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A Comparative Study of Three Strengthening Programs to Improve Performance in Tennis Serve

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Abstract:*Tennis serve is the more delicate and complex stroke in competitive tennis. Serve movement produces high loads on the shoulder and lumbar spine. Also tennis serve as a complex stroke which requires the smooth activation of muscles and joints involved in the kinetic chain for the production of kinetic energy. Players of all levels are constantly seeking to improve performance, accuracy and speed of their serve. The aim of this study was to compare three strengthening programs: one for the upper limbs, one for the lower limbs and one for the core, in order to improve performance in tennis serve of novice tennis players. In this research participated 60 novice tennis players aged 23-45 years. Participants were divided randomly into four groups. Three groups followed strengthening programs intervention and the forth was control group. Pre and post interventions, lasting twelve weeks, we evaluated tennis serve performance of each participant. For the statistical analysis, the statistical package SPSS 25.0 was used. One way Anova was used to check for differences between groups at baseline and then Repeated Measures Anova to identify differences between measurements. The results showed that the greatest improvement in tennis serve performance was recorded on the group followed the intervention program of the lower limbs. Followed by the group with the intervention of the upper limbs and third was the group with the intervention on thecore. The smallest improvement was observed in the control group, which followedonly technique training. This study leads us to conclude that strength training may be used in the learning stage of tennis serve and might lead to significant results. More specifically, strengthening lower limpsaffect most the performance on tennis serve.*

KeyWords*: Tennis serve, performance, strengthening, upper limb, lower limb, core*

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I. Introduction

Tennis serve is the starting stroke to play each point. The player must hit the ball with his racket and land in opposite diagonal side of the court and inside the area defined by the serve line, without touching the net. As every "tennis rally" starts with a serve, it is logical to suppose that the ability to properly perform this stroke plays an important role in the outcome of the match. Serve is the most skillful and complicated stroke on a tennis game, especially for novice players (Girard, 2005).Tennis serve produces huge loads on the shoulder joint and the lumbar spine. These loads can lead to overload injuries (Fleisig, Nicholls, Elliott, & Escamilla, 2003; Kibler&Safran, 2005; Kovacs, 2007; Chow, Park, & Tillman, 2009). It is also a complex stroke as it requires the harmonic activation of many muscle groups and joints involved in the kinetic chain to produce kinetic energy (Ryu, McCormick, Jobe, Moynes,&Antonell, 1988).

The difficulty in the execution of this movement lies in the ability to sum up the forces from the ground to the upper limb through the kinetic chain and then to transfer the kinetic energy to the ball. In tennis serve, if this energy transfer is successful, te sum of forces is transferred to the ball, just below the maximum flight height and before the ball starts its downward route (zero point) (Bahamonde, 2000). In tennis serve, the right placement of the racket, its trajectory, its height and its speed are necessary at the time of impact with the ball and must be perfectly coordinated with the upper and lower extremities of the body (Brody, 1987; Elliott, 1983).Players, who serve successfully, use the kinetic chain by synchronizing the activation of the lower limb muscles, which provide a stable base for the trunk. Thus, the trunk has the ability to perform rotation, stretching, and bending, helping to produce strength in the upper limbs. If some of the chain links are not effectively synchronized, the result of the serve will not be the expected (ie, speed, spin and positioning) (Kibler, 2009).

An important aspect of the tennis service is the player's ability to exert high muscle strength. Given the required kinetic chain, there must be a sequential summing of the forces, which must be transferred from the ground to the upper extremities of the body for efficient energy production. A key determinant of success in tennis service is the speed of the ball. Several researchers have examined the relationship between ball velocity and upper limb strength. Cohen, Mont, Campbell, Vogelstein, and Loewy (1994) found moderate but significant correlations (r = 0.47 and r = 34, SI = .05) between the ball spin in tennis serve and the isokinetic

extensiontorqueof the elbow at 60° and 180°. Ellenbecker (1991) examined the isokinetic force in the inner and outer shoulder rotation, flexion and extension of the wrist and forearm at 90°,210°, and 300°, and reported that no significant correlation was found between the strength and the speed of the ball.

Strength training has been proven to offer benefits and improve performance in tennis. A significant increase in ball velocity during tennis service was reported after four weeks of muscle training of the shoulder muscles using rubber straps and light dumbbells on club-level players (Treiber, Lott, Duncan, Slavens, & Davis, 1998).Ellenbecker, Davies, and Rowinslu (1988) also performed isokinetic interference in college-level tennis players for six weeks. They found that only the group that followed a concentric training program showed a significant increase in service speed. The group that followed the eccentric training session showed no significant increases in ball velocity with more than half of the team's participants showing a decrease in the speed of the ball. In conclusion, it could be assumed that the muscle strength assessment could partly predict the speed of the tennis serving ball.

In kinematic analyses on tennis service it appears that the strength of both the upper and lower limbs is important for creating the maximum speed of the racket. From kinematic analysis it appears that, first, in importance, the movement of the servomotor is the shifting of the shoulder (Cohen, et al., 1994). Measurements of lower limb movement have reported the importance of knee extension force (Ellenbecker&Roetert, 1995). However, there are no studies dealing with lower limb strength and service performance for tennis players. In addition, strength in upper limb muscles may be related to the speed of the ball, but the exact contribution of the lower limb muscles has not yet been established.

Tennis players use the trunk muscles in all moves on the court, especially when performing the serve. They are emphasising on the involvement of trunk in each of these movements by performing exercises specifically designed to improve the performance of the kicks on the pitch. Typically, trunk muscles include transverse abdominal, multi-faceted, inward and outward oblique, rectal abdominal and sacral muscles. In addition, hip and trunk muscles contribute to the stability of the trunk needed to transport kinetic energy through the kinetic chain. The trunk should be considered as the connection between the lower and upper limbs of the body and not just as a group of individual muscles.

Furthermore, trunk muscles are particularly involved in the serve of all levelstennis players. During the service loading stage, the trunk participates by performing the horizontal torsion of the trunk, through the contraction cycle of the trunk muscles. In right-handed players, this includes, at first, the storage of potentialenergy (through eccentric contractions) from the lateral muscles to the left side of the trunk, left sacrum muscles and multifidus muscle. During this position, sometimes referred as posterior lateral flexion, shoulders and hips are inclined downwards and away from the net. This is the main stage where the power is stored during the serve (charging stage). At the beginning of shoulder movement for the serve, the right lower limb has begun rotating in the sagittal plane. Some coaches have the misconception that tennis players need to train in the transverse rather than the sagittal plane. It is important to emphasize the need for strength training in lateral flexion of the trunk (Roetert, Ellenbacker, & Reid, 2009). It is also important to note that research has shown an imbalance in the strength of tennis athletes between the anterior (abdominal) and posterior (lumbar spine) trunk muscles (Roetert, McCormick, Brown, &Ellenbecker, 1996).Decreased trunk muscle strength might have negative effect on performance of a tennis athlete in case of astrength program is not included in his training. Interventions to improve corestrength are suggested to be included in tennis training to help improve the strength and stability of trunk muscles (Kovacs, Etcheberry, & Ramos, 2010).

Sports scientists, players, coaches and physiotherapists have made great efforts to improve tennis service performance. The aim of this study is to compare three separate strengthening programs, one for the upper limbs, one for the core and one for the lower extremities, on tennis serve performance, in beginner tennis athletes

II. Materials& Methods

This research was conducted at the premises of the Department of Physical Education and Sports Sciences at Aristotle University of Thessaloniki, Greece, during the tennis training courses and at the Municipal Gym for the groups that followed a strengthening program as an intervention.

Participants

60 adult tennis players (31 men and 29 women) totally participated in this study. They were randomly divided to four groups. Three interventions groups followed technique training and strengthening programs (for upper limbs, lower limbs and core) and one control group which followed only the tennis technique training.The first group consisted of fifteen (15) adults (9 males and 6 females), followed by a technique training and a program of muscle strengthening of the upper limbs and the technique training.The second group consisted of fifteen (15) adults (8 males and 7 females) who followed the technique training and a strengthening programfor the core. The third group consisted of fifteen (15) adults (7 males and 8 females) and they attended the

technique training and a strengthening programfor the lower limbs. The control group consisted of fifteen (15) adults (7 males and 8 females) who only followed the basic tennis technique practice. Mean age and basic somatometric characteristics of participants on each group are presented in table 1.

Table 1. Mean age and basic somatometric characteristics of participants on each group

Participants characteristics	Group A		Group B		Group C		Control group	
	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Age	29.00	5.76	29.00	5.33	28.73	3.76	28.73	5.63
Weight	71.66	10.48	73.40	13.64	63.80	14.53	69.20	13.65
Height	176.00	7.87	177.66	9.52	174.33	6.27	174.00	8.20
BMI	23	-	23	-	21	-	22	-

Procedure

Prior the start of the intervention program we record the tennis serve performance. Successful and failed serves, as well as their order of execution, were recorded.In order to evaluate tennis serve performance, participants were asked to perform fifteen serves, from the right side of the court. A tennis serve was counted as successful if it was complied with the rules established by the International Tennis Federation (ITA).

After the three-month intervention, a new record was made. The intervention lasted twelve weeks.The frequency of the intervention program was 3 times a week. Theintervention program, for all groups, was held from 17:00 to 21:00.

Statistical analysis

For the statistical analysis of data SPSS 25.0 for Windows was used. One Way Anova was used in order to identify possible, significant differences between the groups at the first measurement. Finally, Repeated Measures Anova, was used to identify possible significant differences between the groups between the two measurements. P value was set at 0.001.

III. Results

As regards tennis serve performance at baseline, One Way Anova has shown no significant differences between all four groups [$F(1,3) = 8.69$, $p > .001$, $\eta^2 = .31$]. Group A performed at means 5.80±2.07 successful serves, group B mentioned 5.53±2.35 successful serves, group C succeed 4.86±1.64 serves and group D performed 5.33±1.98 successful serves.

After Intervention, Group A mentioned at means 8.66±2.16successful serves, group B mentioned 7.93±1.86 successful serves, group C succeed 9.53±1.50 serves and group D performed 5.93±1.79 successful serves.Group C showed the greatest improvement in tennis serve performance from initial to final measurement compared to other groups (Table 1).

Table 2. Number of successful tennis serves in each group

Participants group	Pre intervention		Post intervention	
	Mean	S.D.	Mean	S.D.
Group A (Upper limbs strengthening program)	5.80	2.07	8.66	2.16
Group B (Core strengthening program)	5.53	2.35	7.93	1.86
Group C (Lower limbs strengthening program)	4.86	1.64	9.53	1.50
Group D (Control group)	5.33	1.98	5.93	1.79

The results of the Repeated Measures Anova (4 groups of X 2 measurements) showed the existence of significant interaction between the groups in the two measurements [$F(1,3) = 38,92$, $p < .001$, $\eta 2 = .67$] in tennis serve performance (Fig. 1).

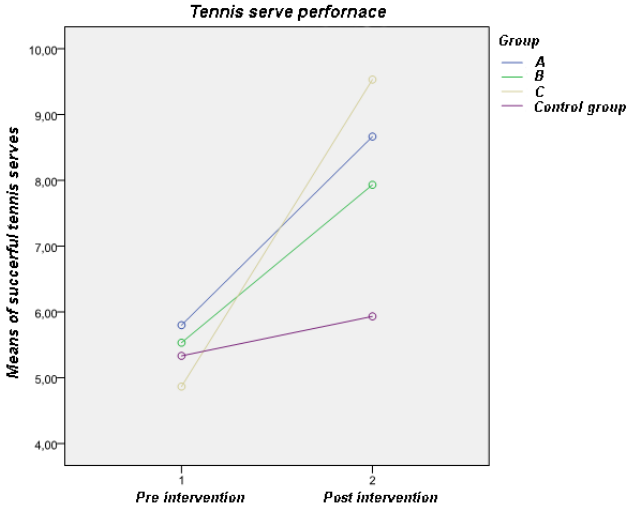

Figure 1.*Tennis serves performance pre-post intervention between groups.*

IV. Discussion

The present study aimed to compare three strengthening programs in order to improve tennis serve performance of beginner adult tennis athletes. In particular, it will be debated whether the implementation of strengthening programs is effective in improving tennis serve performance.

As regardstennis serve performance, the results in the present study showed that the greatest performance improvement was observed in the group following an intervention strengthening program for the lower limbs. Tennis serve performance is followed by the upper limbs strengthening intervention group and third was the core strengthening intervention group. The lowest improvement in tennis serve performance was observed in the control group which did not follow any strengthening program but only technique training.

The findings from the lower limb intervention groupare in line with the results of other studies confirming that knee flexion before stretching is a prerequisite for effective serving regardless the level of the players. However, some differences in performance parameters were found between players at different levels (Girard, Micallef,& Millet, 2005). Experienced players servefaster than the less experienced. This difference is related to the difference in the strength of the upper limbs. In line with the results of this study, another research ofMarshall and Elliott (2000) has suggested that the torso and lower leg muscles contribute 54% to creating the forces required to perform a tennis service.

Concerning the second position of the group that followed an upper limb intervention program, according to Kovacs and Ellenbecker (2011), players who serve successfully use their outer shoulders and pelvis to save energy for speed and spins in the ball during the preparation phase of the service. The acceleration of the racket prior to impact with the ball is accompanied by rapid rotation of the lumbar spine. Furthermore, Ellenbecker et al., 1988; Ellenbecker, 1991, 1992; Gozlan et al., 2006 emphasized that there is a significant effect on the dominant hand and ball velocity in both genders as well as on the concentric and eccentric force of the internal rotation.In addition,Treiberet al., (1998), showed that resistance training on tennis players with Therabands and light dumbbells seems to increase the strength of the internal and external shoulders rotation muscles and increase performance (serve speed). Compared to women, men showed higher serve speed, greater force in the internal and externalrotations compared to body weight and differences in the strength ratio of the internal and external shoulders rotation muscles.

Regarding the third place of the core strengthening intervention group, the results of this study are consistent with other researchers who have dealt with the importance of trunk power in the movement of the tennis serve. The study by Girard et al., (2005) showed a direct relationship between the trunk muscles, rectus abdominis, internaloblique, external oblique and transverse abdominis.In line with the results of this study, another Marshall and Elliott (2000) research has suggested that the core and lower leg muscles contribute 54% to creating the forces required to perform a tennis serve.

The literature review showed that researchers involved in tennis conducted research on the recording and assessment of strength, range of motion, muscle activation and angular velocities. All these parameters have been evaluated in professional or high-level players. However, it has not been studied how strengthening programs affect service performance and how through power programs we can facilitate the learning of serving service to beginner players. The present study leads us to the conclusion that strengthening programs can be used while learning tennis serve, with significant results.

V. Conclusions

In conclusion, this study showed that the strengthening of lower limbs positively affects tennis serve performance. This is followed by strengthening with core strengthening and lastly strengthening the upper limbs. The small improvement observed in the control group compared to the performance of the intervention teams can be attributed to time effect and leads us to the conclusion that strengthening programs must be an integral part of the training procedurewhile learning tennis serve.

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