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Relationships between physical characteristics and ranking of young tennis players

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Abstract
The purpose of the present study was: 1) to determine young tennis players' fitness and anthropometric characteristics; and 2) to determine to what extent these characteristics relate to the players' national ranking. Forty young (age 15.1 ±0.4) trained male tennis players, who were ranked from 1 to 40 in their age group, were tested for speed, speed endurance, flexibility, strength, specific agility and quickness, aerobic capacity, height, and weight. Significant correlations were found between the players' ranking and speed (r = 0.430 – 0.475), specific agility and quickness (r = 0.626), speed endurance (r = 0.562), strength (r = –0.416), aerobic capacity (r = –0.581), flexibility (r = 0.352), height (r = –0.443), and weight (r = –0.293). Stepwise regression analysis indicated that specific agility and quickness accounted for almost 40% of the players' ranking, while its combination with the players' height accounted for 56%. The results imply the overall importance of anaerobic capabilities and tennis-specific movements to the young tennis players' ranking. The results also emphasize the importance of tennis-specific tests to the young tennis players' performance evaluation.

Keywords: Tennis, fitness, speed, strength, anthropometry, endurance

1. Introduction
Tennis is a game of intermittent-type activity characterized by quick starts, short sprints, changes of direction, and sudden stops. The duration of these activities fluctuates from brief periods of maximal work to longer periods of moderate- or low-intensity activity. The mean duration of work and rest periods during a tennis match are 5–10 sec and 10–20 sec, respectively (Fernandez *et al*. 2006; Kovacs 2006) [8, 13]. The high-intensity type activities rely mostly on the anaerobic breakdown of creatine phosphate for energy production in the activated muscles. Consequently, tennis may be classified as mainly an anaerobic sport. However, despite its stop-and-start nature, tennis also has an aerobic component because the high-energy phosphate used for the immediate energy requirements of muscles is resynthesized, predominately by oxidation during recovery periods (Glaister 2005) [10]. Other variables such as game strategy, type of surface, game duration, and environmental factors were reported to influence the pattern of activity and recovery, as well as the physiological responses during the game (Fernandez *et al*. 2006; Lees 2003; Smekal *et al*. 2001) [8, 14, 20].
The average physiological responses to a tennis match have been reported to be rather modest, with mean exercise intensities of less than 60–70% of VO_2 max and mean heart rate of 60–80% of maximal values (Fernandez *et al*. 2006) [8]. Blood lactate concentrations also usually remain low (1.8–2.8 mmol/l) during a tennis match (Kovacs 2006) [13]. However, occasionally, following long and intense game rallies, lactate concentration may increase up to 7 mmol/l, suggesting that anaerobic glycolytic processes also take part in the muscle energy supply during a game (Birrer *et al*. 1986) [3].
The diverse activity pattern and the mixed energy requirements in tennis forces players to develop and improve different physical fitness elements in order to excel. As examples, high speed and agility are required to reach fast balls, upper and lower body strength is needed to produce powerful strokes, and high aerobic capacity is necessary for proper recovery and for maintaining the level of intensity during long matches. Therefore, in addition to the multifaceted technical and tactical training, the complexity of the game requires that specific conditioning programs be designed that will improve the player's anaerobic and aerobic

Capacities. Because tennis players need to possess a variety of skills and fitness capabilities, and since training time is limited (especially among high-level players who often travel between tournaments), ranking the relative importance of the different fitness variables seems essential.

The purpose of the present study, therefore, was 1) to determine trained young tennis players' fitness, and anthropometric characteristics; and 2) to determine to what extent these characteristics relate to the players' national ranking.

2. Methods

2.1 Subjects

Forty young, trained male tennis players (age 15.1 ±0.4 years, body mass 60 ±8.6 kg, height 167 ±7.4 cm, BMI 21 ±1.8, Tanner stage 4–5), who were ranked from 1 to 40 in their age group in the country's youth tennis players listing, participated in the study. The players had six to eight years of playing experience. The players had four to five tennis training sessions per week, each lasting two hrs. They also had two to three tennis-specific conditioning sessions per week, lasting 45 min each, including agility, speed, and specific coordination drills. Subjects competed in tournaments every few weeks throughout the year, with a total of 25 to 35 matches per year. The study was approved by the Zinman College ethical committee, and a written informed consent was obtained from all players and their parents.

2.2 Testing procedures

Subjects performed six tests to evaluate six different fitness and tennis-specific performance capabilities. Tests were performed in a set order among the players, divided into two different days with three days in between. The rationale for the selection of the current testing protocols was their application to the fitness components and movement types of the game of tennis. This selection is in line with other studies reporting fitness and performance capabilities of tennis players (e.g. Kovacs 2006; Lees 2003) [13, 14]. The test-retest reliability of most tests we used in the present study is high (0.80–0.95) (see Chandler 1998; Kibler *et al*. 1988; Lees 2003; St Clair Gibson *et al*. 1998; Stolen *et al*. 2005) [4, 11, 14, 21, 22]. Subjects were familiar with the testing procedures, since they had routinely performed them in previous years. Before each set of tests, subjects performed a standard warm-up of about 20–25 min. A 20-min resting period separated the different tests on each day. In order to prevent unnecessary fatigue effect, players and coaches were instructed to avoid intense training 24 hr prior to each day of testing. All tests were performed on a hard surface tennis court in the late afternoon, about four hours after lunch, and in a comfortable average air temperature of about 22°C. None of the subjects were taking any medication or food supplements.

On the first day the subjects' height and weight were measured using standard calibrated scale and a stadiometer (Seca 220, Germany). The subjects then performed the following three tests:

2.3 Speed Test – 10m and 20m Run: A 20m sprint run, with a 10m split time, was used to evaluate the subjects' speed and acceleration ability. Subjects self-started after getting into a standing ready position. Two runs were completed, and the better time was recorded. Subjects rested for five min between runs. Each subject performed the test individually. Running times were recorded using a photoelectric cell timing system (Alge-Timing Electronic, Vienna, Austria) with an accuracy of 0.001 s, linked to a digital chronoscope. A standing start, with the front foot placed 30cm behind the timing lights, was used for all sprints. Timing was initiated when the subject broke the light beam.

2.4 Flexibility Test – Sit and Reach: Subjects sat with their legs extended on the floor. Their feet were placed against a box with a yardstick attached to it. Subjects placed their hands one on top of the other and slowly extended them forward, and then held them at the maximum stretch point for 3 sec. The distance reached on the yardstick was recorded. Three attempts were made and the longest distance on the yardstick was recorded.

2.5 Specific Speed Endurance Test – Spider Run: The spider test involved quick runs to collect five balls that were located on the court at the back corners of the service boxes located at the back corners of the court. The subjects started from the middle of the baseline and ran to collect each of the balls and bring them, one by one, to the starting point. Although traditionally the spider test is considered an agility test, due to its relatively long duration (around 17 sec) it can also be used to evaluate specific speed endurance in tennis. Each subject performed a single test, individually.

On the second day subjects performed the following three tests:

2.6 Specific Agility and Quickness Test – Box Drill: Subjects stood along one side of a 15 cm – high box. The test started as the subject jumped laterally onto the box and to the other side, then back onto the box and then back to the initial side of the box, with both legs parallel during the entire time. Subjects had to make a total of 20 back and forth jumps as quickly as possible. Each subject performed two trials, and the fastest time was recorded. This test is popular among tennis coaches for evaluating specific tennis agility and quickness (Chandler 1998) [4].

2.7 Upper Body Power Test – Overhead Medicine Ball Toss: Subjects stood behind the line facing forward with both feet parallel. They held a 3 kg medicine ball behind their head with both hands, and then tossed the ball over their head as far forward as possible. In order to measure upper body power alone, subjects were instructed to maintain straight legs and to avoid any push from the legs before the release of the ball (Kibler *et al*. 1988) [11]. The subjects performed the test twice and the better of the two trials was recorded.

2.8 Aerobic Power Test – Twenty-Meter Shuttle Run Test: The 20m shuttle run test is a reliable and valid field test that predicts aerobic fitness (VO_2max) in various populations (St Clair Gibson *et al*. 1998) [21]. The test consisted of shuttle running at increasing speeds between two markers placed 20m apart. A portable compact disc (Sony CFD-V7) dictated the pace of the test by emitting tones at appropriate intervals. Each subject was required to be at one of the two ends of the 20 m course at the signal. A starting speed of 8.5 km/hour was maintained for one minute, and was increased by 0.5 km/hour every minute thereafter. The test score recorded was the number of 20 m laps completed before the subject either withdrew voluntarily from the test or failed to arrive within 3 m of the end line on two consecutive tones. VO_2 was derived by the formula: $y = 6.0x - 24.4$, where y equals the predicted VO_2max and x equals the maximum speed achieved (St Clair Gibson *et al*. 1998) [21].

2.9 Statistical analysis
Pearson correlations coefficients (r) were computed between all the fitness variables measured in the study and the tennis ranking. In addition, a stepwise regression analysis was performed to determine the factors (i.e. fitness test scores and anthropometric characteristics) that contributed to the players' ranking. Data are presented as mean ± SD. Statistical significance was set at $p < 0.05$.

3. Results
Results of the fitness tests and measurements of the anthropometric characteristics of the study's subjects are summarized in Table 1. Correlations between all the fitness and anthropometric variables in the study and the player's national ranking are presented in Table 2. Significant and positive correlations were found between the players' ranking and the 10 m sprint time (r = 0.430), 20m sprint times (r = 0.475), box drill (r = 0.626), and spider run (r = 0.562). Significant negative correlations were found between the players' ranking and the ball toss (r = –0.416), 20m shuttle run test (r = –0.581), sit and reach test (r = 0.352), height (r = –0.443), and weight (r = –0.293). No significant correlation was found between the players' ranking and BMI. The stepwise regression analysis, presented in Table 3, indicated that the box drill test results accounted for almost 40% of the players' ranking. Furthermore, the regression model indicated that the combination of the box test results and the players' height was the most efficient predictor of the players ranking, accounting for 56% of the ranking. The other tested variables were found as non-significant contributors to the players' ranking.

Table 1: Anthropometric measures and fitness characteristics of the study subjects (N = 40)

Parameters	Mean ± SD	
Body height (cm)	167	±0.08
Body weight (kg)	60.08	±8.59
BMI	21.25	±1.75
10m sprint (sec)	1.90	±0.10
20m sprint (sec)	3.32	±0.19
Overhead medicine ball toss (m)	8.40	±1.63
Box drill (sec)	11.79	±1.42
Spider run (sec)	16.31	±1.05
Sit and reach (cm)	7.90	±6.31
Twenty-meter shuttle run test (ml/kg/m)	49.90	±5.12

Table 2: Correlations between fitness, anthropometric variables and the player's ranking

Variable	RK	10 m	20 m	BD	SR	BT	SpR	20 sr	H	W	BMI
RK	1.000	0.430*	0.475*	0.626*	–0.352*	–0.416*	0.562*	–0.581*	–0.443*	–0.293*	–0.035
10 m		1.000	0.957*	0.655*	–0.264*	–0.488*	0.821*	–0.677*	–0.233	–0.213	–0.096
20 m			1.000	0.625*	–0.311*	–0.594*	0.823*	–0.720*	–0.304*	–0.323*	–0.216
BD				1.000	–0.411*	–0.487*	0.763*	–0.738*	–0.054	0.051	0.170
SR					1.000	0.393*	–0.360*	0.317*	0.079	0.214	0.262
BT						1.000	–0.506*	0.575*	0.321*	0.385*	0.286*
SpR							1.000	–0.756*	–0.218	–0.154	–0.025
20 sr								1.000	0.130	0.102	0.018
H									1.000	0.827*	0.341*
W										1.000	0.807*
BMI											1.000

Table 3: Stepwise regression for prediction of the player's ranking.

Predicted Variable	Multiple R-Square	Regression Coefficient, Beta	P value
Drill Box	0.392	0.60	0.000
Height	0.560	–0.41	0.001

4. Discussion
A player's fitness and physical capabilities may be influential factors in tennis match outcomes (Roetert *et al*. 1992; Smekal *et al*. 2000) [17, 19]. Thus, physiological profiling may become essential for designing an optimal physical conditioning program for tennis players. In addition, the players' anthropometric characteristics also make an important contribution to match results (Barbaros-Tudor *et al*. 2011) [2].

The findings of this study displayed significant correlations between certain fitness and anthropometric characteristics and tennis national ranking at age 15. The results also revealed that the box drill test is the most efficient predictor of young tennis players' ranking, and when combined with the players' height accounted for 56% of the players' ranking. The box drill is a tennis-specific test (Chandler 1998) [4] that is very popular among players and coaches, since it represents basic tennis movements. This test combines several anaerobic-type fitness components, including agility, speed, power, balance, and coordination. Hence, the results of the present study emphasize the importance of sport-specific fitness tests, and demonstrate their value and contribution to athletes' performance. However, one should take into account that our results relate only to fitness and anthropometrical variables, and that no technical or tactical variables were measured. Therefore, a reliable prediction of a players' future success is not possible based only on the present study findings.

We found a significant correlation between several fitness tests, such as short sprints, medicine ball toss, and sit and reach (representing speed, power and flexibility, respectively) and the player's ranking (Table 2), suggesting that each of these fitness components has an effect on tennis performance. However, following the stepwise regression analysis only the box drill test, which combines all these fitness components, contributed significantly to the tennis ranking, and not each of the tests separately.

The significance of anaerobic- or power-speed-related variables to tennis performance has been demonstrated previously. Reilly and Benton (1995) [16] reported that female regional tennis players had 40% greater back and 15% greater leg strength than club players. Similarly, Chandler and Kibler (1992) [5] reported that female college tennis players produced significantly higher strength during internal rotation of the dominant arm than the non-dominant arm, and this difference was attributed to the stretch-shortened muscle action required in a tennis serve. The importance of strength to tennis was also demonstrated by studies showing that internal, external and diagonal peak torques of the shoulder contribute substantially to service ball velocity (e.g. Perry *et al*. 2004) [15]. Significant moderate correlations ($r^2 = 0.68$) were found between shoulder strength and the velocity of tennis strokes (Signorile *et al*. 2005) [18]. Consistent with these findings, we found a significant correlation between players' ranking and the overhead medicine ball toss test (r = –0.416). It is recommended, therefore, that strength training be included in the training program of tennis players in order to improve their performance (Kovacs 2006) [13]. In agreement with the present findings, Girard and Millet (2009) [9] reported that sprint, power, and strength were good predictors of tennis performance in 13–14 year-old players. In contrast, Birrer *et al*. (1986) [3] found, in a study of 500 pre-adolescent players (8–12 years old), that athletic ability parameters were poor predictors of ranking. Similarly, Roetert *et al*. (1992) [17] indicated that agility was the only significant fitness variable to predict competitive rankings in 83 prepubescent tennis players. The differences in these results might be age- and maturity-related, due to the remarkable puberty-associated increase in muscle mass and strength and, as a consequence, in speed and power (Girard and Millet 2009) [9]. The positive contribution of height to the ranking, as suggested by the regression analysis in the present study (Table 3), should be tested in other age groups before a definite conclusion can be made about the significance of this anthropometric variable to tennis performance.

To evaluate the significance of flexibility to tennis, Reilly and Benton (1995) [16] used the sit and reach test, and reported greater flexibility in regional female tennis players than in club tennis players. On the other hand, Chandler *et al*. (1990) [6] reported that tennis players were less flexible than non-tennis athletes in the shoulder and arm joints. They suggested that the reduced flexibility in the upper limb reflects an undesirable adaptation to the repetitive, short, high-velocity musculoskeletal movement of tennis. These conflicting results suggest that the importance of flexibility to tennis excellence is currently not clear. This was also demonstrated by our finding of a low, although significant, correlation (r = –0.352) between the sit and reach test score and the player's ranking.

Creatine phosphate re-synthesis is mediated primarily by oxidative processes (Glaister 2005) [10]. This emphasizes the importance of aerobic metabolism to tennis, as it enhances the recovery from intense activities and maintains power output, especially throughout long-lasting games. The significant correlation (r = –0,581) in the present study between aerobic capacity and the players' ranking supports this assumption. In accordance with this, strong relationships were found between aerobic capacity during preparation period and the following year's entry ranking for top players (Banzer *et al*. 2008) [1]. Improved aerobic capacity may also decrease the reliance on anaerobic energy sources and the accumulation of lactate and fatigue levels in the exercising muscles (König *et al*. 2001) [12]. A high level of fatigue was found to reduce skill and hitting accuracy by as much as 80% (Dovey *et al*. 2002) [7]. It is therefore not surprising that world-class tennis players were found to demonstrate higher aerobic fitness and lower lactate levels at comparable intensities than lower-ranking players (Banzer 2008; Kovacs 2006) [1, 13].

5. Conclusions

The results of the present study displayed significant correlations between fitness and anthropometric characteristics and tennis national ranking at age 15. The results also revealed that the tennis-specific box drill test is the most efficient predictor of the young tennis players' ranking, and when combined with the players' height accounted for 56% of the players' ranking.

The results imply the overall importance of anaerobic capabilities for tennis, suggesting that anaerobic-specific tennis-like movements should be a significant part of the young players' training program. These findings also emphasize the importance of tennis-specific tests in the evaluation of young tennis player's performance.

It should be emphasized, however, that a more comprehensive set of tests, including evaluation of technical and tactical ability, should be applied before a more reliable estimation of future success can be made in young tennis players.

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