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ORIGINAL

EFFECTS OF STRENGTH TRAINING ON HITTING SPEED IN YOUNG TENNIS PLAYERS

EFECTOS DEL ENTRENAMIENTO DE FUERZA EN LA VELOCIDAD DE GOLPEO EN TENISTAS JÓVENES

Terraza-Rebollo, M.[1]; Baiget, E.[2]; Corbi, F.[3] and Planas Anzano, A.[4]

[1] Preparador físico escuela de competición tenis, C.N. Lleida. Lleida (Spain) manuelterrazarebollo@gmail.com
[2] Profesor Titular. Sport Performance Analysis Research Group (SPARG), Universidad de Vic (Spain) ernest.baiget@uvic.cat
[3] Profesor Titular. Departamento de Salud y Gestión. Institut Nacional d'Educació Física de Catalunya, Centro de Lleida. Universidad de Lleida. Lleida (Spain) fcorbi@inefc.es
[4] Profesor Titular. Departamento de Salud y Gestión. Institut Nacional d'Educació Física de Catalunya, Centro de Lleida. Universidad de Lleida. Lleida (Spain) tplanas@inefc.es

Spanish-English translator: Rocío Domínguez Castells, rocio@sport-science.net

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ABSTRACT

Nowadays, hitting speed is an important component of tennis performance. The purpose of this study was to determine the effect of two different strength training methods on hitting speed. 20 tennis players were (mean ± SD: age 15.5 ± 0.9 years; weight 61.4 ± 7.6 kg; height 170.3 ± 9.4 cm) randomly divided into 3 groups. During 8 weeks with a frequency of 3 days per week, the first group (SC) performed one additional training with overloads, the second group (L) completed an additional training with medicine ball and elastic band; and the third group (C, control), only completed the technical-tactical training. Each group increased their strength, except the control group. SC group had the best improvement in serve speed. L group increased the strength levels although there was no transfer from the improved strength to the hitting speed.

KEY WORDS: tennis, hitting speed, strength training, resistance training.

RESUMEN

La velocidad de golpeo es uno de los factores fundamentales para el rendimiento en tenis competitivo. El objetivo del estudio fue determinar el efecto de dos métodos de entrenamiento de fuerza sobre la velocidad de golpeo en tenis. 20 jugadores de nivel regional (promedio ± SD: edad 15.5 ± 0.9 años; peso 61.4 ± 7.6 Kg; talla 170.3 ± 9.4 cm) fueron asignados aleatoriamente en tres grupos. Durante 8 semanas a 3 días·sem^{-1}, un grupo realizó un entrenamiento adicional con sobrecargas (SC), un segundo grupo entrenamiento adicional mediante lanzamientos con balón medicinal y banda elástica (L) y un tercer grupo (C, control) únicamente realizó el entrenamiento técnico-táctico. Todos los grupos mejoraron los niveles de fuerza, excepto el grupo control. El grupo SC obtuvo mayores incrementos en la velocidad de servicio. El grupo L mejoró la velocidad de lanzamiento de balón medicinal aunque no hubo transferencia en la velocidad de golpeo.

PALABRAS CLAVE: entrenamiento fuerza, tenis, velocidad de golpeo.

INTRODUCTION

Competitive tennis requires good physical condition, high level of motor skills and big tactical capacity, which makes it a multifactor sport (Fernández et al., 2006, Unierzyski, 2006; Baiget, 2008; Fernández et al., 2012; Fernández et al., 2013). In the last years, the requirements of this sport have changed substantially: the distance covered in displacements, the high strength levels developed and the change in hitting mechanics have made tennis a very physically-demanding sport (Kovacs, 2010). This suggests that tennis has evolved from being a sport where performance was mostly dependent on technical and tactical skills to a new context where physical capacities have gained relevance (Fernández et al., 2012). These changes have influenced on physical and physiological demands of tennis games, giving more importance to power and speed (Sarabia et al., 2010). Simultaneously, there is growing interest in improving these capacities with training. However, sometimes the methods used have been based more on intuition and coaches' experience than on the scientific method (Fernández et al., 2006).

Strength development plays an important role in tennis training and has the purpose to optimize shots and displacements, as well as to prevent injuries (Kovacs, 2006; Ortiz, 2004). Currently, hitting speed is a determining performance factor in modern tennis (Signorile et al., 2005; Baiget, 2011). In order to increase this speed, strength training should focus on maintaining or improving the levels of useful or applied strength (Baiget, 2011), increasing the power developed in the competitive skill (Badillo y Serna, 2002). For this reason, it becomes very important to use training methods which are specific to the necessities of each sport and to have the right tools to monitor its evolution (Van den Tillaar y Ettema, 2004).

Several studies have proved that explosive strength training by means of SSC (stretch-shortening cycle) allows to improve the hitting speed in sports like tennis (Treiber et al., 1998; Fernández et al., 2013; Genevois et al., 2013) or baseball (Escamilla et al., 2012). In this regard, several authors recommend doing rotational medicine ball throws to improve the hitting speed in tennis (Roetert y Ellenbecker, 2008; Roetert et al., 2009; Earp y Kraemer, 2010; Baiget, 2011) or the use of overloads (Kraemer et al., 2000; Kraemer et al., 2003). The aims of the present study are to examine the effectiveness of training with medicine ball and overloads on hitting speed of the serve, forehand and backhand tennis strokes and to analyze the relationship between maximal medicine ball throwing speed and hitting speed in youth tennis players.

MATERIAL AND METHOD

Participants

20 competitive tennis players (15 boys and 5 girls), belonging to under-16 or under-19 categories participated in this study (mean ± SD: age 15.5 ± 0.9 years; body mass 61.4 ± 7.6 kg; height 170.3 ± 9.4 cm). General characteristics of the participants are shown in Table 1. None of them underwent significant

changes in their anthropometric characteristics during the study. Inclusion criteria for this study were: to have longer experience in tennis training than 4 years, not to practice any other competitive sport, not to have participated in any specific strength training program, and not to have been injured in the last six months. All participants volunteered to take part in the study and were previously informed of its aims, methods and potential risks. They did not receive any kind of reward for participating. They, or their legal tutors in case of under-eighteen, signed an informed consent document. This study was designed according to the Declaration of Helsinki of 1975, revised in 2008, and the protocol was approved by the local ethics committee.

Table 1: General characteristics of the groups (mean ± SD). SC: experimental group following overloads training; L: experimental group using medicine ball throws and elastic band; CON: control group. *No significant differences ($p < 0.05$) were found in age, body mass or height among the control and experimental groups.

	n	Age (years)	Body mass (kg)	Height (cm)
SC	7	14.9 ± 0.7	62.5 ± 10.1	170.8 ± 13.3
L	7	16.0 ± 0.8	58.4 ± 3.8	167.5 ± 5.9
CON	6	15.4 ± 0.9	63.6 ± 7.9	173.1 ± 7.8

Instruments

A radar (Stalker Pro, USA) was used for the measurements. It was calibrated before each participant was measured, according to the instructions of the manufacturer. This radar, which had been previously validated by Sedano et al. (2009), uses Ka band microwaves, with 20 miliwatt power and two polarized horns destined to jointly transmit and receive the signals. This kind of band uses a frequency of 34.7 GHz, which protects it against electromagnetic noise. To prevent the error due to the cosine effect, the radar was placed in the line of the ball's displacement and the shots which did not meet this requirement were not considered for the study. Only maximal hitting speeds were considered, following Fernández et al. (2013). The same device has been used in tennis to assess the speed of the serve (Blackwell & Knudson, 2002; Girard et al., 2005), the forehand and backhand strokes (Signoreli et al., 2005; Corbi, 2008). Balls approved by the International Tennis Federation (Babolat Gold) were used for the hitting tests. New balls were used in every testing session, in order to keep internal pressure uniform. A 2-kg Salter medicine ball was used for the throwing tests.

Protocol

The participants were assigned in a stratified and randomized way to one of three training groups: experimental group 1 (SC), experimental group 2 (L) and control group (CON). The inclusion of a control group was necessary to control for the effect of the technical-tactical training completed during the study and for the improvement due to natural development of the participants.

No significant differences were observed among groups once they were created. The three groups completed the same technical-tactical training for 8 weeks. The SC group performed additional training with overloads, the L group underwent additional training with medicine ball throws and elastic bands and the CON group only did the regular tennis training. The training program lasted for 8 weeks, with 3 sessions per week. Both experimental groups did 2 hours of on-court technical-tactical training and one additional hour of strength training, while the CON group only completed the 2 hours of technical-tactical training. The strength training in the additional sessions focused on improving the hitting speed. Each strength training session lasted for 45 min and consisted of a 15-min warm up, which included running and dynamic stretching, and specific exercises (Ayala et al., 2012). During the whole intervention phase, the players did not change their hitting technique, racquets or string tension. All the participants attended a minimum of 80% of the programmed training sessions.

One week prior to the beginning of the intervention, the participants were asked to attend a briefing where they handed the informed consent in, the study protocol was explained to them and they were instructed how to correctly perform every exercise. The SC group performed the exercises with effort rates between 6 (12) and 10 (14), depending on the exercise (González Badillo & Gorostiaga, 1995; González-Badillo & Ribas, 2003; González Badillo, 2008). Execution speed was maximal (maximal intention) in both training methods, since biggest transference seems to occur when execution speed is high and it allowed to compare the power developed by different participants (González Badillo y Gorostiaga, 2011). Three sets per exercise were prescribed in the strength training, according to Rhea et al. (2004). The training protocols used with each group of this study may be found in the table 2 and 3.

Table 2: Exercises used in the overload method (SC) and [effort rate]. 3 sets of each exercise were completed, with 1 minute rest between exercises and 3 minutes between sets.

DAY 1	DAY 2	DAY 3
Horizontal barbell bench press [8(12)]	Supinated and semisupinated grip pull ups [6(12)]	Incline dumbbell flies (30º) [8(12)]
Trunk curl on the floor 50	Trunk curl on the floor 50	Trunk curl on the floor 50
Incline leg press [8(12)]	½ squat [8(12)]	Incline leg press [8(12)]
Forehand/backhand with barbell [6(12)]	Dumbbell snatch [6(12)]	Barbell throw [6(12)]
Trunk extensions on bench 20 kg	Trunk extensions on bench 20 kg	Trunk extensions on bench 20 kg
Dumbbell lying shoulder external rotation [10(14)]	Dumbbell lying shoulder external rotation [10(14)]	Dumbbell lying shoulder external rotation [10(14)]
One-arm dumbbell row to waist [8(12)]	Dumbbell pullover [8(12)]	One-arm dumbbell row to waist [8(12)]
Standing high-pulley internal rotation [10(14)]	Standing high-pulley internal rotation [10(14)]	Standing high-pulley internal rotation [10(14)]
Barbell throw [6(12)]	Forehand/backhand with barbell [6(12)]	Dumbbell snatch [6(12)]

Table 3: Exercises included in the training method using medicine ball throws and elastic band (LT). 3 sets of 6 repetitions were performed per exercise. Medicine ball weight: 2 kg.

MEDICINE BALL	ELASTIC BAND
Forehand and backhand side throws	Two-arm trunk rotation
Chest throws	One-arm diagonal trunk flexion
Two-arm overhead forward throws	
Two-arm overhead backwards throws	
One-arm overhead forward throws	
Side floor throws	

Image 1: A: Side throws starting position (forehand-backhand). B: Side throw end position (forehand-backhand). C: Chest throw starting position. D: Chest throw end position.

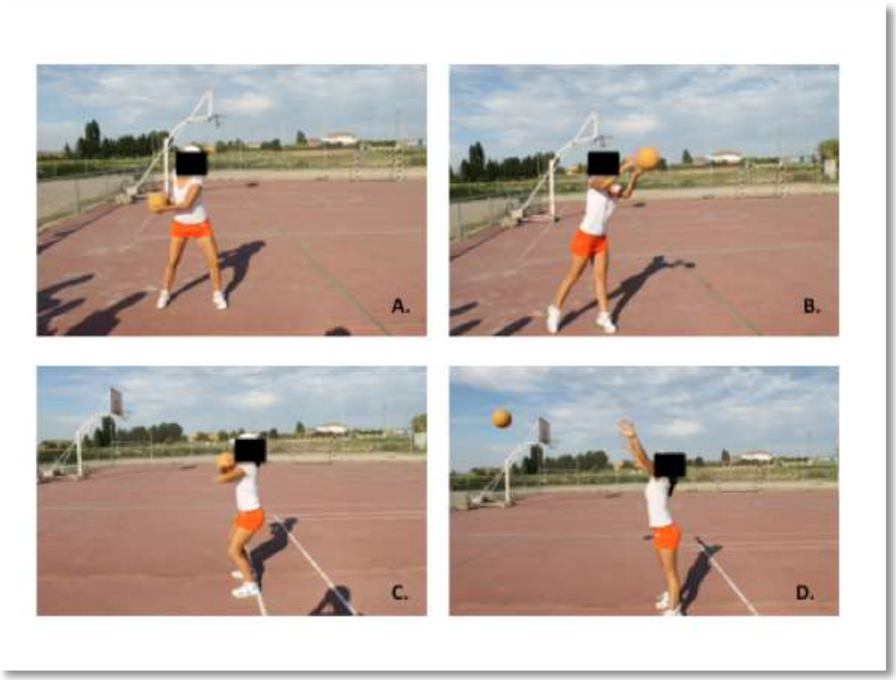

Image 2: A: Starting position for the two-arm overhead forward throw. B: End position for the two-arm overhead forward throw. C: Starting position for the two-arm overhead backwards throw. D: End position for the two-arm overhead backwards throw.

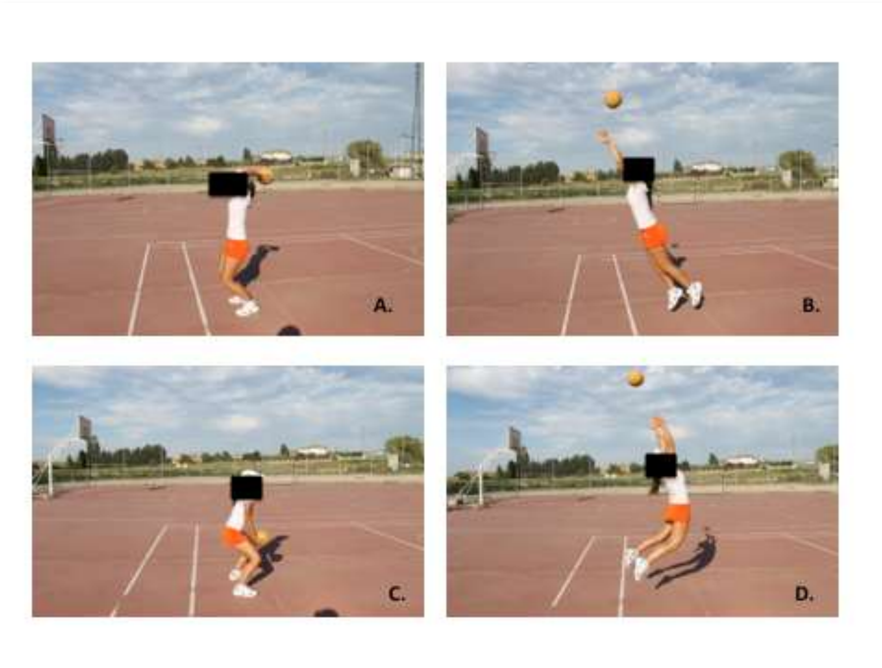

Image 3: A: Starting position for the one-arm overhead forward throws. B: End position for the one-arm overhead forward throws. C: Starting position for the two-arm side floor throws. D: End position for the two-arm side floor throws.

Image 4: A: Starting position for the two-arm trunk rotation with elastic band. B: End position for the two-arm trunk rotation with elastic band. C: Starting position for the one-arm diagonal trunk flexion. D: End position for the one-arm diagonal trunk flexion.

Three assessments of the hitting and throwing speeds were made: pre-test (two days prior to the intervention), inter-test (after 4 weeks of intervention) and post-test (five days after the end of the intervention).

The test consisted in assessing the speed of 12 flat serves (6 on each court side), 12 backhand and 12 forehand strokes (6 parallel and 6 crosscourt), 3 two-arm overhead throws with a 2-kg medicine ball and 3 single-arm throws per player. The participants were constantly encouraged to perform the shots and throws at maximal speed. Only the shots which followed the desired trajectory and landed within the court were taken into account. The participants rested 20 seconds between shots and 3 minutes between tests. During the training sessions, no maximal effort was performed 48 hours prior to the tests. No food rich in carbohydrates was ingested 2 hours prior to the tests.

Statistical analysis

Descriptive statistical methods were used to calculate means and standard deviations. After having applied the Shapiro-Wilk normality test to all the variables, a one-way ANOVA was applied to determine the differences among groups in body mass, height and age. In order to compare the different types of training, a repeated-measures analysis of variance was conducted, with three groups (between-subject: training with overloads –SC-, training with throws and elastic band –L-, control –CON-) by three moments (within-subject: pre-test, inter-test and post-test). In those cases in which the ANOVA showed significant differences, Bonferroni post hoc tests were applied. Statistical significance level was set at $p < .05$. The statistical analysis was conducted with the software package SPSS Statistics 20.

RESULTS

No significant differences were found in age ($F_{2,17} = 2.935$; $p = .08$), body mass ($F_{2,17} = 0.837$; $p = .45$) or height ($F_{2,17} = 0.569$; $p = .577$) among groups (Table 1). Descriptive statistics regarding hitting speed are shown in Table 4. No significant differences were found among the three groups during the pre-test in the speed of the serve ($F_{2,17} = 0.110$; $p = .897$), the forehand stroke ($F_{2,17} = 0.639$; $p = .540$), the backhand stroke ($F_{2,17} = 2.340$; $p = .1278$), the two-arm medicine ball throw ($F_{2,17} = 1.297$; $p = .299$) or the one-arm medicine ball throw ($F_{2,17} = 0.412$; $p = .669$).

Significant correlations were observed among most of the studied variables, although the correlations between the one-arm medicine ball throwing speed and both forehand and backhand stroke speeds were not as high as the rest. There were no significant correlations between the two-arm medicine ball throwing speed and both forehand and backhand stroke speeds (Table 5).

Table 4: Hitting speed (mean ± SD) obtained in the three tests (T1, T2 and T3). CON: Control group; SC: Group training with overloads; L: Group training with medicine ball throws and elastic band.

	PRE-TEST (T1)			**INTER-TEST (T2)**			**POST-TEST (T3)**		
	CON (n=6)	**SC** (n=7)	**L** (n=7)	**CON** (n=6)	**SC** (n=7)	**L** (n=7)	**CON** (n=6)	**SC** (n=7)	**L** (n=7)
SERVE (Km/h)	150.3± 14.6	146.57± 14.39	149.43± 15.38	147.50± 16.87	147.7± 18.63	150.8± 16.89	148.67± 15.48	152.57± 17.16	151.57± 16.62
FOREHAND (Km/h)	135.67± 11.74	140.43± 11.73	143.14± 15.32	137.83± 8.09	139.8± 12.39	140.2± 17.99	139.17± 5.95	142.86± 12.48	136.86± 11.42
BACKHAND (Km/h)	117.33± 7.31	124.14± 7.22	128.00± 11.36	117.33± 4.55	124.5± 13.16	124.7± 10.58	118.17± 2.32	126.29± 7.78	124.57± 8.18
2-ARM THROW (Km/h)	32.62± 2.88	33.00± 4.90	29.71± 4.28	32.83± 3.06	34.00± 5.26	32.57± 3.91	33.17± 3.31	34.43± 3.60	32.43± 3.65
1-ARM THROW (Km/h)	31.67± 3.67	33.00± 5.63	30.71± 4.54	32.33± 3.93	34.57± 4.89	31.86± 3.84	32.67± 2.86	34.14± 5.08	33.71± 4.35

Significant differences were identified in the serve hitting speed ($F_{(2,17)} = 3.028$; $p = .04$; ES = 0.151; 1-β = 0.548) between the pre- and post-test ($M_{dif} = 2.16$ km/h; $p = .030$; CI95% 0.238 to 4.080 km/h) and between the inter- and post-test ($M_{dif} = 2.25$ km/h; $p = .037$; CI95% 0.152 to 4.341 km/h).

Significant differences were also found in the development of SC group (ES = 0.534; 1-β = 0.945) between the pre- and post-test ($M_{dif} = 6$ km/h; $p = .001$; CI95% 2.763 to 9.237 km/h) and between the inter- and post-test ($M_{dif} = 4.86$ km/h; $p = .010$; CI95% 1.327 to 8.39 km/h).

In forehand hitting speed significant differences (ES = 0.239; 1-β = 0.430) were only observed in L group development, between the pre- and post-test (M_{dif} = 6.29 km/h; p = .035; CI95% 0.501 to 12.07 km/h).

No significant differences were found in backhand hitting speed among groups, among moments or in the interaction of groups and moments.

The two-arm medicine ball throwing speed showed significant differences ($F_{(2,17)}$ = 6.448; p = .01; ES = 0.275; 1-β = 0.877) between the pre- and inter-test (M_{dif} = 1.34 km/h; p =.029; CI95% 0.151 to 2.52 km/h) and between the pre- and post-test (M_{dif} = 1.55 km/h; p = .006; CI95% 0.505 to 2.59 km/h). Mauchly's sphericity test was significant for this variable (null hypothesis rejected) and Greenhouse-Geisser's correction was applied.

Significant differences were also found in the evolution of L group (ES = 0.39; 1-β = 0.741) between the pre- and inter-test (M_{dif} = 2.86 km/h; p = .008; CI95% 0.85 to 4.86 km/h) and between the pre- and post-test (M_{dif} = 2.71 km/h; p = .005; CI95% 0.856 to 4.47 km/h).

There were significant differences in the one-arm medicine ball throwing speed ($F_{(2,17)}$ = 7.912; p = .002; ES = 0.318; 1-β = 0.936) between the pre- and post-test (M_{dif} = 1.71 km/h; p = .001; CI95% 0.79 to 2.64 km/h).

They were also found in SC group (ES = 0.592; 1-β = 0.981) evolution between the pre- and post-test (M_{dif} = 3.00 km/h; p = .001; CI95% 1.442 to 4.56 km/h) and between the inter- and post-test (M_{dif} = 1.86 km/h; p = .004; CI95% 0.666 to 3.05 km/h).

Table 5: Correlation among the speed of the one-arm and two-arm overhead medicine ball throws and the hitting speed of the serve, forehand and backhand strokes in the three testing moments: 1: Pre-test, 2: Inter-test, 3: Post-test. (* $p < .05$; ** $p < .001$).

(n=20)	**Forehand 1**	**Backhand 1**	**Ball throw (2-arm) 1**	**Ball throw (1-arm) 1**
Serve 1	.663**	.642**	.600**	.617**
Forehand 1		.667**	.337	.477*
Backhand 1			.405	.489*
Ball throw (2-arm) 1				.912**
	Forehand 2	**Backhand 2**	**Ball throw (2-arm) 2**	**Ball throw (1-arm) 2**
Serve 2	.716**	.571**	.567**	.570**
Forehand 2		.770**	.288	.358
Backhand 2			.348	.385
Ball throw (2-arm) 2				.947**
	Forehand 3	**Backhand 3**	**Ball throw (2-arm) 3**	**Ball throw (1-arm) 3**
Serve 3	.765**	.691**	.680**	.736**
Forehand 3		.696**	.469*	.511*
Backhand 3			.397	.524*
Ball throw (2-arm) 3				.911**

DISCUSSION

The present study shows that an eight-week training program with overloads, medicine balls and elastic bands has positive effects on serve speed, as well as on one- and two-arm medicine ball throwing capacity. These results would justify the introduction of training programs aimed at improving strength of adolescent tennis players.

The results obtained suggest that applying different strength training methods (overloads, medicine ball and elastic bands) leads to improvement of the throwing capacity with low loads (2 kg) in all the studied groups, except for the control group. The magnitude of the changes achieved should be considered according to the sample size (Tejero-González et al., 2012). In our study, the magnitude of the observed changes may be rated as high (Cohen, 1988). This fact justifies the introduction of this type of training methods as a way to improve performance.

Several authors have proved that the implementation of strength training programs may be especially interesting when applied to children and adolescents, and more particularly when neural adaptation processes related to motor unit activation, synchronization and recruitment capacity are involved (Behringer et al., 2011).

The lack of improvement in strength levels observed in the control group in one- and two-arm medicine ball tests suggests that neither the on-court technical-tactical training nor the natural development of the player in this age range had an influence on the strength increase measured in the tests performed. Several authors have verified a considerable improvement in the strength-generating capacity due to the increase of height, age, body mass and biological development (Brent et al., 2013; Beuen & Thomis, 2000; Malina & Bouchard, 1991; Malina, 1994). These changes were dependant on the athlete's gender (Brent et al., 2013). In our study, these differences were not observed, which means that the differences in performance were caused by the intervention protocol and not by a change in strength levels. This could be, at least partly, due to the fact that the tests selected assess the capacity to generate medium and low strength levels in short time intervals, which seems to be less influenced by biological factors (Behm et al., 2008; Christou et al., 2006; Faigenbaum et al., 2002, 2005).

In regard to specific movement patterns, the serve speed experienced the greatest improvement, the biggest increase being detected in the overloads group. These results are in line with those reported by other authors, who observed improvements in tennis and baseball after a training program of similar characteristics (Fernández et al., 2013; Genevois et al., 2013; Escamilla et al., 2012). Fernández et al. (2013) found a significant increase in the serve speed (4.9%) of 30 male junior tennis players who underwent a 6-week training program, including core muscles exercises, elastic bands and medicine ball. In the study conducted by Genevois et al. (2013) 44 male adult tennis players completed a 6-week training program consisting in medicine ball throws. The forehand stroke speed improved significantly (11%). Escamilla et al. (2012) performed a study with 68 youth baseball players (14-17 years old). They found that the group who trained with medicine ball throws and elastic band exercises significantly improved ball throwing speed (2.1%).

Medicine ball throwing exercises were chosen in this study to develop strength since they are mechanically comparable to tennis shots (Roetert et al., 2009; Earp y Kraemer, 2010). The use of medicine balls allows to activate the tennis specific movement chain (Baiget, 2011), generating transference since the ball weight was modified (Van den Tillar y Marques, 2013). However, in our case, the improvement in medicine ball throwing speed did not imply an increase in forehand hitting speed. The improvement in the throwing tests was probably caused by the specificity of the training and by the neural adaptations achieved with it. On the other hand, we must acknowledge a possible learning effect from the exercises used in the training sessions to the tests.

Improvements were observed short-term (after 4 weeks) as well as mid-term (after 8 weeks), which supports the duration of the chosen protocol. Although several authors have reported that biggest strength increases in young athletes occur after 8 to 20 weeks of training (Westcott, 1992, Faigenbaum, 1993), other authors (Fernández-Fernández et al., 2013; Treiber et al., 1998) have found improvements in tennis between 4 and 6 weeks after starting a strength training program. This could be due to the fact that improvements in the first 50 ms of the force-time curve appear after 4 weeks of explosive strength training, caused by higher electromyographic activation of the muscles involved (Tillin & Folland, 2014). In fact, from the first and second weeks of training, improvements in the activation threshold, the muscle activation frequency and the motor evoked potential may be observed (Griffin & Cafarelli, 2003; Patten et al., 2001; Keen et al., 1994). All this suggests that in the first weeks of training the detected improvements may be caused by cortical, spinal and neural adaptations (Griffin & Cafarelli, 2005).

Acceptable correlations (0.70-0.79) (Barrow & McGee, 1971) were found between the forehand stroke and the serve, between the forehand and backhand strokes and between the serve and the single-arm throw (p<.001). The rest of the analyzed movements presented controversial correlation values. This could be due to different reasons. Firstly, the existing similarities in the space-time organization of the kinetic chains involved in the movement patterns analyzed. The correct application of the partial impulses generated by each joint in an appropriate time and space guarantees the optimization of hitting and throwing speed (Hochmuth, 1984; Corbi, 2008). Moreover, a certain degree of transference has been proved between motor skills with similar characteristics (Zatsiorsky, 1995). Secondly, the level of the athletes analyzed in this study facilitates the existence of transference among different kinds of tennis shots. Low- and medium-level athletes seem to be much more sensitive to any type of training and to possible transference among different movements (Issurin, 2008, 2013). Despite this, the need of high specificity for strength adaptations prevents from obtaining higher correlation coefficients (Cale-Benzoor et al., 2014; Langford et al., 2007).

CONCLUSION

The implementation of an 8-week training program using overloads, medicine balls and elastic bands led to significant improvement in the serve speed, as well as in the one- and two-arm medicine ball (2 Kg) throwing capacity. These results justify the introduction of strength training programs for youth tennis players, since these seem to improve not only their general but also specific strength levels. Future studies are necessary to know more about which kind of method and temporalization would optimize tennis shot performance.

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