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Research article

Comparing Matchplay Characteristics and Physical Demands of Junior and Professional Tennis Athletes in the Era of Big Data

Stephanie A. Kovalchik [1,2]✉ and Machar Reid [2]
[1] Institute of Sport, Exercise and Active Living, Victoria University, Melbourne, VIC, Australia
[2] Game Insight Group, Tennis Australia, Richmond South, VIC, Australia

Abstract
Differences in the competitive performance characteristics of junior and professional tennis players are not well understood. The present study provides a comprehensive comparative analysis of junior and professional matchplay. The study utilized multiple large-scale datasets covering match, point, and shot outcomes over multiple years of competition. Regression analysis was used to identify differences between junior and professional matchplay. Top professional men and women were found to play significantly more matches, sets, and games compared to junior players of an equivalent ranking. Professional players had a greater serve advantage, men winning 4 and women winning 2 additional percentage points on serve compared to juniors. Clutch ability in break point conversion was 6 to 8 percentage points greater for junior players. In general, shots were more powerful and more accurate at the professional level with the largest differences observed for male players on serve. Serving to the center of the court was more than two times more common for junior players on first serve. While male professionals performed 50% more total work in a Grand Slam match than juniors, junior girls performed 50% more work than professional women. Understanding how competitiveness, play demands, and the physical characteristics of shots differ between junior and professional tennis players can help set realistic expectations and developmentally appropriate training for transitioning players.

Key words: Competition; data; performance; tactics; youth.

Introduction

Coaches are increasingly familiar with the effect of maturation on tennis stroke technique (Whiteside and Reid 2017). Skill acquisition research has highlighted the pitfalls with treating junior players like professionals (Buszard et al., 2016) and advocated for coaches to tailor training and technique to the developmental stage of the athlete (Crespo and Miley, 1998). Although this may be the goal of current coaches, there has been limited research into the tactics of junior players to inform developmentally appropriate training. There is also a limited understanding of why current junior match activity is not predictive of future professional success (Brouwers et al., 2012; Crespo and Miley, 1998) or how changes to junior play and training could better prepare young tennis players for their transition into the elite level (Reid et al., 2007).

Research attention into the tactical and physical characteristics of tennis play has been primarily focused at the professional level. The growing body of research on point and match outcomes has reached a number of conclusions about professional play, such as the importance of performance on second serve for match (Klaassen and Magnus, 2014) and rankings success (Reid et al., 2010); evidence that players are less effective on more important points (Klaassen and Magnus, 2001; Knight and O'Donoghue, 2012; González-Díaz et al., 2012); evidence of momentum effects (Jackson and Mosurski, 1997; Kovalchik and Ingram, 2016); and trends in game playing style (Kovalchik, 2014). The introduction of ball and player tracking onto the professional tour in 2007 has also resulted in a number of papers examining the physical characteristics and demands of elite play. These studies have begun to detail the types (Reid et al., 2016; Unierzyski and Wieczorek, 2004; Wei et al., 2016) and frequency of shots (Gillet et al., 2009), stroke counts (Johnson and McHugh, 2006), and player movement (Gillet et al., 2010; Martínez-Gallego et al., 2013).

The advent of the precise automated motion tracking systems, such as Hawk-Eye, has also spawned a more refined understanding of the similarities and differences in shot and movement characteristics of professional male and female tennis players. For example, men competing at the Grand Slam level have been shown to serve, hit groundstrokes and move at higher average speeds than their female counterparts (Reid et al., 2016). Women, on the other hand, strike their returns further inside the court, lower and with flatter trajectories.

Comparatively less research has investigated the characteristics of junior tennis or how the junior game contrasts with the professional game. The biomechanical and kinematic natures of junior technique have received some of the most research attention. This research has included examination of the flexibility (Chandler et al., 1990), range of motion of the glenohumeral joint (Ellenbecker, 1996; Ellenbecker and Roetert , 2003a), wrist and forearm strength (Ellenbecker and Roetert, 2003b) and shoulder strength (Silva et al., 2006) of elite junior tennis athletes. The major motivation of these investigations have been injury prevention rather than performance and, with the exception of some studies of overall fitness (Kuroda et al., 2015), direct comparisons to professional senior athletes have been limited.

Although studies of matchplay have received less attention, a series of studies by Hizan and colleagues (2011; 2014; 2015) gave a rare glimpse into some basic differences in the serve and return characteristics of juniors and professionals. On serve, professionals hit fewer

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double faults and won relatively more first serve points than younger players (Hizan et al., 2011), which might relate to evidence of less accurate and more variable serving locations among junior players (Hizan et al., 2014). On return, professionals won more second serve return points, a likely product of a more aggressive approach to play. While these findings offer an insight into how age/maturation and skill level might shape serve and return performance, they originate from a single event and year and fail to consider other features of point play which limits their generalisability.

With the increasing availability of data about junior competitive tennis, it is possible to investigate a number of questions that have not yet been considered. Little is understood, for example, about how the strength of competitive matches, the amount of competitive play in a season, or mental toughness in matches differs between juniors and professionals. The abovementioned advances in tracking technologies have also made it feasible to examine the differences of the physical characteristics of shots and player movement between juniors and professionals in greater detail than ever before. With this in mind, the aims of the current study were to (a) describe the age and competition profile of elite junior tennis players, (b) contrast the match, game and shot characteristics, and (c) compare the match factors most associated with match wins of junior and professional tennis.

Methods

Data

A variety of data sources on tennis singles play were sourced for the present study. Match activity from 2000-2015 of competitive junior players were obtained from the Website of the International Tennis Federation (http://www.itftennis.com) and for professional men's and women's players were obtained from the *Tennis Abstract* website (http://www.tennisabstract.com). Only players who had competed in one junior or one professional main draw match were considered.

Point-by-point data for Grand Slam matches were extracted from the website *FlashScore* (http://www.flashscore.com). These data include the scoreline of every point in a match and the player who won. They were available for the junior and professional matches in the 2017 Australian Open and 2016 French Open, Wimbledon and US Open.

More detailed point-by-point statistics were obtained for main draw matches at the 2017 Australian Open, while Hawk-Eye ball and player trajectory information were available for the 2012 to 2017 Australian Opens. The Hawk-Eye data include the physical arc of every shot in a tennis match and location of players every 40 ms of play during points. From these data variables about ball and player movement, including location and speed, were derived. For main draw singles matches, 362 men's and 371 women's matches were available for analysis. In contrast, Hawk-eye technology is only used on a select number of final and semifinal matches of the Junior Australian Open Championships, leaving a total of 12 boys and 6 girls matches for the analysis.

Analysis

A series of comparisons between junior and professional play were performed. Medians and interquartile ranges were used to describe each play characteristic. Regression analyses examined differences between juniors and professionals. Where relevant, the model also included an interaction factor, for example, with surface or shot type, to investigate differences in these effects by player group. The global effect of group was evaluated with a chi-square test between the full model that included player group and the nested model that excluded this variable. Differences that had a p-value of 5% or less were considered statistically significant.

For the shot characteristics where junior matches were only available for semifinals and finals, we used a subset of professional matches in each year that occurred in the quarterfinal round or later to reduce possible confounding.

To determine the relative importance of match statistics for winning, we used a generalized boosted regression (Friedman, 2002). The boosted regression is an ensemble method in which the relative importance of covariates is based on the frequency with which they are selected across the ensemble. The approach we use in this paper examined the importance of the differential in simple percentages and clutch averages, defined by the approach of Kovalchik and Reid (2017), for a range of serve and return statistics.

Results

Population

Over the past 15 years, the size of junior population has consistently been larger than professional population (Figure 1). In 2015 there were 8,339 boys competing on the junior tour, whereas there were 3,617 men competing at the professional level, making the junior boys' population more than two-fold larger than the professional population. Between 2000 and 2015 the boys' circuit has added an average of 323 players per year whilst the men's pro circuit has added 80 players per year, a statistically significant slower rate of growth ($p < 0.001$).

The relative differences in population size between junior girls and professional women are similar, though both populations are smaller compared to their male counterparts. In 2015, there were 6,391 competitive junior girls and 2,870 professional women. Professional female players have added an average of 66 players per year while the junior circuit has added an average of 240 players ($p < 0.001$).

Age distribution

Between 2000 and 2015, among the top 1000 ranked junior boys, the median age by rank group ranged between 17.1 and 17.5 years. Among top 1000 professional men, the range was 23.0 to 24.2 years, differing from their junior counterparts by 5.9 and 6.7 years of age. Top 1000 junior girls were younger than junior boys, with the median range being between 16.8 and 16.9 years. Professional women in the top 1000 were also younger, having a median age of 20.8 to 22.9 years from lowest to highest rank group. This implies a much smaller age gap among the

lower ranked junior and professional female players (4 years) and a gap more comparable to the male players among higher ranked players (6 years).

Competitive activity

Focusing on the top 1000 players in each circuit, we found that the highest ranked players, whether juniors or professionals, competed in more events per year than lower ranked players. The median events for the top 250 boys was 21 and for professional men was 24, which was 11 and 13 events more than the median for players ranked 751-1000, respectively. In each ranking group, professional men generally played 3 events more than their junior counterparts (Table 1, $p < 0.001$).

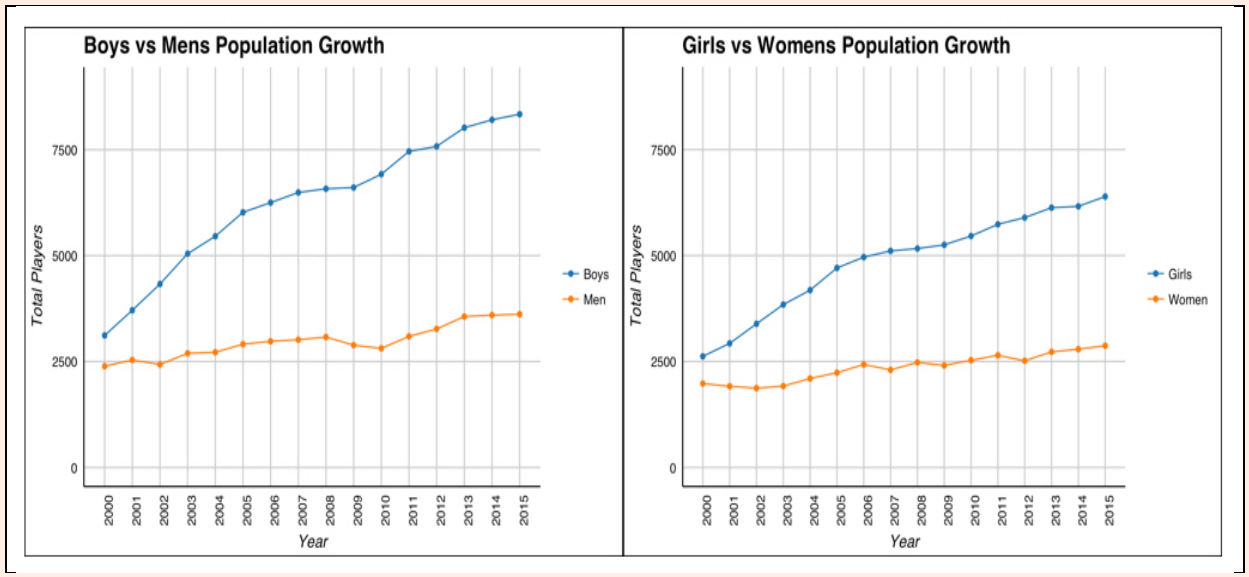

Figure 1. Population count of junior and professional men's players between 2000 and 2015 (left panel) and junior and professional women's players (right panel).

Table 1. Median (IQR) of competitive singles activity of junior and professional tennis players between 2000-2015.

Activity	Junior Boys	Professional Men	Junior Girls	Professional Women
Sample Size (matches)	1.8 million	0.8 million	1.5 million	0.6 million
Sample Size (players)	34,986	14,033	26,189	11,727
Events Per Season[a,b]				
1-250	21 (17-25)	24 (21-27)	18 (15-22)	23 (19-26)
251-500	16 (12-21)	21 (18-24)	14 (11-18)	17 (13-21)
501-750	13 (8-18)	16 (13-20)	12 (8-16)	11 (8-15)
751-1000	10 (6-15)	11 (8-15)	9 (6-13)	7 (4-10)
Matches Per Season[a,b]				
1-250	56 (47-65)	60 (54-67)	48 (41-56)	54 (47-61)
251-500	40 (29-47)	45 (40-49)	34 (26-40)	34 (28-41)
501-750	30 (20-37)	31 (26-36)	26 (18-32)	20 (16-25)
751-1000	23 (14-30)	19 (15-24)	20 (12-26)	12 (8-15)
Sets Per Season[a,b]				
1-250	129 (106-150)	142 (126-160)	109 (91-126)	123 (107-140)
251-500	90 (65-108)	104 (91-117)	76 (59-90)	78 (65-93)
501-750	68 (45-85)	72 (59-84)	59 (41-72)	46 (36-57)
751-1000	52 (31-68)	44 (34-54)	45 (27-58)	26 (18-35)
Games Per Season[a,b]				
1-250	652 (532-759)	711 (632-811)	535 (452-625)	590 (514-686)
251-500	440 (315-529)	503 (444-567)	364 (279-426)	359 (301-422)
501-750	325 (208-406)	334 (278-390)	273 (184-332)	203 (159-250)
751-1000	240 (139-314)	190 (150-238)	205 (121-262)	107 (76-142)
Win Percentage Per Season[a,b]				
1-250	64.2 (59.4-69.2)	63.5 (59.2-67.8)	65.1 (60.0-70.8)	60.8 (55.7-66.7)
251-500	57.9 (52.4-63.6)	54.7 (50.0-59.2)	57.8 (52.1-64.9)	52.6 (46.7-59.5)
501-750	54.5 (47.7-61.5)	48.0 (42.9-54.2)	53.6 (46.9-60.7)	46.9 (40.0-55.6)
751-1000	51.5 (44.4-60.0)	41.2 (35.3-50.0)	50.0 (42.9-57.9)	40.0 (33.3-50.0)

[a] Indicates a difference between junior boys and professional men at the 5% level or less
[b] Indicates a difference between junior girls and professional women at the 5% level or less

Table 2. Median (IQR) of match statistics for junior and professional tennis players at the 2017 Australian Open.

Match Statistic	Junior Boys	Professional Men	Junior Girls	Professional Women
Sample Size (matches)	62	124	63	127
Service Points Won				
Percentage[a]	59.3 (51.1-66.0)	63.7 (59.2-69.0)	55.0 (50.2-61.4)	57.1 (51.2-63.9)
Clutch	55.8 (31.2-74.7)	56.5 (0.0-70.2)	57.0 (45.1-66.0)	56.9 (44.7-68.2)
First Service Points				
Percentage[b]	61.6 (55.1-65.5)	59.6 (56.1-65.3)	58.0 (52.1-63.5)	60.3 (55.7-65.9)
Clutch	61.9 (46.3-71.8)	58.5 (0.0-69.0)	59.8 (47.8-69.0)	62.2 (51.7-70.5)
First Service Points Won				
Percentage[a]	66.7 (59.3-74.2)	72.1 (66.7-78.4)	64.1 (55.6-72.8)	64.2 (57.8-72.7)
Clutch	62.6 (33.1-77.6)	63.0 (0.0-77.7)	61.9 (50.6-72.7)	63.2 (48.8-74.0)
Second Service Points Won				
Percentage[a]	47.3 (41.0-55.1)	50.4 (44.1-56.8)	44.3 (39.7-52.4)	45.6 (38.5-53.3)
Clutch	41.6 (15.8-57.2)	42.1 (0.0-56.9)	44.2 (30.3-56.8)	42.8 (28.9-54.9)
Aces				
Percentage[a,b]	3.6 (1.5-6.6)	8.0 (4.7-12.1)	2.8 (0.0-4.5)	3.8 (1.8-6.9)
Clutch[a,b]	0.0 (0.0-5.2)	2.9 (0.0-9.5)	1.0 (0.0-4.0)	2.9 (0.0-7.1)
Double Faults				
Percentage[a]	4.9 (2.7-7.5)	3.8 (2.3-5.3)	5.4 (3.2-8.4)	5.0 (3.2-7.9)
Clutch[a]	3.0 (0.0-7.1)	1.6 (0.0-4.7)	4.1 (0.2-8.1)	4.0 (0.0-7.5)
Break Points				
Percentage[b]	8.8 (3.5-12.7)	7.5 (4.6-10.7)	9.7 (4.9-14.1)	10.4 (6.5-14.3)
Clutch[a]	20.5 (0.0-35.8)	14.6 (0.0-26.2)	11.9 (0.0-19.8)	13.2 (0.0-20.5)
Break Points Won				
Percentage	42.9 (25.0-57.1)	37.5 (25.0-50.0)	44.4 (33.3-55.6)	42.9 (33.3-54.2)
Clutch[a,b]	42.2 (11.0-66.3)	34.1 (6.7-53.2)	46.1 (28.2-63.0)	39.8 (19.5-56.3)
Net Points				
Percentage[a,b]	7.9 (4.7-12.4)	10.1 (7.1-13.6)	4.9 (1.7-7.8)	6.3 (4.1-9.9)
Clutch	4.9 (0.0-11.1)	4.8 (0.0-13.8)	3.5 (0.0-7.4)	4.7 (0.0-9.3)
Net Points Won				
Percentage[a,b]	62.5 (50.0-75.0)	65.3 (57.1-72.7)	63.6 (50.0-77.8)	66.7 (55.3-80.0)
Clutch[b]	47.2 (0.0-73.6)	53.8 (0.0-72.5)	51.7 (0.0-73.1)	64.0 (3.6-81.2)
Total Winners				
Percentage	39.0 (29.6-48.7)	49.7 (41.6-57.2)	34.0 (25.2-42.3)	42.9 (35.7-50.0)
Clutch[a,b]	30.3 (0.0-47.5)	35.9 (0.0-55.1)	30.1 (1.0-39.8)	38.5 (18.2-48.6)
Total Unforced Errors				
Percentage[a,b]	61.0 (51.3-70.4)	50.3 (42.8-58.4)	65.8 (57.5-73.9)	57.1 (50.0-64.3)
Clutch	52.7 (0.0-71.8)	38.1 (0.0-55.9)	64.6 (44.0-76.3)	54.1 (34.4-64.6)
Total Points Won				
Percentage[a,b]	53.0 (45.3-60.8)	50.8 (45.8-55.4)	52.7 (46.5-60.2)	51.0 (45.0-56.6)
Clutch[b]	49.8 (25.9-65.4)	42.8 (0.0-57.3)	49.2 (39.7-60.5)	48.0 (36.3-59.3)

[a] Indicates a difference between junior boys and professional men at the 5% level or less
[b] Indicates a difference between junior girls and professional women at the 5% level or less

Matches, sets, and games played were even more positively associated with player ranking. Top 250 boys competed in a median of 56 matches and top 250 professionals 60 matches, which were 33 and 41 more matches than players ranked 751-1000. Top 250 boys played a median of 129 sets and 652 games, while professional men in the same rank group played a median of 140 sets and 711 games. This activity was significantly greater than lower ranked players. Juniors ranked 751-1000 played a median of 77 fewer sets and 412 fewer games, while the professional counterparts played 96 fewer sets and 521 fewer games.

Top 500 professional men played significantly more matches, sets, and games than junior boys in the same rank category (Table 1). Lower ranked players had more similar activity.

Despite having less match activity than professionals, junior boys tended to have a higher match win percentage per rank group than professionals ($p < 0.001$). These differences increased as player ranking decreased.

Event activity patterns between junior girls and professional women followed a similar pattern as the boys and men. Higher levels of match, set, and game activity per season were observed for professional women compared to junior girls; with the differences being most notable among the top 250 but less so among the lower ranked groups. However, differences in win percentage were larger between girls and professional women ranging from 5 to 10% and increasing with lower ranking (Table 1).

Match characteristics

Match data from the 2017 Australian Open revealed a number of differences in the match characteristics of juniors and professionals. For both male and female players, professionals had a higher frequency of aces, a higher percentage of points won at net, and a higher percentage of winners relative to unforced errors (Table 2). The per-

centage of total points won was the only statistic that both junior boys and girls had a statistically significantly higher percentage than professionals.

Professional men were found to perform significantly better than juniors across several service statistics, including service points won, first service points won, and second service points won. However, the same difference was not observed for female players.

Several clutch measures differed between juniors and professionals. Clutch averages on aces were significantly higher among professional players, while clutch averages in break points converted and unforced errors relative to winners were significantly higher for junior players (Table 2).

Game characteristics

Game characteristics at Majors show several notable differences between junior and professional play. Both male and female professionals show a higher serve advantage across surfaces compared to juniors ($p < 0.001$, Table 3) with a larger gap for males than females. Junior players had higher average point spreads and break point opportunities, suggesting that Grand Slam matches have been less tightly contested for juniors than professionals.

For male players, we also observed a higher frequency of tiebreaks (a median difference of +2 percentage points) and a higher median number of points (+85 points played) among professionals in contrast with the junior players (Table 3). The difference in points played can be attributed to the fact that professional men play a best of 5 match format while junior boys play a best of 3.

Shot characteristics

Stroke production, measured as the number of shots played in a match, was generally greater for professional players compared to junior players (Table 4). The differences were largest for male players, where the average production in a Grand Slam match was +62 on serve, on forehand was +97, and on backhand was +100 compared to the typical production in a junior Grand Slam match. For female players, the differences were +11 on serve, +2 on forehand, and +21 on backhand.

Both male and female professional players show higher impact speeds compared to juniors, with the largest differences found on serve (median for men was 179 kph vs 158 for boys; median for women was 153 vs 146 for girls, $p < 0.001$; Table 4). Forehand speeds at baseline were a median of 4 kph faster for men and 6 kph faster for women professionals compared to juniors. Similar differences were found on the backhand speeds for male players but not female players. Professionals also hit groundstrokes nearer to sidelines than junior players.

While professional men hit to the body on only 7% of first serves, junior boys hit to that region 19% of the time ($p < 0.001$, Table 4). A similar gap was found for female players, with junior girls hitting to the body on first serves 12 percentage points more often than professionals. On second serve, these differences persisted. Junior boys hit 48% of second serves to the body compared to just 31% for professional men. Juniors girls hit an even higher percentage to the body on second serves (57%) and 22 percentage points more often than professional women.

Professional men travelled greater distances per point and nearly twice the distance per Grand Slam match compared to junior boys (Table 4). However, the average peak foot speed and changes of direction per point tended to be great for junior boys compared to professionals.

Table 3. Median (IQR) of competitive singles game characteristics of junior and professional tennis players for four Grand Slams*

Game Characteristic	Junior Boys	Professional Men	Junior Girls	Professional Women
Sample Size (matches)	246	1,089	250	1,126
Points Per Match[a]				
Clay	131 (112-158)	213 (174-258)	122 (104-150)	133 (108-170)
Grass	137 (118-162)	221 (180-275)	115 (100-177)	130 (111-169)
Hard	130 (104-167)	216 (177-265)	122 (105-175)	129 (108-171)
Serve Percentage Won Per Match[a,b]				
Clay	58.3 (52.4-65.4)	62.7 (56.5-68.3)	52.8 (46.8-59.1)	56.1 (49.4-62.0)
Grass	63.6 (58.0-67.8)	66.4 (61.2-71.8)	57.2 (49.6-64.1)	59.0 (52.7-64.7)
Hard	58.7 (52.5-65.9)	63.8 (58.4-69.2)	55.0 (50.0-62.1)	57.1 (50.5-63.6)
Point Spread Per Match[a,b]				
Clay	4.0 (3.1-4.7)	3.6 (2.9-4.4)	4.0 (2.9-5.0)	3.9 (3.0-4.9)
Grass	3.2 (2.3-4.0)	3.4 (2.8-4.1)	3.9 (3.0-4.9)	3.6 (3.0-4.8)
Hard	3.8 (3.0-4.9)	3.6 (2.9-4.3)	3.5 (2.8-4.5)	3.8 (2.9-4.7)
Break Point Chances Per Match[a,b]				
Clay	6 (4-8)	5 (3-8)	8 (6-10)	7 (5-9)
Grass	5 (3-8)	4 (2-6)	7 (4-10)	6 (4-8)
Hard	6 (4-8)	5 (3-7)	7 (4.5-9)	7 (5-9)
Tiebreaks Per Match[a], Mean				
Clay	11.6	14.1	5.7	9.2
Grass	18.2	20.2	10.5	12.1
Hard	9.3	17.1	7.3	9.0

* The data include the 2017 Australian Open for juniors and the 2016 Majors for all other junior Grand Slams; the professional data included matches from the 2016-2016 Grand Slams

[a] Indicates a difference between junior boys and professional men at the 5% level or less

[b] Indicates a difference between junior girls and professional women at the 5% level or less

Table 4. Median (IQR) of shot and movement characteristics of junior and professional tennis players at the 2012-2017 Australian Opens.

Activity	Junior Boys	Professional Men	Junior Girls	Professional Women
Sample Size (matches)	12	21*	6	21*
Sample Size (shots)	8,282	25,906	3,361	13,281
Rally Length	4.8 (1-13)	5.0 (1-14)	4.4 (1-10)	4.6 (1-12)
Shot Production[a,b]				
Serve	72 (49-103)	134 (91-168)	64 (48-81)	75 (51-114)
Forehand	140 (84-227)	237 (138-367)	118 (84-147)	120 (74-173)
Backhand	119 (61-185)	219 (122-344)	89 (57-112)	110 (56-206)
Shot Speed[a,b] (kph)				
Serve	158 (119-193)	179 (140-213)	146 (116-176)	153 (122-186)
Forehand	113 (75-142)	119 (77-148)	110 (75-134)	111 (76-135)
Backhand	105 (68-131)	108 (70-137)	103 (69-128)	106 (68-129)
Speed at Baseline[a,b] (kph)				
Forehand	56 (47-65)	60 (54-67)	48 (41-56)	54 (47-61)
Backhand	40 (29-47)	45 (40-49)	34 (26-40)	34 (28-41)
Net Clearance[a,b] (m)				
Serve	129 (106-150)	142 (126-160)	109 (91-126)	123 (107-140)
Forehand	90 (65-108)	104 (91-117)	76 (59-90)	78 (65-93)
Backhand	68 (45-85)	72 (59-84)	59 (41-72)	46 (36-57)
First Serve Patterns[a,b] (%)				
Wide	37.8	45.7	36.2	36.3
T	43.2	46.9	35.9	47.7
Body	19.0	7.4	27.9	16.0
Second Serve Patterns[a,b] (%)				
Wide	21.9	32.0	21.0	23.8
T	30.7	36.7	21.7	41.0
Body	47.5	31.3	57.3	35.1
First Serve Patterns[a,b] (%)				
Wide	37.8	45.7	36.2	36.3
T	43.2	46.9	35.9	47.7
Body	19.0	7.4	27.9	16.0
Serve Return Time[b] (s)	0.54 (0.38-0.80)	0.55 (0.37-0.81)	0.52 (0.38-0.76)	0.48 (0.35-0.75)
Serve Return Reaction Time[a,b] (s)	0.73 (0.56-0.95)	0.66 (0.52-0.87)	0.78 (0.63-0.97)	0.73 (0.58-0.92)
Serve + 1 Stretch[b] (m)	4.99 (1.46-8.77)	5.10 (1.65-8.77)	4.92 (1.42-8.67)	5.25 (1.68-9.25)
Sideline Distance[a,b] (m)				
Forehand	1.94 (0.35-3.68)	1.77 (0.38-3.56)	1.93 (0.32-3.67)	1.89 (0.37-3.66)
Backhand	2.27 (0.53-3.81)	2.09 (0.47-3.71)	2.30 (0.48-3.84)	2.14 (0.45-3.78)
Distance from Baseline[a] (m)				
Forehand	3.05 (0.54-5.19)	3.11 (0.59-5.17)	2.98 (0.55-5.15)	3.03 (0.57-5.18)
Backhand	3.11 (0.58-5.17)	3.00 (0.59-5.17)	3.06 (0.46-5.19)	3.04 (0.57-5.30)
Inside Out Forehand[a] (%)	9	10	8	8
Down the line Backhand[a,b] (%)	9	11	9	11
Distance travelled per point[a,b] (m)	6.9 (0.3-19.9)	7.4 (0.3-24.2)	6.3 (0.2-18.4)	5.9 (0.2-19.6)
Distance travelled per match[a,b] (m)	993 (562-1,610)	1,990 (1,243-2,916)	798 (549-1,012)	881 (556-1,504)
Peak foot speed[a,b] (kph)	12.0 (5.1-21.6)	10.5 (4.7-18.2)	11.9 (4.9-21.1)	9.1 (3.7-16.3)
Changes of direction per point[a,b]	6.0 (0-18)	5.0 (0-22)	6.0 (0-18)	4.5 (0-18)
Work per point[a,b]	2,236 (36-7,335)	1,761 (27-6,257)	1,690 (30-5,462)	917 (17-3,342)
Work per match[a,b] (per 1000 units)	320 (168-641)	475 (290-695)	216 (166-278)	138 (85-248)

* Professional matches were matched on the round of junior matches
[a] Indicates a difference between junior boys and professional men at the 5% level or less
[b] Indicates a difference between junior girls and professional women at the 5% level or less

These factors contributed to a work rate per point that was a median of 27% higher for junior boys ($p < 0.001$). Owing to the greater distances travelled, total work in matches was nearly 50% greater for professional men than professional boys.

Junior girls also showed higher foot speeds and changes of direction per point compared to professional women (Table 4). Because distances travelled in matches were more similar for female players than male players, junior girls tended to perform greater work per point (median of 84% more) and match (median of 56% more) compared to professional women.

Drivers of match win

For junior boys, the differential in the total percentage points won and first service points won were the strongest explanatory factors for match outcomes. Among clutch statistics, the difference in total clutch points won was the most strongly associated variable by far, having a relative influence of 87%, while clutch break points won had the second greatest influence (10%, Table 5). Professional men showed strikingly similar associations, with the same number one explanatory factor for both the simple percentage statistics and clutch statistics.

More differences were found between junior girls

and professional women players. While the differential in first serve points won was the most strongly influential statistic for junior girls (85%), the differential in total points won was the most important factor for professional women (93%, Table 3). In terms of clutch statistics, however, both player groups showed strong similarity as the first and second most influential clutch statistics were total points won and first serve points won.

Table 5. Relative influence* of the association of match statistics for match wins at the 2017 Australian Open.

Player Group	Type	Match Statistic	Relative Influence
Junior Boys	Simple Percentage	Total Points Won	66
		First Serve Points Won	30
		Winners vs Unforced Errors	2
		Second Serve Point Won	2
Junior Boys	Clutch Average	Total Points Won	87
		Break Points Won	10
		Winners vs Unforced Errors	2
		First Serve Points Won	1
Professional Men	Simple Percentage	Total Points Won	100
Professional Men	Clutch Average	Total Points Won	68
		Break Points Won	16
		First Serve Points Won	10
		Winners vs Unforced Errors	6
Junior Girls	Simple Percentage	First Serve Points Won	85
		Total Points Won	15
Junior Girls	Clutch Average	Total Points Won	74
		First Serve Points Won	26
Professional Women	Simple Percentage	Total Points Won	93
		Winners vs Unforced Errors	4
		First Serve Points Won	3
Professional Women	Clutch Average	Total Points Won	88
		First Serve Points Won	10
		Winners vs Unforced Errors	2

* The frequency factor was selected across models in a generalized boosted regression

Discussion

The current population of junior competitors is twice the size of the professional tour and lacks the competitiveness and depth of the professional game. Thus, in the transition from the junior to professional level, players must become accustomed to an environment with a deeper and higher-quality group of athletes. These findings substantiate the perceived loss of competence and confidence that has been reported by transitioning junior players (Newman, 2009).

As junior players rise in the professional ranks, they can expect to be competing in more events, matches, sets and games throughout the year. This appears to support the popular view that the professional game is more physical than junior tennis (United States Tennis Association, 2004). Even talented junior player can expect to have fewer wins as a professional and players will have to prepare psychologically for this change if they are going to successfully navigate the early years of their professional career. This fits with the importance placed on skills like self-regulation among professional athletes (Weinberg et al., 1992), including those managing the junior-professional transition in tennis (Matthews et al., 2012).

The margins differentiating winners and losers of matches at the professional level are significantly narrower than in junior matches. At the same time, the average junior player might expect to experience a greater serve advantage as a professional, to find it more difficult to get break point opportunities, and to play in more tiebreaks than when they were a junior. These competitiveness findings are consistent with the results of the cross-sectional study of Hizan et al. (2011), who compared similar characteristics across 12U, 16U and professional matchplay, and suggest that these observations might be generalizable to other tennis populations.

Some of the largest differences we found between juniors and professionals were in the observed physical demands of play. Professional players play with more power and accuracy than junior players competing at a comparable level (late stages of Grand Slams). This would appear, at least in part, to be due to the physical capacity maturation of athletes (Lehance et al., 2009), although direct evidence of this process is surprisingly limited. The largest difference in power was observed on serve where the men's serve was an average of 20 kph faster than the boy's serve and the women's serve was 10 kph faster than the girl's serve, accounting for the increased serve advantage at the professional level. Serve placement also showed considerably fewer deliveries hit near to lines at the junior level, which might be explained by technical and strategic skill as well as stature (Vaverka and Cernosek, 2013). Whatever the mechanism, these differences highlight a considerable adjustment for junior players in the transition to the professional game where they can expect to play at higher speeds and closer to the margins of the court.

The physical demands of the professional game were considerably greater for professional men than jun-

ior boys. Shot production on serve and rally shots nearly double at the senior level and the total distance and work performed in the second week of a men's Grand Slam was also more than two times the demands of the second week matches of a junior boys Major. This finding extends the previous conceptualisation of the physical demands of Grand Slam tennis (Unierzyski and Wieczorek, 2004), both through its examination of the junior game as well as focus on the second week. Because the same was not found for female players, we can attribute most of these differences to the difference in match format at men's Grand Slams which is a best of 5 match format compared to the best of 3 match format for junior boys and all junior girls and professional women's matches. It is also notable that the speed and changes of direction were actually higher for junior players, both boys and girls, compared to professionals. Thus, while juniors have the potential to play at the same intensity as professionals, the sustainability of that effort is put to the test in the professional game, especially for transitioning male players.

There were several areas of the analysis where we found smaller differences between professional women and junior girls than professional men and junior boys. This was found for match characteristics, where female player service statistics were more comparable; and physical characteristics, where female player hitting speed and movement characteristics were also more analogous than for male players. In addition to the similarity of match format, we believe that more homogenous age profiles of junior and professional female tennis players, as evidenced by the greater overlap in age distributions of the two cohorts in the current study, may be a factor. Indeed, a combination of policy measures (ie., the age eligibility rule) as well as evidence of earlier transitioning (Kovalchik et al., 2017; Otis, et al., 2006) reaffirm the view that female players are capable of reaching their peak performance in tennis at earlier ages than male players. Notwithstanding the larger overlap in age distribution, prior developmental studies suggest that an equal age difference between a junior girl and professional woman may represent less of a developmental difference than that between a junior boy and professional male. Collectively, these insights help to explain why we might expect the differences between the variants of the female game to be less pronounced than the men's game.

While detailed data about the characteristics of junior matchplay is still more limited than for professional matchplay and sample sizes can be especially small for comparisons with modern tracking data, we have demonstrated that there is sufficient information available to make meaningful comparisons between junior and professional play. Identifying the ways in which the junior and professional levels differ in competitiveness, play demands, and the physical characteristics of shot and movement can be useful for young tennis players and their coaches to set realistic expectations as they transition. Another possible application of these findings is to set benchmarks for juniors aiming for a professional career. An important direction for future research will be to explore the design and effectiveness of changes in training influenced by the increasing detail we have presented on the differences of junior and professional matchplay.

Conclusions

This study has provided one of the most comprehensive comparisons of the junior and professional tennis tours. By compiling multiple data sources, including match activity, match statistics, point-level data, and tracking data with ball and player movement, the present paper evaluated the similarities and differences of matchplay between junior and professional players across multiple dimensions. Our results provide important insights into how competitive experience will change as young tennis players transition from the junior to the professional level.

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References

Brouwers, J., De Bosscher, V. and 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.

Buszard, T., Reid, M., Masters, R. and Farrow, D. (2016) Scaling the equipment and play area in children's sport to improve motor skill acquisition: A systematic review. *Sports Medicine* **46(6),** 829-843.

Chandler, T.J., Kibler, W.B., Uhl, T.L., Wooten, B., Kiser, A. and Stone, E. (1990) Flexibility comparisons of junior elite tennis players to other athletes. *The American Journal of Sports Medicine* **18(2),** 134-136.

Crespo, M. and Miley, D. (1998) *Advanced Coaches Manual.* London: International Tennis Federation Ltd.

Ellenbecker, T.S., Roetert, E.P., Piorkowski, P.A. and Schulz, D.A. (1996) Glenohumeral joint internal and external rotation range of motion in elite junior tennis players. *Journal of Orthopaedic & Sports Physical Therapy* **24(6),** 336-341.

Ellenbecker, T. and Roetert, E.P. (2003a) Age specific isokinetic glenohumeral internal and external rotation strength in elite junior tennis players. *Journal of Science and Medicine in Sport* **6(1),** 63-70.

Ellenbecker, T.S. and Roetert, E.P. (2003b). Isokinetic profile of elbow flexion and extension strength in elite junior tennis players. *Journal of Orthopaedic & Sports Physical Therapy* **33(2),** 79-84.

Friedman, J.H. (2002) Stochastic gradient boosting. Computational *Statistics & Data Analysis* **38(4),** 367-378.

Gillet, E., Leroy, D., Thouvarecq, R. and Stein, J. F. (2009) A notational analysis of elite tennis serve and serve-return strategies on slow surface. *The Journal of Strength & Conditioning Research* **23(2),** 532-539.

Gillet, E., Leroy, D., Thouvarecq, R., Mégrot, F. and Stein, J.F. (2010) Movement-production strategy in tennis: A case study. *The Journal of Strength & Conditioning Research* **24(7),** 1942-1947.

González-Díaz, J., Gossner, O. and Rogers, B.W. (2012) Performing best when it matters most: Evidence from professional tennis. *Journal of Economic Behavior & Organization* **84(3),** 767-781.

Hizan, H., Whipp, P. and Reid, M. (2011) Comparison of serve and serve return statistics of high performance male and female tennis players from different age-groups. *International Journal of Performance Analysis in Sport* **11(2),** 365-375.

Hizan, H., Whipp, P. and Reid, M. (2015) Gender differences in the spatial distributions of the tennis serve. *International Journal of Sports Science & Coaching* **10(1),** 87-96.

Hizan, H., Whipp, P., Reid, M. and Wheat, J. (2014) A comparative analysis of the spatial distributions of the serve return. *International Journal of Performance Analysis in Sport* **14(3),** 884-893.

Jackson, D. and Mosurski, K. (1997) Heavy defeats in tennis: Psychological momentum or random effects? *Chance* **10(1),** 27-34.

Johnson, C.D. and McHugh, M.P. (2006) Performance demands of professional male tennis players. *British Journal of Sports Medicine* **40(8),** 696-699.

Klaassen, F.J. Magnus, J.R. (2001) Are points in tennis independent and identically distributed? Evidence from a dynamic binary panel data model. *Journal of the American Statistical Association* **96(454),** 500-509.

Klaassen, F. and Magnus, J.R. (2014) First and second service. In: *Analyzing Wimbledon: The Power of Statistics*. Eds: Klaassen, F. and Magnus, F.R. New York: Oxford University Press. 127-136.

Knight, G. and O'Donoghue, P. (2012) The probability of winning break points in Grand Slam men's singles tennis. *European Journal of Sport Science* **12(6),** 462-468.

Kovalchik, S.A. (2014) The older they rise the younger they fall: Age and performance trends in men's professional tennis from 1991 to 2012. *Journal of Quantitative Analysis in Sports* **10(2),** 99-107.

Kovalchik, S.A., Bane, M.K. and Reid, M. (2017) Getting to the top: an analysis of 25 years of career rankings trajectories for professional women's tennis. *Journal of Sports Sciences* **35(19),** 1914-1910.

Kovalchik, S. and Ingram, M. (2016) Hot heads, cool heads, and tacticians: Measuring the mental game in tennis. In: *MIT Sloan Sports Analytics Conference*, March 11-12, Boston, USA. ID: 1464. Available form URL: http://www.sloansportsconference. com/wp-content/uploads/2016/02/1464-Hot-heads-cool-heads-and-tacticians.pdf

Kovalchik, S. and Reid, M. (2017) Measuring Clutch Performance in Professional Tennis. *Italian Journal of Applied Statistics*. In Press.

Kuroda, Y., Suzuki, N., Dei, A., Umebayashi, K., Takizawa, K. and Mizuno, M. (2015) A comparison of the physical fitness, athletic performance and competitive achievements of junior and senior tennis players. *Movement, Health & Exercise* **4(1).**

Lehance, C., Binet, J., Bury, T. and Croisier, J.L. (2009) Muscular strength, functional performances and injury risk in professional and junior elite soccer players. *Scandinavian Journal of Medicine & Science in Sports* **19(2),** 243-251.

Martínez-Gallego, R., Guzmán, J.F., James, N., Pers, J., Ramón-Llin, J. and Vuckovic, G. (2013) Movement characteristics of elite tennis players on hard courts with respect to the direction of ground strokes. *Journal of Sports Science & Medicine* **12(2),** 275-281.

Matthews, A., Farrow, D., MacMahon, C. and Weissensteiner, J. (2012) Talent and expertise: Examining the barriers and facilitators of the junior to senior transition experience in Australian tennis-An in-depth analysis of the journey towards a professional tennis career. *Journal of Sport & Exercise Psychology* **34(1),** S48-S49.

Newman, J. (2009) *How Do the Motivational Profiles of Elite Male Tennis Players Affect Their Ability to Transition from Junior to Professional Tennis?* Doctoral Dissertation, Roehampton University, London.

Otis, C., Crespo, M., Flygare, C., Johnston, P., Keber, A., Lloyd-Kolkin, D., Loehr, J., Martin, K., Pluim, B.M., Quinn, A., Roetert, P., Stroia, K.A. and 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.

Reid, M., Crespo, M., Santilli, L., Miley, D. and 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.

Reid, M., Mcmurtrie, D. and Crespo, M. (2010) The relationship between match statistics and top 100 ranking in professional men's tennis. *International Journal of Performance Analysis in Sport* **10(2),** 131-138.

Reid, M., Morgan, S. and Whiteside, D. (2016) Matchplay characteristics of Grand Slam tennis: implications for training and conditioning. *Journal of Sports Sciences* **34(19),** 1791-1798.

Silva, R.T., Gracitelli, G.C., Saccol, M.F., de Souza Laurino, C.F., Silva, A.C. and Braga-Silva, J.L. (2006) Shoulder strength profile in elite junior tennis players: horizontal adduction and abduction isokinetic evaluation. *British Journal of Sports Medicine* **40(6),** 513-517.

Unierzyski, P. and Wieczorek, A. (2004) Comparison of tactical solutions and game patterns in the finals of two grand slam tournaments in tennis. *Science and Racket Sports III* 200-205.

United States Tennis Association. (2004) *Coaching Tennis Successfully*. Champaign, IL: Human Kinetics.

Vaverka, F. and Cernosek, M. (2013) Association between body height and serve speed in elite tennis players. *Sports Biomechanics* **12(1),** 30-37.

Wei, X., Lucey, P., Morgan, S., Reid, M., & Sridharan, S. (2016). "The Thin Edge of the Wedge": Accurately Predicting Shot Outcomes in Tennis using Style and Context Priors. MIT Sloan Sports Analytics Conference.

Weinberg, R., Grove, R. and Jackson, A. (1992) Strategies for building self-efficacy in tennis players: A comparative analysis of Australian and American coaches. *The Sport Psychologist* **6(1),** 3-13.

Whiteside, D. and Reid, M. (2017) External match workloads during the first week of Australian Open tennis competition. *International Journal of Sports Physiology and Performance* **12(6),** 756-763.

Key points

- Junior players transitioning to professional level, must adapt to a field of a deeper and higher-quality athletes
- Junior players rise in the professional ranks, they can expect to compete in more events, matches, sets and games throughout the year
- The margins differentiating winners and losers of matches at the professional level are significantly narrower than at the junior level
- Some of the largest differences between junior and professional tennis are in its physical demands

AUTHOR BIOGRAPHY

Stephanie A. KOVALCHIK
Employment
Game Insight Group, Tennis Australia
Victoria University
Degree
PhD
Research interest
Sports performance, statistics
E-mail: stephanie.kovalchik@vu.edu.au

Machar REID
Employment
Game Insight Group, Tennis Australia
Degree
PhD
Research interest
Sports biomechanics, coaching
E-mail: mreid@tennis.com.au

✉ **Stephanie A. Kovalchik**
Institute of Sport, Exercise and Active Living, Victoria University, PO Box 14428, Melbourne 8001, VIC, Australia