock, J. (2007). Tournament structure and nations' success in women's professional tennis. *Journal of Sports Sciences*, 25(11), 1221–1228. doi:10.1080/02640410600982691

Reid, M., Crespo, M., & Santilli, L. (2009). Importance of the ITF Junior Girls' Circuit in the development of women professional tennis players. *Journal of Sports Sciences*, 27(13), 1443–1448. doi:10.1080/02640410903037714

Reid, M., Crespo, M., Santilli, L., Miley, D., & Dimmock, J. (2007). The importance of the International Tennis Federation's junior boys' circuit in the development of professional tennis players. *Journal of Sports Sciences*, 25(6), 667–672. doi:10.1080/02640410600811932

Reid, M., Morgan, S., Churchill, T., & Bane, M. K. (2014). Rankings in professional men's tennis: A rich but underutilized source of information. *Journal of Sports Sciences*, 32(10), 986–992. doi:10.1080/02640414.2013.876086

Reid, M., & Morris, C. (2011). Ranking benchmarks of top 100 players in men's professional tennis. *European Journal of Sport Science*, iFirst, 1–6.

Rodenberg, R., & Stone, D. (2011). The short and long-run labor market effects of age eligibility rules: Evidence from women's professional tennis. *Journal of Labor Research*, 32(2), 181–198. doi:10.1007/s12122-011-9108-7

Rodenberg, R. M. (2000). Age eligibility rules in women's professional tennis: Necessary for the integrity, viability, and administration of the game or an unreasonable restraint of trade in violation of antitrust law? *Sports Lawyers Journal*, 7, 183–212.

Sackmann, J. (2016). WTA Rankings. Retrieved from http://tennisabstract.com/reports/wtaRankings.html

Stosur, S. (2013). Sam Stosur defends players' dispute over money, saying youngsters will benefit from extra cash. Retrieved from http://www.foxsports.com.au/tennis/sam-stosur-defends-players-dispute-over-money-saying-youngsters-will-benefit-from-extra-cash/story-e6frf4mu-1226548640443

Tennis Australia. (2013). Athlete Development Scholarship Criteria. Retrieved from http://www.tennis.com.au/players/development/national-academies

Women's Tennis Association. (2013). Age eligibility and player development. Retrieved from http://www.wtatennis.com/SEWTATour-Archive/Archive/AboutTheTour/aer.pdf

Women's Tennis Association. (2016). The WTA Tour 2016 Official Rulebook. Retrieved from http://www.wtatennis.com/SEWTATour-Archive/Archive/AboutTheTour/rules2016.pdf