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Relationship of Speed, Agility, Neuromuscular Power, and Selected Anthropometrical Variables and Performance Results of Male and Female Junior Tennis Players

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A B S T R A C T

The aim of the study was to analyses the relation between the selected speed, agility, and neuromuscular power test items. The sample of subjects consisted of 154 male and 152 female young tennis players. Using six motor and three anthropometrical tests we investigate differences between males and females and between two age categories. Finally, we analyzed the relation between motor and anthropometrical tests and a player's tennis performance. The correlation between the two agility test items and 5-m sprint is very large in male players, while only moderate with 20-m sprint in female category. Male tennis players have higher correlations between speed test items and neuromuscular test items. The speed test item (5-m sprint) has large correlation with a player's tennis performance. One-way analysis of variance results indicated that young male tennis players performed significantly better than females in all motor test items. Significant differences between genders have not been revealed only in the body mass index. Differences between the males aged 18& under and 16& under have been noted as significant in all test items, except the vertical jump, while differences between the females have been noted as significant in three anthropometrical tests, quarter jump, and the fan-drill test. Regression analyses have shown that the system of prediction variables explains a relatively small part of variance (46% – males and 40% – females). In both genders, it has been revealed that test items measuring speed significantly influence a player's tennis performance.

Key words: *tennis, speed, agility, neuromuscular power, performance*

Introduction

Tennis is a dynamic sports game in which the speeds of shots and mobility of players are constantly on the increase. Speed, agility and neuromuscular power thus remain important abilities for determining tennis performances.

Screening consists of a comprehensive medical or sports examination to evaluate general health, injury risk and long-term sport development. Feedback from the screening process provides players, coaches and fitness trainers with important information about preventive and corrective strategies, about the sport of tennis itself, and fitness training programs that specially cater to individual needs[1].

Speed or velocity describes the rate at which an athlete moves from one location to another. In addition to the movement speed, there are important features like acceleration speed, reaction speed, frequency speed, and single movement acceleration. Müller, Bunc et al. and Filipčič & Filipčič[2–4] established that speed is of great importance in determining tennis performances in competition.

Agility can be defined as the motor ability to effectively carry out acceleration or deceleration types of movements, including changes in direction. Traditional definitions of agility have simply identified speed in directional changes as the defining component[5]. Young, James and

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Montgomery[6] identified agility as comprising two key subcomponents: speed in changing direction, and cognitive factors. More recently, agility was identified as »a rapid whole-body movement with change of velocity or direction in response to a stimulus«[7]. This definition recognizes the inclusion of cognitive skills in determining agility performance, and only applies to open skills. These open skills cannot be pre-planned whereas closed skills, such as sprint running or pre-determined changes in direction, can be pre-planned[8]. Jon and Mayes[9] examined the reliability of different components of speed and agility where the change in direction was either planned or reactive. The results revealed a high degree of common variance between planned and reactive agility.

Müller[2], Filipčič[10–11], Filipčič and Filipčič[4], and Unierzyski[12] established that agility tests elucidate competitive performance at a statistically significant level. In a study by Young, McDowell, and Scarlett[13], straight speed and agility were identified as independent qualities that are specific and have a limited transfer to each other. Clark[14] established that the correlation between agility tests and sprint tests is generally moderate to large in female players and high in male players. The correlation between agility tests and sprint tests was stronger in males and females as the sprint distance increased. Leone et al.[15] concluded that speed and agility are very specific and must therefore be assessed and developed in different tennis-related conditions, while Vescovi and McGuigan[16] proved that linear sprinting, agility, and vertical jump are independent locomotor skills.

The aim of this study was to determine the correlation between selected speed, agility and neuromuscular power tests to find differences between males and females and between two age categories of junior Slovenian tennis players and, finally, to analyze the relationship of body height and mass, speed, agility, and neuromuscular power with the tennis performance of the young tennis players.

Materials and Methods

Participants

The study sample consisted of male and female junior tennis players aged between 15 and 18 years ranked on the Slovenian Tennis Association list in certain periods and who had undergone the morphological and annual motor testing of the Slovenian National Junior Tennis Team. The selected players included 154 male (age 16.90±1.74 years, body height 1.76±0.07 m, body mass 65.32±9.84 kg, BMI 21.05±2.12 kg/m^2) and 152 female junior tennis players (16.76±1.67 years, 1.68±0.05 m, 59.21±6.85 kg, BMI 20.97±2.02 kg/m^2).

Procedures

The test items selected for the study were based on their use in previous studies of young tennis players[2,4,10–12]. Speed, agility and acceleration have been shown to be relatively independent qualities[13]. Distances of 5 and 20 meters were chosen to indicate acceleration and maximum running velocity[2,10]. For this study, we chose selected anthropometrical measurements and speed, agility and neuromuscular power test items. The data collection procedures met international ethical standards and were consistent with the Helsinki Declaration. The subjects' parents were informed via the protocol described in the study's project. The University of Ljubljana Institutional Review Board approved the study before it commenced.

The measurements were conducted annually at the laboratories of the Institute of Sport in Ljubljana. All players were assessed by experienced assessors in the same conditions on the same indoor tennis court. Each subject performed the test three times and the best attempt was recorded. The following test items (Table 1) were conducted by the participants:

1. Body height was measured with a portable Seca anthropometer, model 206 (Seca, Hamburg, Germany) with an accuracy of 0.05 m.
2. Body mass was calculated with a Soehnle electronic scale, model TH 0641 (Soehnle, Nassau, Germany) with an accuracy of 0.1 kg.
3. Body mass index was calculated from body height and mass.
4. A 5-metre (S5) and 20-metre dash sprint (S20). This test item assessed a subject's acceleration and speed. The players had to run 20 meters in a straight line alongside the tennis court as fast as possible. Their feet were placed side-by-side in the tennis-ready position behind the starting line. Time was measured with the MicroGate (Italy) Optojump system. Five pairs of wireless, single-beam photocells (Brower Timing, USA) were installed along a 20-metre distance. Each pair was placed 5 meters apart. The measurement was processed via the serial port on a portable PC[17].

TABLE 1
ANTHROPOMETRICAL MEASURES, SPEED, AGILITY, NEUROMUSCULAR POWER TESTS, AND TENNIS RANKING.

Code	Name of test	Area of testing	Unit
BH	Body height	Longitudinal dimension of the body	cm
BM	Body mass	Volume of the body	kg
BMI	Body mass index	Percentage of body mass	kg×m^2
S5	5-m run	Acceleration speed	0.1 sec
S20	20-m run	Speed	0.1 sec
FAN	Fan drill test	Agility	0.1 sec
9X6R	9×6-m run	Agility	0.1sec
QJ	Quarter Jump	Neuromuscular power of legs – (take-off power)	cm
VJ	Vertical Jump	Neuromuscular power of legs – (take-off power)	cm
TR	Tennis ranking	Player's tennis performance	points

5. The fan-drill test item (FAN). The subject had to run with a racket in their dominant hand, along a marked-out course of five directions of 4.0 and 4.5 meters. The subject always had to step on the central marker and the other bases, or at least touch them with one foot. In addition, the racket had to touch the ground in front of the player at each of the outside bases. Attempt number three always had to be run backward, while the other attempts could be completed in any manner desired, as quickly as possible.
6. 9×6-m run (9X6R). The subject had to stand behind the first line and on a signal start running to the second line. The six-meter distance had to be covered nine times and the subject had to finish the run over by crossing over the second line.
7. Quarter jump (QJ). From a sideways stance with their feet apart behind the line, the subject had to take four alternate jump steps, landing on both feet. The distance from the line to the last set of footprints (heel) was measured.
8. Vertical jump (VJ). Each subject performed a countermovement vertical jump. The participants were instructed to stand on the center of a plate with a special digital belt tightly fitted around their waist. The belt was connected to the plate by a cord. Before jumping, any slack was removed from the cord and the participants were instructed to jump vertically using a countermovement with an arm swing.

For each subject, the current number of points in their age category according to the national ranking list was collected. We used this data as an independent variable.

TABLE 2
PEARSON'S CORRELATION COEFFICIENTS FOR MALE TENNIS PLAYERS

	VJ	QJ	S20	S5	FAN	9X6R	TR
VJ	1.00						
QJ	0.37**	1.00					
S20	0.32**	0.59**	1.00				
S5	0.63**	0.43**	0.91**	1.00			
FAN	0.12	0.40**	0.25**	0.27**	1.00		
9X6R	0.03	0.29**	0.14*	0.58**	0.51**	1.00	
TR	0.13	0.24**	0.43**	0.62**	0.23**	0.32	1.00

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

TABLE 3
PEARSON'S CORRELATION COEFFICIENTS FOR FEMALE TENNIS PLAYERS

	VJ	QJ	S20	S5	FAN	9X6R	TR
VJ	1.00						
QJ	0.07	1.00					
S20	0.12	0.49**	1.00				
S5	0.05	0.64**	0.68**	1.00			
FAN	0.07	0.42**	0.33**	0.28*	1.00		
9X6R	0.36**	0.11	0.07	0.31*	0.19**	1.00	
TR	0.14	0.11	0.14*	0.52**	0.22**	0.19**	1.00

* Correlation is significant at the 0.05 level
** Correlation is significant at the 0.01 level

Statistical analyses

Statistical analyses were performed using the SPSS software package. Descriptive statistics ($\overline{X}$±SD) were conducted for the three morphological measures and six motor test items. The reliability of the selected test items was assessed with an interclass correlation coefficient, and a coefficient of variation using the test-retest method[10]. All the test items passed Shapiro-Wilks' test of normality. Correlations between the test items were performed using Pearson's product-moment correlation coefficient. Three series of one-way ANOVA tests were used to analyze the differences between the male and female tennis players and two different age categories (16 & under and 18 & under). Regression analyses were performed to identify the relationship between the dependent variables and a player's number of points on the national ranking list as a criterion variable. The significance level for all statistical analyses was set at 0.01 and 0.05.

Results

The results of descriptive statistics for the male and female junior players are presented in Table 4. Tables 2 and 3 display Pearson's product-moment correlation coefficients for both genders. The strengths of the association were interpreted as trivial (0.0–0.1), small (0.1–0.3), moderate (0.3–0.5), large (0.5–0.7), very large (0.7–0.9), and nearly perfect (0.9–0.99). As anticipated, both speed test items have high Pearson product-moment correlation coefficients (M=0.91, F=0.68). The correlation coefficients between the two agility test items (M=0.51, F=0.19) and neuromuscular power test items (M= 0.37, F= 0.07) are significantly higher in the male tennis players.

The two speed test items have a large to trivial correlation with the two agility test items (M=0.58 to 0.14; F=0.33 to 0.07). The highest correlation in the males is noted in the 9X6R and S5 test items, whereas in the females the highest correlation is noted in the FAN and S20 test items. The speed test items have an inverse and large to trivial correlation with the two neuromuscular power test items (M=0.63 to 0.32; F=0.64 to 0.05). In the males there is a slightly higher correlation coefficient between the S5 and VJ than between the S20 and the QJ tests, whereas in the females a slightly higher correlation coefficient exists between the QJ and the two speed test items (S5, S20). Moderate to trivial and inverse correlations exist between the two agility test items and the vertical jump test item, as well as the QJ (M=0.40 to 0.03; F=0.42 to 0.07). The highest correlation exists between the FAN and

TABLE 4
DESCRIPTIVE CHARACTERISTICS, DIFFERENCES IN %, AND RESULTS OF 1-WAY ANOVA FOR MALE AND FEMALE YOUNG TENNIS PLAYERS

Variable	Group	$\overline{X}$	SD	Diff. %	F	Sig.
BH	Male	176.5	8.0	4.53	163.26	0.00
	Female	168.5	5.6			
BM	Male	65.9	9.7	9.54	67.75	0.00
	Female	59.6	6.8			
BMI	Male	20.1	2.0	0.38	0.18	0.67
	Female	21.1	2.2			
VJ	Male	52.6	9.0	17.99	104.85	0.00
	Female	43.2	8.1			
QJ	Male	933.5	90.8	15.61	391.77	0.00
	Female	787.8	72.3			
S20	Male	3.4	0.2	6.02	128.31	0.00
	Female	3.7	0.2			
S5	Male	1.4	0.2	2.75	128.31	0.00
	Female	1.5	0.2			
FAN	Male	13.7	1.2	9.6	180.24	0.00
	Female	15.2	1.3			
9X6R	Male	15.8	1.9	8.82	84.77	0.00
	Female	17.4	2.0			

QJ tests. S5 (M=0.62, F=0.52) has a large and inverse correlation with a player's tennis performance (TR).

Table 4 presents the mean, standard deviations, the difference in percentage, F, and statistical significance for the dependent variables. A one-way ANOVA test was applied to show significant differences between the male and female tennis players in all variables, except BMI. The male tennis players were taller (4.5%), heavier (9.5%), and had a slightly lower BMI (0.4%). They performed better in all test items. In VJ, males performed 18% better and in QJ 15.6% better. In both agility test items (FAN, 9X6R), the respective differences between the genders were as high as 9.6% and 8.8%. The smallest differences between the males and females were revealed in the test items S5 and S20, where the males achieved 6% and 2.7% better results, respectively.

In addition, the groups of young tennis players were divided into two different age groups. In the first group there were males aged 16 and under as well as 18 and under, while the next group included females aged 16 and under, along with those aged 18 and under. Descriptive characteristics, differences in percentage, and the results of the one-way ANOVA are presented in Table 5. The one-way ANOVA test was applied to show significant differences between the two male age groups in all variables, except VJ.

The older males are taller (4.3%), heavier (14.4%), and have a higher BMI (7%). Males aged 18 and under performed better in all selected test items. The differences between the age groups of males vary; the biggest differences were revealed in QJ (8.4%) and S20 (6.7%), slightly smaller ones in the test items S5 (5.4%), FAN (5.4%), and 9X6R (5.2%), whereas the smallest differences were shown in the VJ test (3.2%).

TABLE 5
DESCRIPTIVE CHARACTERISTICS, DIFFERENCES IN %, AND RESULTS OF 1-WAY ANOVA FOR TWO AGE CATEGORIES

Variable	Group	$\overline{X}$	SD	Diff. %	F	Sig.	Group	$\overline{X}$	SD	Diff. %	F	Sig.
BH	M16U	172.3	8.3	4.29	110.73	0.00	F16U	167.2	5.5	1.36	9.19	0.00
	M18U	180.0	5.7				F18U	169.6	5.5			
BM	M16U	60.4	9.7	14.43	134.57	0.00	F16U	57.3	6.8	6.99	23.1	0.00
	M18U	70.5	6.9				F18U	61.6	6.1			
BMI	M16U	20.2	2.2	7.03	54.03	0.00	F16U	20.5	2.1	4.48	12.09	0.00
	M18U	21.8	1.8				F18U	21.4	1.9			
VJ	M16U	51.63	10.23	3.27	1.88	0.17	F16U	43.3	8.4	0.6	0.4	0.84
	M18U	53.38	7.9				F18U	43.0	7.9			
QJ	M16U	889.3	78.7	8.39	90.5	0.00	F16U	776.8	63.7	2.55	4.14	0.04
	M18U	970.8	83.4				F18U	797.2	78.1			
S20	M16U	3.6	0.2	6.74	131.94	0.00	F16U	3.7	0.2	0.54	1.14	0.28
	M18U	3.3	0.2				F18U	3.6	0.2			
S5	M16U	1.5	0.1	5.47	12.71	0.00	F16U	1.5	0.2	2.72	2	0.15
	M18U	1.4	0.1				F18U	1.4	0.2			
FAN	M16U	14.1	1.1	5.44	38.84	0.00	F16U	15.4	1.3	2.91	6.3	0.01
	M18U	13.4	1.1				F18U	15.0	1.3			
9X6R	M16U	16.3	1.8	5.28	20.49	0.00	F16U	17.5	2.1	1.71	1.18	0.27
	M18U	15.4	1.8				F18U	17.2	1.9			

Descriptive characteristics, differences in percentage, and the results of a one-way ANOVA test are presented in Table 6. The one-way ANOVA test was applied to show significant differences between females aged 16 and under as well as 18 and under in BH, BM, BMI, QJ, and FAN. The females aged 18 and under are taller (1.3%), heavier (7%), and have a higher BMI (4.4%). The differences between the various age groups are less striking in the females than in the males. Nevertheless, the females aged 18 and under achieved slightly better results. The older females were 2.9% faster in the FAN test item, 1.7% faster in the 9×6R test item, 2.7% faster in the S5 test item, and only 0.5% faster in the S20 test item. The females aged 18 and under achieved 2.5% longer jumps in the QJ test items and only 0.6% higher values for the VJ test item.

In addition, a multiple regression analysis was used to assess the relationship between the speed, agility and neuromuscular test items, and the tennis performance expressed by the male and female young tennis players' position on the national ranking list.

Table 6 shows that the predictor system (speed, agility, and neuromuscular test items) and the criterion variable are correlated with statistical significance ($p<0.05$) among the males. The coefficient of determination ($R^2=0.46$) shows that the predictor system of variables explains 46% of the variance of the criterion variable. The coefficient of multiple correlation (R=0.67) reveals that the system of predictor variables has a moderate relationship with the criterion variable. Among the selected predictor variables, only S5 significantly explains the variance of the criterion variable.

Table 6 also shows that the predictor system and the criterion variable are correlated with statistical significance ($p<0.05$) among the females. The coefficient of determination ($R^2=0.39$) reveals that the predictor system of variables explains 40% of the variance of the criterion variable. The coefficient of multiple correlation (R=0.63) shows that the relationship of the system of predictor variables with the criterion variable is large. Among the selected predictor variables, BM, S20 and S5 significantly explain the variance of the criterion variable.

TABLE 6
RELATIONSHIP BETWEEN POSITION ON NATIONAL RANKING LIST (TR) AND AGILITY, SPEED, AND NEUROMUSCULAR POWER TESTS IN YOUNG MALE AND FEMALE TENNIS PLAYERS

Variable	Male				Female			
	R	R²	F	Sig.	R	R²	F	Sig.
	0.67	0.46	20.47	0.00	0.63	0.39	11.69	0.00
	Beta		Sig.		Beta		Sig.	
BH	0.03		0.31		0.12		0.12	
BM	0.10		0.43		0.30		0.00	
BMI	0.02		0.96		0.04		0.45	
VJ	0.08		0.20		0.00		0.96	
QJ	0.01		0.84		0.00		0.98	
S20	0.11		0.11		0.11		0.02	
S5	0.55		0.00		0.56		0.00	
FAN	0.04		0.43		0.02		0.76	
9X6R	0.09		0.16		0.06		0.35	

Discussion and Conclusions

As indicated in Tables 2 and 3, the speed test items show nearly perfect (M=0.91) and large (F=0.68) correlations among them. Clark and Leone et al.[14–15] came to the same conclusions. They conducted their research on a sample of male and female tennis players, while Vescovi and McGuigan[16] conducted their research on soccer players and lacrosse athletes of both genders. All of them noted higher correlation coefficients in the male than in the female soccer players and lacrosse athletes.

In the present research, it was discovered that a higher correlation exists between the two agility test items and the 5-m sprint test item in the male tennis players. This is contrary to the findings of Clark[14] as well as of Leone et al.[15] and Pauole et al.[18] who established a higher correlation between the longer distance speed test items (20-m or more) and agility test items. A lower correlation between the fan-drill test item and the 20-m sprint, as well as between the 9×6-m run and 5-m sprint, exists in the female players. The authors believe that the differences are the result of a greater and more representative sample of male and female tennis players, thus indicating a higher degree of the correlation between the ability to accelerate over a short distance run, the ability to accelerate over a short distance run up to 6 m (FAN, 9X6R), as well as the ability to stop and change directions.

The correlation between the speed and neuromuscular power of legs test items (take-off power) shows differences in the male and female players. In the males, there is a large and inverse correlation between the vertical jump and the 5-m sprint, as well as between the quarter jump and the 20-m sprint. Obviously, the ability to perform a vertical jump with a counter movement influences the short distance sprint more, and the ability to perform repeating jumps merely influences the longer distance sprint. Vescovi and McGuigan[16] discovered that there is a high correlation between the counter movement jump and longer distance sprint. Douvis et al.[19] analyzed trained and untrained tennis players and found a moderate negative correlation between the triple step jump and a 22-m sprint. In females, there was a large to moderate correlation between the Quarter Jump, 5-m and 20-m sprint.

A comparison of the correlation between the agility and neuromuscular power of legs test items shows that in the males there is a moderate to small and inverse correlation between the Quarter Jump and the two agility test items. In the females, it shows the same between the Quarter Jump and fan-drill test items, as well as between the Vertical Jump and 9x6-m run. The results indicate that a variety of mechanisms is responsible for the performance of vertical or repeating jumps and of the agility test items. In agility, the ability to accelerate, stop and change directions, together with an appropriate movement technique based on the exploitation of biomechanical principles, are the very factors that influence the effectiveness of a tennis player's movements. It is also worth noting the high level of importance of elementary time programs (acyclic and cyclic type according to Bauersfeld and Voss[20]), which primarily depend on the quality of neuromuscular control and regulatory processes. Elementary time programs are not dependent on strength and gender.

The current study investigated differences between genders and age categories. Significant differences between males and females are expected and are based on biological differences between genders. Males are taller and heavier. According to the age category, it is evident that the mean values of the variables BH and BM reveal that males in the 16 and under, as well as the 18 and under, categories are physically more developed than females from the same age categories. The differences in body height correspond to findings by Pluim[21] who noticed that male tennis players are on average 0.10x0.12 m taller and 10 kg heavier than female players. The biggest differences were revealed in both test items measuring neuromuscular power. In VJ and QJ, the males were significantly more successful than the females. Pluim[21] thus found that the main strength differences are found in the upper body, where their overall strength is 54% that of men, in contrast to 68% of male strength in the lower body. The male-female difference in strength is primarily due to the anabolic effect of testosterone on a male's musculature. Testosterone is suggested to be a potential trigger of glycolytic development.During puberty, muscle strength is affected by maturation as a correlation of strength and chronological age. The increased production of anabolic hormones during puberty affects muscle hypertrophy. Males increase the production of anabolic hormones more than females, which may explain the smaller increase in muscle strength through puberty females exhibit[22]. The most efficient strength trainings of young athletes are dynamic methods which firstly develop intra- and intermuscular coordination, so-called sequencing and recruiting, followed by methods with protein-anabolic effects (muscle hypertrophy). This allows females aged 14 to 15 years and males aged 16 to 17 years to begin serious training in strength and neuromuscular power[23].

The differences revealed between the genders were according to expectations and have already been confirmed in several studies. Such differences between the age groups of males and females 18 and under and 16 and under are, in the opinion of the authors, a result of intensive physical and biological development which in males aged 16 to 18 is still occurring, whereas in females of the same age physical development is starting to slow down or even stopping entirely. The phenomenon of increased BM and BMI is noticed in females and even more so in males, which could indicate the increase in muscle mass and entire body mass. Nevertheless, besides body height and mass in performance in sport-specific skill test items, neural control of movement, maturation status and perceptual-cognitive skills have to be considered[24–25]. Due to inaccessibility to similar studies on young tennis players of both genders, the results were compared to similar studies in other sports (soccer, athletics, rugby, hockey, racket sports etc.).

Apart from differences arising from physical development, several changes occur due to carefully planned physical preparation training which in this period is directed to the development of neuromuscular power, speed, agility and endurance. Volver, Viru and Viru[26], Figueiredo et al.[27] and Young, James, and Montgomery[6] found that in the period of adolescence significant changes occur in speed, agility, neuromuscular power, strength and endurance. Therefore, physical preparation training and technical tennis training in this period aim to develop these abilities so as to ensure competitive success and at the same time prevent injuries to players of both genders. The positive effects of such training can be detected in changes in three systems[28]: neuromuscular (neuronal control and regulatory processes, stimulus channeling speed, preenervation, reflex enervation, inter- and intra-muscular coordination), psychic (concentration, perception, motivation, and will power), and tendon-muscular (sectional area of fast-twitch fibers, stiffness, viscosity, and energy supply).

Statistically significant differences in the females were noticed in the BH, BM, BMI, QJ and FAN test items, indicating the aforementioned intensive physical and biological development in the females and even more so in the males. This is also reflected in the relatively high increase in BM and BMI, with only a slight simultaneous increase in BH. According to some findings[29], females in the period between 12 and 14 years of age and males between 13 and 15 years of age have approximately 30–35% the muscle mass of the total body mass and in the period between 16 and 19 years adolescents have approximately 33–45% the muscle mass of the total body mass. Differences in the pace of development are a result of different ages when young people enter adolescence which among females is 1 to 2 years earlier than among males. Females enter adolescence at the age of 11 to 12 and males at the age of 13 to 14. In the period between 16 and 18 years of age, a disruption in the optimum proportion between BH and BM can be noticed, manifested in an increase in the BMI and consequently also in excess weight in males and even more often in females. Excess weight means additional ballast, which has particularly negative effects on accelerating, running speed, vertical jumps and above all on stopping, changes in direction, and accelerating after these actions. Other consequences of excess weight include a larger loading on the joints, mainly the knees and ankles, which can lead to injuries.

In addition, a comparison of the differences between the males in the categories 16 and under and 18 and under revealed statistically significant differences between both groups in all variables except for VJ. An analysis of tennis shows a relatively small number of vertical movements (jumps) that only occur in specific situations such as an overhead smash or else a jump occurs as a result of the intensive and coordinated movement of a player (kinetic muscle chain) in the serve, forehand and backhand. Thus, Bencke et al.[30] found that, when performing different types of jumps, the central nervous system uses different motor programs to achieve the neuromuscular coordination needed for a specific jump. The counter movement jump (VJ) or several consequent jumps (QJ) require moderate eccentric activation followed by high concentric activation, which require the very precise coordination and extensive activation of motor units[30]. In addition to the importance of neuromuscular coordination and level of activation and agility, the significance of the number and quality of automated movement patterns has to be mentioned.

Smaller differences between the categories of females 18 and under and 16 and under were expected as older females are not that much better than younger female players, in contrast to males. In all test items of speed, agility, and neuromuscular power, the differences in both absolute values and percentages were very small. The higher BM and BMI resulted in a negative influence on the QJ results and both speed test items as well as on one agility test item (9X6R). The slightly better results of the females in the test items QJ and FAN are presumably the outcome of a better movement technique and better activation of motor units, and precise coordination[30].

The anthropometrical measures (BH, BM, BMI) and speed (S5, S20), agility (FAN, 9X6R), and neuromuscular power test items (VJ, QJ) significantly contributed to the variation in tennis performances. The variance explained was relatively small (46% males and 40% females). Positive Beta coefficients suggest an increase, while negative coefficients suggest a decrease in tennis performance associated with changes in independent variables. In contrast, in the male category only one predictor variable (S5) significantly contributes to tennis performance and three predictor variables (BM, S20, S5) do so in the female category. Various authors have pointed out the great importance of speed in explaining competitive success in tennis[2–4,10–12,28]. In both males and females, a quick beginning of movement (the first three steps after the split step) has proved to be particularly important in situations where a player has to cover a short distance (3 to 5 meters) with three to five steps starting from a standstill, in the majority of actions when a player makes a shot outside their comfort zone or when a longer distance needs to be covered (10 m or more) when trying to reach drop shots or balls that are far from the player[28]. The split step, the most common and most efficient start of movement, acceleration and stopping, along with constant changes in direction of movement, occurs many times in a single point in a game[31]. These findings also point out the importance of anaerobic capacity and high level of sprint endurance in tennis players[32].

Speed is one of the most crucial motor abilities, not only in tennis but in the majority of sports and cannot be fully compensated by any other ability. In tennis, partial compensation is possible with highly developed perceptual and anticipation abilities or when certain tactical patterns or intentions of an opponent are recognized. According to the trend of the development of tennis, on the both ATP and WTA Tours, as well as the ITF Junior Tour, nowadays there is less and less maneuvering space to compensate for speed.

Particularly in females, an optimum body mass also corresponds with a better tennis performance. Obviously, players with a higher BM achieved worse results in the test items of speed, agility, and neuromuscular power. A large number of females with excess weight as a result of ballast (body fat) and not muscle tissue experienced problems in starting their movement, acceleration, stopping, and changing of direction. Since tennis matches can last several hours, an inappropriate body mass also indirectly affects endurance.

Speed, agility, neuromuscular test items and anthropometrical measures only represent a small part of the characteristics and abilities holding overall importance for tennis, although to a certain extent they can indicate a relationship between the predictive and criterion variable. Undoubtedly, the gender of tennis players and characteristics of the tennis game have an important role to play in explaining tennis performance. The game performance is also influenced by a court surface a match is played on, as the game elements influencing a match outcome on grass surface obviously vary from those on clay surface[33]. Nevertheless, a partial analysis of the bio-psycho-social status of a tennis player can also reveal the importance of the adequate physical preparation of young males and females and its effect on tennis performance.

Based on the results of the present study, its practical applications would be that running speed, agility, and the neuromuscular power of the legs are specific abilities mostly correlated at a moderate or low rate, singles out the possible importance of the anaerobic capacity and the high level of sprint endurance in tennis players.

In training, coaches should consequently consider specific characteristics of the development of an individual ability with regard to when to start training, which exercises to select and how to set the volume and intensity. Finally, it should be reiterated that speed and agility are very important for success in tennis. The development of neuromuscular power has a positive and indirect influence on both speed and agility. In the opinion of the authors of the present study, tennis and physical preparation coaches of young tennis player aged 16 to 18 all too often neglect to pay attention to these factors.

In any case, it is necessary to determine the level of a particular ability in an individual player's assessment. It is also essential to define the priority areas of activities that would ensure an efficient training process. When setting the loading in physical preparation training with the aim of developing speed, agility and neuromuscular power, a coach should consider the biological development of young players. Therefore, females can begin such training earlier than males. In the period of intensive physical development, the morphological characteristics of players must be constantly monitored, particularly in terms of controlling the optimum body mass, which players of both genders should also achieve with a suitable diet.

REFERENCES

1. QUINN A, REID M, Screening and testing. In: REID M, QUINN A, CRESPO M. (Eds) Strength and Conditioning for tennis (The International Tennis Federation, London, 2003). — 2. MÜLLER E, Leistungssport, 19 (1989) 5. — 3. BUNC A, DLOUHA O, HÖHM J, SAFARIK J, TPV, 38 (1990) 194. — 4. FILIPČIČ A, FILIPČIČ T, Acta Univ Palacki Olomuc Gymn, 35 (2005) 35. — 5. DRAPER JA, LANCASTER MG, Australian Journal of Science & Medicine in Sport, 17 (1985) 15. — 6. YOUNG WB, JAMES R, MONTGOMERY JI, J Sport Med Phys Fit, 42 (2002) 282. — 7. SHEPPARD J, YOUNG W, J Sport Sci, 24 (2006) 919. — 8. COX RH, Sport psychology: concepts and applications. 4th ed. (WCB/McGraw-Hill, Boston, 1998). — 9. JON LO, MAYES RW, International Journal of Sports Physiology and Performance, 4 (2009) 345. — 10. FILIPČIČ A, Zanesljivost in veljavnost izbranih motoričnih testov v tenisu, MS Thesis. In Slovenian. (University of Ljubljana, Ljubljana, 1993). — 11. FILIPČIČ A, Evalvacija tekmovalne in potencialne uspešnosti mladih teniških igralcev. Phd Thesis. In Slovenian. (University of Ljubljana, Ljubljana, 1996). — 12. UNIERZYSKI P, Motor Abilities and Performance Level Among Young Tennis Players. In: Proceedings (Sport Kinetics, Poznan, 1993). — 13. YOUNG WB, MCDOWELL MH, SCARLETT BJ, J Strength Cond Res, 15 (2001) 315. — 14. CLARK S, Relationship between speed and agility in nationally ranked junior tennis players. In: Proceedings (Australian Conference of Science and Medicine in Sport, Adelaide, 1998). — 15. LEONE M, COMTOIS AS, TREMBLAY F, LÉGER L, Med Sci Tennis, 11 (2006) 10. — 16. VESCOVI JD, MCGUIGAN MR, J Sport Sci, 26 (2008) 97. — 17. DOLENEC A, ČOH M, Kinesiologia Slovenica, 15 (2009) 16. — 18. PAUOLE K, MADOLE K, GARHAMMER J, LACOURSE M, ROZENEK R, J Strength Cond Res, 14 (2000) 443. — 19. DOUVIS S, MAVIDIS A, MALLIOS VJ, DALLAS G, International Journal of Fitness, 4 (2008) 25. — 20. BAUERSFELD M, VOSS G, Neue wege im schnelligketstraining (Philippka-Verlag, Münster, 1992). — 21. PLUIM B, Males vs females. In: CRESPO M, PLUIM B, REID M (Eds) Tennis medicine for tennis coaches. (The International Tennis Federation, London, 2001). — 22. PRATT M, Am J Dis Child, 143 (1989) 560. — 23. GROSSER M, SCHÖNBORN R, Competitive tennis for young tennis players (Meyer & Meyer, Aachen, 2002). — 24. WILLIAMS AM, J Sport Sci, 18 (2000) 737. — 25. WILLIAMS AM, REILLY T, J Sport Sci, 18 (2000) 657. — 26. VOLVER A, VIRU M, VIRU K, Acta Academiae Olymiquae Estoniae, 13 (2005) 11. — 27. FIGUEIREDO AJ, COELHO E, SILVA MJ, CUMMING SP, MALINA RM, Pediatr Exerc Sci, 22 (2010) 596. — 28. GROSSER M, KRAFT H, SCHÖNBORN R, Speed training for tennis (Meyer & Meyer, Oxford, 2000). — 29. GROSSER M, STARISCHKA S, Das neue Koordinationstraining (BLV, München, 1998). — 30. BENCKE J, DAMSGAARD R, SAEKMOSE A, JORGENSEN P, JORGENSEN K, KLAUSEN K, SCAND J MED SCI SPOR, 12 (2002) 171. — 31. SCHÖNBORN R, Advanced Techniques for Competitive Tennis (Meyer und Meyer, Aachen, 1999). — 32. NOVAK D, VUČETIĆ V, ŽUGAJ S, Coll Antropol, 37 (2013) 107. — 33. KATIĆ R, MILAT S, ZAGORAC N, ĐUROVIĆ N, Coll Antropol, 35 (2011) 341.

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POVEZANOST IZABRANIH MOTORIČKIH TESTOVA (BRZINA, AGILNOST, EKSPLOZIVNA SNAGA) I ANTROPOMETRIJSKIH VARIJABLI S NATJECATELJSKOM USPJEŠNOŠĆU TENISAČA/-ICA JUNIORSKE DOBI

SAŽETAK

Cilj ovog istraživanja bio je utvrditi odnose između izabranih testova brzine, agilnosti i eksplozivne snage na uzorku od 154 mlada tenisača i 152 mlade tenisačice. Koristeći šest motoričkih i tri antropometrijska testa istraživane su razlike između spolova u dvije dobne kategorije. Zaključno, analizirani su odnosi motoričkih i antropometrijskih testova s natjecateljskom uspješnošću tenisača. Povezanost dvaju testova agilnosti i 5-m sprinta veoma je velika kod tenisača, a umjerena u 20-m sprintu kod tenisačica. Povezanost između testova brzine i eksplozivne snage veća je kod tenisača, a test brzine (5-m sprint) ima veliku korelaciju s natjecateljskom uspješnošću igrača. Rezultati univarijantne analize varijance pokazuju da mladi tenisači ostvaruju značajno bolje rezultate od tenisačica iste dobi na svim provedenim motoričkim testovima. Značajne razlike među spolovima nisu zabilježene jedino u indeksu tjelesne mase. Razlike među tenisačima između kategorija do 18 i do 16 god. značajne su na svim varijablama osim na varijabli koja mjeri eksplozivnu snagu vertikalnog skoka, dok su kod tenisačica u istim dobnim kategorijama razlike značajne na sve tri antropometrijske varijable kao i testu eksplozivne snage (četveroskok) te agilnosti (fan-drill). Regresijska analiza pokazala je da provedeni testovi i mjerenja, koji čine sistem prediktorskih varijabli, imaju relativno mali udio (46% – kod tenisača i 40% – kod tenisačica) u objašnjavanju ukupne natjecateljske uspješnosti igrača-/ica juniorske dobi. Kod oba spola utvrđeno je da testovi brzine značajno utječu na natjecateljsku uspješnost u tenisu.