

Prediction of Tennis Performance in Junior Elite Tennis Players

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Abstract

Predicting current and future tennis performance can lead to improving the development of junior tennis players. The aim of this study is to investigate whether age, maturation, or physical fitness in junior elite tennis players in U13 can explain current and future tennis performance. The value of current tennis performance for future tennis performance is also investigated. A total of 86 junior elite tennis players (boys, $n = 44$; girls, $n = 42$) U13 (aged: 12.5 ± 0.3 years), and followed to U16, took part in this study. All players were top-30 ranked on the Dutch national ranking list at U13, and top-50 at U16. Age, maturation, and physical fitness, were measured at U13. A principal component analysis was used to extract four physical components from eight tests (medicine ball throwing overhead and reverse, ball throwing, SJ, CMJas, Sprint 5 and 10 meter, and the spider test). The possible relationship of age, maturation, and the physical components; “upper body power”, “lower body power”, “speed”, and “agility” with tennis performance at U13 and U16 was analyzed. Tennis performance was measured by using the ranking position on the Dutch national ranking list at U13 and U16. Regression analyses were conducted based on correlations between variables and tennis performance for boys and girls, separately. In boys U13, positive correlations were found between upper body power and tennis performance (R^2 is 25%). In girls, positive correlations between maturation and lower body power with tennis performance were found at U13. Early maturing players were associated with a better tennis performance (R^2 is 15%). In girls U16, only maturation correlated with tennis performance (R^2 is 13%); later-maturing girls at U13 had better tennis performances at U16. Measuring junior elite tennis players at U13 is important for monitoring their development. These measurements did not predict future tennis performance of junior elite tennis players three years later. Future research should focus on other aspects in order to predict tennis performance better.

Key words: Talent, adolescent, sports, athletic performance, maturation, physical fitness.

Introduction

Several researchers have pointed out the importance of physical fitness for tennis performance (Fernandez et al., 2006; Ferrauti et al., 2011; Girard and Millet, 2009; Kovacs, 2006; Kovacs, 2007; Reid and Schneiker, 2008; Roetert et al., 1992). Physical fitness in tennis consists of upper and lower body power, speed, and agility (Kovacs, 2006). In junior tennis also maturation and the relative age can influence tennis performance. In junior tennis, players compete within age categories. Within an age category, differences between players can be a maximum of two years. This difference can lead to biological, physiological, and cognitive differences. Therefore, it is im-

portant to include the relative age of the players and to analyze the possible effect of relative age (RAE) (Loffing et al., 2010; Ulbricht et al., 2015). Furthermore, when adolescent tennis players are measured in relation to their level of tennis performance, physical maturation should be included as part of the measurements (Kramer et al., 2016a). In tennis, both age and maturation might lead to physical advantages for some players, while not for others, and they may possibly be related to tennis performance.

A recent study has shown that physical fitness is important for tennis performance during adolescence (Ulbricht et al., 2016). Ulbricht and colleagues (2016) measured 755 regional tennis players and 147 national tennis players aged between 11-16 years. They found that serve velocity (radar gun), and upper body power (medicine ball throws; overhead, forehand, and backhand) were predictors for tennis performance in boys and girls. When they compared different performance levels, players with a higher level scored better in serve velocity (ES 0.78-1.02), upper body power (ES .66-1.04), and tennis-specific endurance (Hit and Turn Tennis Test) (ES .05-.95) than lower-level players. Furthermore, a study on junior male tennis players found that, at young ages (10-13 years), elite players were faster than sub-elite players; when players became older, however, this advantage for elite players disappeared (Kramer et al., 2016a). In contradiction, a study on Danish elite and non-elite male and female tennis players (aged 10-12 years) did not find any differences in power (i.e. SJ and CMJ) physical fitness between performance levels (Bencke et al., 2002). Elite players were the more talented players selected by trainers and trained around nine hours, while non-elite players were the less talented players who trained around six hours. However, to our knowledge no studies exist within tennis in which physical fitness is related to future success. It is unknown if physical fitness can be used for talent identification and which role it plays in talent-development. Previous studies have shown that physical fitness can be important tennis performance, but none of these studies investigated whether physical fitness can predict future tennis performance.

Earlier studies in tennis found that physical fitness, measured by short-term maximal protocols, was important for tennis performance in junior tennis (Kramer et al., 2016a; Ulbricht et al., 2016). However, to the best of our knowledge, no study has reported so far how physical fitness measured in U13 can predict current and future tennis performance. The added value of monitoring physical fitness needs to be clarified so that talent-development programs can be optimized for junior tennis

players and tennis performance can increase. Insight into predicting current and future tennis performance is necessary for improving the development of junior tennis players. Therefore, the aim of this study is to investigate whether age, maturation, or physical fitness can predict current and future tennis performance in junior elite tennis players in U13. The value of current tennis performance (U13) for future tennis performance (U16) is also investigated.

Methods

Procedures

All participants played competitive tennis and were part of the talent-development program of the Royal Dutch Lawn Tennis Association (KNLTB). The players were informed about the procedures of the study before they gave their consent, and permission was given by the trainers and parents. This study met the guidelines for ethical standards for sports medicine research (Harriss and Atkinson, 2009; 2011; 2014) and was approved by the KNLTB. The tests were performed on an indoor hard-surface tennis court. Anthropometrics were measured before the standardized warm-up. The warm-up, executed before the tests, included a shuttle run test, up to stage eight. After the shuttle run test, some acceleration sprints and stretching were executed. After finishing the warm-up, the tests were conducted.

Sample

The inclusion criterion was that players were part of the talent development program of the KNLTB and had a ranking at the Dutch national ranking list at U13 and U16. The study started with 92 players; however six players did not have a ranking at U16 and were left out the study. So, a total of 86 junior elite tennis players (boys, $n = 44$; girls, $n = 42$), who turned 13 (range 11.9-13.2 years) in the year the measurements were taken, were part of this study. All players were top-30 ranked on the Dutch national ranking list at U13, and top-50 at U16. The ranking that was used was the end ranking of the year in which the player turned either 13 or 16. The (physical) measurements from U13 were used to predict ranking at both U13 and U16, therefore one group of players was used and we did not use cross-sectional data. For example, if a player was born in 1996, the year-end ranking for 2012 was used for tennis performance at U16.

Protocols

Three anthropometric tests were conducted, namely standing height, sitting height, and body mass. One single observer measured standing height, sitting height, and body mass, following standard procedures (Lohman, Roche, and Martorell, 1988). Standing and sitting height were measured to the nearest 0.1 cm with a SECA height tape instrument (Model 206, Seca Instruments Ltd., Hamburg, Germany). Players sat on a table when measuring sitting height. Body mass was measured to the nearest 0.1 kg using a UWE balance (Model ATM B150, Universal Weight Enterprise Co., Ltd., Taiwan). Leg length was calculated as standing height minus sitting height. For

calculating age peak height velocity (APHV), the Mirwald method was used (Mirwald et al., 2002), in which the maturation offset is calculated and used to determine APHV.

A total of eight physical tests were conducted, a medicine ball overarm toss and a reverse overarm toss were both measured. Players stood behind a line with feet at shoulder width; they held a medicine ball weighing 1.0 kilogram. Players faced forward for overarm throws and backwards for reverse overarm throws (Berg et al., 2006; Roetert and Ellenbecker, 1998; Stockbrugger and Haenel, 2001). Distance from start position until hitting the floor was measured in meters to two decimal points. Furthermore, overarm ball throw was measured using a ball of 200 grams (diameter of 6.5 centimeters). Players held the ball in their dominant hand (Berg et al., 2006). They positioned their feet as if they were serving and threw the ball overarm as far as possible, while keeping both feet on the floor. Distance from start position until hitting the floor was measured in meters, to two decimal points.

The squat jump (SJ) and countermovement jump with arms (CJMAs) were both measured. Players were instructed to position their feet at shoulder width and keep their hands on their hips from start to finish during the SJ (Samozino et al., 2008). The starting position for the SJ was with the knees bent 100 degrees, holding this position for two seconds, and then jumping as high as possible. For the CMJAs, a player jumped as high as possible, while bending their knees and using their arms. Electronic measurement was obtained by combining the Muscle Lab with an infrared light mat, on which the player stood (Muscle Lab, Ergotest Technology A.S, Langesund, Norway). The Bosco protocol (Bosco et al., 1983) was used; these tests measured power.

Sprinting five and ten meters was measured. Each player executed a ten-meter straight sprint from a standing start, in which a player stood behind a line with feet apart at shoulder width. Players were allowed to start when ready. Time was measured at five and ten meters. Electronic time measurement was obtained by combining the Muscle Lab with an infrared light mat, on which the player stood (behind a line) before starting (Muscle Lab, Ergotest Technology A.S, Langesund, Norway).

The spider test was executed. A player needed to pick up five balls from different parts of the court as fast as possible. The balls were placed at the cross points of the singles sidelines with the baseline and the service line, and on the T. Players started in the middle of the baseline, picked up a ball, and brought the tennis ball back to the rectangle, and so on, in a clockwise direction. The researcher counted down from three to zero, and then the test started; time stopped when the last ball was placed in the rectangle. Time was measured with a stopwatch in seconds.

In an additional study, the reliability of the tests was investigated. A subgroup of 16 junior tennis players (aged 13-15 years) repeated the physical tests in the same week in order to assess data quality. For all tests, ICC's were found between 0.87-0.99, and therefore all tests were considered to be reliable.

In the current study, tennis performance was

measured by the ranking position of the players. The ranking of a player is the result of earning points in junior ranking list tournaments in the Netherlands. These tournaments are categorized in terms of one to five stars. The five-star tournaments are the strongest national tournaments, in which players can earn most points. Only a few of these are held during the year, and players are accepted for these tournaments based on their national ranking. The winner of a five-star tournament earns 2400 points outdoors and 2000 indoors, while numbers 17 through 32 earn 120 and 100, outdoors and indoors respectively, in a five-star tournament in singles. The one-star tournaments are district tournaments, which any junior tennis member in the age category may join. Many one-star tournaments are held in the Netherlands. In every tournament with four stars or less, players can play singles and doubles. The points earned for winning the doubles are fewer: four-star tournaments award the winners 400 points, and place 9-16 earn 40 points. If a player has played between one and eight singles tournaments in a season, October to September, the points earned are divided by one, and if it is more than eight tournaments, divided by two. If a player has played in one to six doubles tournaments, the points earned are divided by one, and, in more than six tournaments, by two. The ranking list total comprises the sum of the singles and doubles points earned. For example, if a player has played five tournaments with four stars in singles and doubles, and earned 2000 points for the singles and 500 for the doubles, then both sets of points are divided by one, and the sum of the earned points for this player is therefore 2500. Based on the total points earned, the ranking list is created so that the player with the most points has a ranking of one, followed by players with fewer points.

Statistical analyses

Descriptive statistics and correlations were calculated using IBM SPSS Statistics 22. The data can be considered as normally distributed due that skewness and kurtosis ranged between -0.098-0.780 and -0.840-1.023 respectively.

For measuring components instead of separate tests, a principal component analysis (see Appendix A) was conducted with a different group of players and carried out according to the Field method (Field, 2005). A total of

196 players (13-15 years) were included. The analyses resulted in four components; based on its content, component 1 was called "upper body power," component 2 "lower body power," component 3 "speed," and component 4 "agility" (Kramer et al., 2016b). With these four components, a total of 90.7% of the variance of the components was explained. Components can be calculated by using the factor loadings. To compute the component scores the following equations were used:

$$\text{Upper body power} = \text{Ball throwing (m)} * 0.840 + \text{Medicine overarm (m)} * 0.828 + \text{Medicine reverse (m)} * 0.741$$

$$\text{Lower body power} = \text{CMJas (cm)} * 0.861 + \text{SJ (cm)} * 0.853$$

$$\text{Speed} = \text{Sprint 5m (s)} * 0.898 + \text{Sprint 10m} * 0.750$$

$$\text{Agility} = \text{Spider test (s)} * 0.812$$

Based on the correlations, only significant variables with ranking at U13 and U16 were used for the regression. Regression analyses were conducted for boys and girls, separately, in order to obtain information on the importance of age, maturation, upper body power, lower body power, speed, and agility for ranking position at ages 13 and 16. The forward stepwise way of inserting variables was used because of their explanatory way of analyzing the important aspects of tennis performance. Forward stepwise means that all variables selected are entered into the regression, based on a probability of F-to-enter of .050. SPSS then calculated for that variable, which had the largest impact, and this was entered first and so on. Significant results were found if $p < 0.05$.

Results

In Table 1, the descriptive statistics of all tests are shown per sex. The APHV for boys and girls are on average around the mean age children have their APHV.

In Table 2, the correlations between all variables are shown per sex. In boys and girls, whether or not the correlations were significant, all correlations at U13 were in the direction that indicates a higher score correlating with a higher ranking. However, at U16, no or a weak correlation was found, and the direction of the correlation changed. For example, in boys at U13, upper body power

Table 1. Descriptive statistics for all physical fitness tests in total and by sex in junior elite tennis players. Data are means (\pm SD).

	Total (n = 92)	Boys (n = 47)	Girls (n = 45)
Age (yrs)	12.46 (.26)	12.48 (.22)	12.43 (.30)
APHV (yrs) [range]	12.93 (1.07) [11.03-15.62]	13.86 (.54) [12.73-15.62]	11.95 (.43) [11.03-12.81]
Standing height (m)	1.58 (.06)	1.57 (.06)	1.59 (.06)
Sitting height (m)	.81 (.04)	.81 (.03)	.82 (.05)
Body mass (kg)	43.8 (5.6)	43.1 (5.7)	44.4 (5.4)
Sitting height / standing height ratio (%)	51.5 (2.1)	51.7 (2.1)	51.3 (2.2)
Medicine reverse (m)	10.58 (1.69)	11.05 (1.64)	10.08 (1.61)
Medicine overhead (m)	9.24 (1.39)	9.30 (1.33)	9.17 (1.46)
Ball throwing (m)	32.14 (4.99)	34.76 (4.87)	29.41 (3.44)
SJ (cm)	26.17 (3.12)	26.82 (2.86)	25.50 (3.27)
CMJas (cm)	30.14 (3.69)	30.65 (3.59)	29.61 (3.76)
Sprint 5m (s)	1.00 (.05)	1.00 (.05)	1.00 (.05)
Sprint 10m (s)	1.89 (.08)	1.89 (.07)	1.90 (.08)
Spider test (s)	17.66 (.70)	17.50 (.70)	17.84 (.67)

Table 2. Pearson correlations between rankings, age, maturations, and physical fitness components by sex in junior elite tennis players (n = 92).

	Ranking U13	Ranking U16	Age	APHV	Upper Body Power	Lower Body Power	Speed	Agility
Boys	Ranking U13	1						
	Ranking U16	-.113	1					
	Age	-.203	.129	1				
	APHV	.062	-.154	-.223	1			
	Upper Body Power	-.500*	.145	.183	-.424*	1		
	Lower Body Power	.003	.011	.021	-.211	.361*	1	
	Speed	.260	-.103	-.083	.372*	-.522*	-.576*	1
	Agility	.254	-.109	-.077	.115	-.307*	-.342*	.507*
Girls	Ranking U13	1						
	Ranking U16	.142	1					
	Age	-.020	.024	1				
	APHV	.383*	-.355*	.136	1			
	Upper Body Power	-.268	.075	.418*	-.422*	1		
	Lower Body Power	-.323*	.048	.252	-.130	.428*	1	
	Speed	.224	-.022	-.347*	.268	-.411*	-.640*	1
	Agility	.263	.133	-.403*	.002	-.356*	-.494*	.649*

* Correlation is significant at the 0.05 level (2-tailed).

was negatively correlated with ranking at U13; with ranking at U16, the correlation was positive but not significant. In boys, a significant correlation was found between ranking at age 13 with upper body power of -0.500 (p < 0.05), which means that the higher the upper body power, the higher their ranking. APHV was negatively related to upper body power (r = -0.424) and positively related to speed (r = 0.372), which means that the earlier a boy has his APHV, the greater their upper body power is. For speed, this means that players with an earlier APHV are faster. Furthermore, all physical fitness components were related to each other (p < 0.05).

In girls, APHV was positively correlated with ranking at U13 (r = 0.383) and negatively with ranking at U16 (r = -0.355). Earlier maturation resulted in higher rankings at U13; however, at U16, those maturing late at U13 were ranked higher at U16. Furthermore, lower body power negatively correlated with ranking at U13 (r = -0.323). Age was positively correlated with upper body power (r = 0.418), and negatively with speed (r = -0.347) and agility (r = -0.403). The older a player was the better her scores were on upper body power, speed, and agility. APHV was negatively correlated with upper body power (r = 0.422), which means that the earlier the girls have their APHV, the better they score on upper body power. All physical components were related to each other.

A regression analysis was conducted to analyze the value of age, maturation, and physical fitness in predicting the tennis performance of junior elite players at U13; the results are shown in Table 3. In addition, Table 3 also

shows the regression analysis for predicting ranking at age 16.

For boys, upper body power explains 25% of the ranking at U13. This means that a higher score on upper body power results in a higher ranking. Furthermore, no correlations were found between the variables and ranking at U16 for boys. So no regression analysis was conducted. For girls, APHV was the only significant contributor for explaining ranking at U13, and it explained 15%; lower body power did not contribute significantly to the regression (p > 0.05). The earlier a girl had her APHV, the higher her ranking was at U13. In girls, APHV correlated with ranking at U16 and was used as predictor for tennis performance at U16. This results in an explanation of 13% for APHV in ranking at U16 for girls. However, later APHV results in higher rankings at U16.

Discussion

The aim of this study was to investigate whether age, maturation, or physical fitness can predict current and future tennis performance in junior elite tennis players U13. Furthermore, we investigated whether age, maturation, physical fitness, and tennis performance measured at U13 can predict tennis performance at U16. At U13, maturation and physical fitness are partly related to tennis performance. In boys, higher scores on upper body power resulted in better tennis performance. However, none of the physical fitness tests at U13 were a predictor for tennis performance at U16 for boys. In girls, earlier-

Table 3. Statistics of the regression analyses with the forward method for the total group and by sex with dependent variable ranking at U13 and U16 in junior elite tennis players (n = 92).

		B	SE B	β	R ²
Boys (n=44)	Ranking U13	Constant	33.35	6.48	.250
		Upper body power	-0.53	0.14	-.50*
Girls (n=42)	Ranking U13	Constant	-66.32	28.72	.147
		APHV	6.29	2.40	-.38*
	Ranking U16	Constant	138.09	51.92	.126
APHV		-10.39	4.33	-.36*	

* p < 0.05; R² is the explained variance by the regression.

maturing girls at age 13 had better tennis performances at U13. Furthermore, maturation was a predictor for tennis performance at U16 (R^2 is 13%). However, contradicting the influence of maturation for ranking at U13, later-maturing girls had better tennis performances at U16.

In the current study, RAE was included by using the age at the date of measurements. With boys, no correlations were found between age and physical fitness. However, age was related in girls to upper body power, speed, and agility; older girls scored higher on these physical components than their younger counterparts. These results could indicate a RAE in girls, which resulted in better physical fitness for girls born earlier. Previous studies have shown that the RAE exists in tennis (Baxter-Jones, 1995; Dudink, 1994; Ulbricht et al., 2015). In British junior tennis, 85% of junior elite players were born in the first half of the year (Baxter-Jones, 1995). In Germany, a RAE was also found, of 42% for players born in the first quarter (Ulbricht et al., 2015). In the Netherlands, half of a sample of top-ranked 12 to 16-year-old players was born between January and March (Dudink, 1994). In the current study, age was not related to physical fitness in boys; older girls scored better in physical fitness, however. Furthermore, more boys and girls were born in the first half than in the second half of the year.

The mean APHV for both boys and girls was around the expected mean age of 14 and 11.8, respectively (Malina et al., 2004). Maturation did not vary much among players; the players measured in the current study were quite a homogenous group. This could affect the insignificant contribution that APHV played in tennis performance for boys. The current study used APHV to give an indication of the physical maturation of the players. As mentioned in the introduction, it was expected that APHV can influence the tennis performance in boys and girls. We found in girls that APHV predict the tennis performance, however in boys APHV did not predict tennis performance. The limitations that are known in the literature of measuring APHV by using, stature, sitting height and body mass could perhaps explain the finding in the current study. The method of Mirwald and colleagues (2002) to calculate APHV is the most accurate and stable around 13 and 15 years of age (Malina and Koziel, 2014). The APHV will be underestimated at younger ages and overestimated at older ages (Malina and Koziel, 2014). In the current study girls are aged around the mean age of their predicted APHV, while the boys are younger than the mean age of their predicted APHV. This could result in less accurate APHV in boys than in girls. Also Table 1 shows that boys in the current study are measured before their APHV and therefore are more homogeneous in their physical maturation than girls who are measured around their APHV and the difference of physical maturation can be more expressed already.

However, in girls, maturation explained 15% of the tennis performance at U13 and 13% at U16. At U13, girls were in their APHV or just beyond it: however, at U16, all girls were beyond their APHV. In predicting tennis performance at U13, the earlier a girl matured, the better her tennis performance was, while at U16 this was the other way around: the later the maturing, the better the

tennis performance. Girls who matured earlier could have a physical advantage at this age, resulting in better tennis performance (Malina et al., 2004). A possible explanation for better tennis performance for later-maturing girls at U16 could be that later-maturing girls have to fight harder to reach the top than earlier-maturing girls, who have the advantage of their physical growth at U13 (Till et al., 2013). Till and colleagues (2013) showed that later-maturing rugby players had more potential than earlier-maturing players. At U13, players in the group of early-maturing players scored better on sprint tests than middle- or late-maturing players. However, at U15, this advantage disappeared, and those in the group of later-maturing players showed greater improvement in these two subsequent years than early- or middle-maturing players. These differences in development can continue into later adolescence (Till et al., 2013). This may raise the question of the best age for coaches to select their players for talent-development programs. The relatively younger and later-maturing players perhaps go through an alternative development phase, which cannot be assessed by cross-sectional comparison in tennis within age categories. Therefore, maturation and relative age should be assessed when selecting players for talent-development programs (Till et al., 2013). Furthermore, once players have all matured, other performance characteristics, like psychological ones, could make a difference in tennis performance. More research is needed in order to understand the changing advantage of early to late maturation in girls.

In boys, only upper body power was a significant predictor at U13, explaining 25% of the tennis performance. Perhaps, at U13, differences on court can show up by hitting the ball as hard as possible when serving as well in groundstrokes. Lower body power, speed, and agility did not predict tennis performance at U13. For speed, the expectation was that, at U13 for boys, this could predict tennis performance at U13 according to the study by Kramer and colleagues (2016a). However, the players measured in the current study were all highly ranked (top-30 at U13) and therefore more homogenous in tennis performance compared to the players in the study by Kramer and colleagues (top-150 U13) (2016a). It might be concluded that speed does discriminate between elite and sub-elite youth players, but not within a group of all elite youth players. The current study shows that the elite players in the current study scored higher on these tests compared to studies conducted earlier in tennis (Bencke et al., 2002; Berg et al., 2006; Kovacs et al., 2007).

In this study, tennis performance was measured by using the ranking of a player. This could be a limitation of this study. As mentioned in the methods section, the ranking of a player is based on the points earned in singles and doubles tournaments. However, a player who played seven tournaments but never wins a tournament can have a higher ranking, than a player who has played two tournaments and won both, but then became seriously injured. Because the points won in all tournaments up to eight will be divided by one, the more tournaments you play, the more points you earn, and the higher your ranking can be. Perhaps ranking should not be the only criterion used for

tennis performance, or perhaps ranking should be calculated in another way. The International Tennis Federation (ITF) uses the points from the best six singles tournaments and 25% of the best six doubles tournaments in order to create the ranking at U18; here, injuries have less of an influence.

Earlier studies showed the importance of physical fitness for tennis performance (Fernandez-Fernandez et al., 2014; Kovacs, 2006; Kramer et al., 2016a; Roetert et al., 1995; Ulbricht et al., 2016). Upper body power, serve velocity, and tennis-specific endurance are especially important for tennis performance. The current study has shown that, for the tennis performance of junior tennis players in the Netherlands, upper body power in boys was related to tennis performance at U13. In girls, maturation was related to tennis performance. However, not one physical fitness component measured at U13 was a predictor for tennis performance at U16. The added value of monitoring physical fitness is that trainers gain insight into the physical fitness of their players and their improvement in this regard; using these parameters for talent identification (selection criteria), however, is not advised based on the results of the current study.

However, based on the results of the current study, perhaps more attention should be paid to aspects such as psychological, technical, or tactical ones, rather than just physical aspects in tennis. It could be that these aspects constitute the decisive difference in tennis performance in a homogenous group of elite players. More research is needed to gain insight into those aspects that influence tennis performance. Furthermore, the results of physical fitness at U13 do partly predict current tennis performance, although not future performance. An earlier study stated that the ages from 15 to 18 were the most important for a tennis player, where physical and tactical improvements are greatest, and tournament results are then more predictable for future success (Reid et al., 2009). The current study showed a relationship between physical fitness and tennis performance in boys, and a relationship between maturation and tennis performance in girls; however, coaches should not look just at physical fitness at U13 when selecting the best players. More research is needed in order to ascertain which performance characteristics, other than physical fitness, should be taken into account when identifying players for talent-development programs.

Conclusion

Measuring a homogeneous group of junior elite tennis players at U13 is important for monitoring their development; however, these measurements cannot be used to predict the future performance of junior elite tennis players three years later. In such a homogeneous group of players, physical fitness had less impact on tennis performance than it has in a more heterogeneous group of junior players. Future research should focus on other performance characteristics in order to predict tennis performance better.

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Key points

- In boys, tennis performance can be partly explained by upper body power at U13, it is not a predictor for performance at U16.
- In girls, APHV is of influence for tennis performance at U13 and U16. At younger age earlier-matured girls were ranked higher, however at U16 later-matured girls were ranked higher.
- Overall, physical fitness in junior tennis is important for monitoring physical fitness development however this should not solely be used for selection criteria in a homogenous group of junior elite players.

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Appendix A

The principal component analysis (PCA) was conducted to examine if components can be created by taking together tests that measure the same physical aspects. The first step in the principal component analysis is to create a correlation matrix between the eight tests. Correlation coefficients should not be above 0.90 between tests (Field, 2005). In the current study all correlation coefficients between tests were below .90. The second step is to investigate the communalities which should be higher than 0.4. All communalities were above 0.84, and thus above the required 0.40.

The third step is to decide how many components should be extracted. Two criteria were used to decide how many components were retained for extraction and rotation. The first criterion was that components with high eigenvalues (>1.0) according to Kaiser's criterion were extracted. Secondly, the scree plot was used to produce a plot of each component's eigenvalue and was analyzed by looking at one or more break points in the data, this is a point where the curve begins to level. With almost 200 participants the scree plot gives a reliable criterion for the analysis. Based on these two criteria the number of components was identified. The PCA showed that with eigenvalues above 1.0, one component can be extracted. The scree plot of the PCA is shown in Figure 1. In Figure 1, two break points are observed at component number two and four. When looking at the theory, four components are more logical than one or two components and therefore four components were extracted.

The fourth step is rotating these components by the Varimax rotation. Items with loadings above 0.4 were considered to load on a given component. After all these steps the The KMO test and Bartlett's Test of Sphericity were analyzed. Level of significance was five percent. In Table 4 the rotated component matrix is shown with only component loadings above 0.4. Based on its content component 1 was named "upper body power", component 2 was named "lower body power", component 3 was named "speed", and component 4 was named "agility". With these four components a total of 90.63% of the variance was explained. The KMO test had a value of 0.884 and this is a very good value according to Field (2005). Bartlett's Test of Sphericity was significant (Approx. Chi2 2683.927, df 28, $p < 0.001$).

Concluding, the PCA combined eight physical tests into four components. These components were also mentioned by Kovacs (2006).

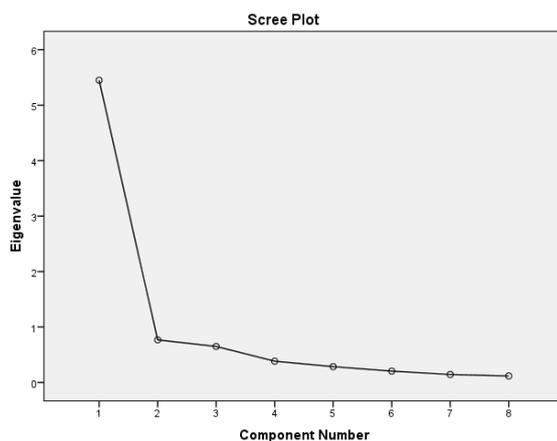


Figure 1. Scree plot of the eigenvalues and number of components from the PCA.

Table 4. Rotated component matrix from PCA.

	Component			
	1	2	3	4
Ball throwing	.840			
Medicine forwards	.828			
Medicine backwards	.741			
CMJas		.861		
SJ		.853		
Sprint 5m			.898	
Sprint 10m			.750	
Spider test				.812