Effects of a 12-Week Strength Training Program on Experimented Fencers' Movement Time

Juan C. Redondo,[1] Cruz J. Alonso,[1] Silvia Sedano,[2] and Ana M. de Benito[3]

[1]*Faculty of Sports Sciences, Department of Movement and Sport Sciences, University of León, León, Spain;* [2]*Laboratory of Physiology, European University Miguel de Cervantes, Valladolid, Spain; and* [3]*Faculty of Sports Sciences, Catholic University of Valencia, Valencia, Spain*

Abstract

Redondo, JC, Alonso, CJ, Sedano, S, and de Benito, AM. Effects of a 12-week strength training program on experimented fencers' movement time. *J Strength Cond Res* 28 (12): 3375–3384, 2014—The purpose of this study was to determine the effects of a 12-week strength training program on movement time (MT) on fencers of national level. Twelve male fencers were randomly divided into 2 groups: the control group (CG: $N = 6$; age, 22.3 ± 8.1 years) and the treatment group (TG: $N = 6$; age, 24.8 ± 7.2 years). The CG fencers followed the standard physical conditioning program, which was partially modified for the TG. The TG participated in a 12-week strength training program divided into 2 parts: maximal strength training, including weightlifting exercises (2 days a week for 6 weeks) and explosive strength training, with combined weights and plyometric exercises (2 days a week for 6 weeks). Body mass, body fat, muscle mass, jumping ability, maximal strength, reaction time, and MT were measured on 4 separate occasions. The TG demonstrated significant increases ($p \leq 0.05$) in maximal strength and jumping ability after 6 weeks of training and in MT after 12 weeks. These improvements remained unaltered during the 4-week detraining period. It may be concluded that a 12-week strength training program can improve maximal and explosive strength, and these increases can be transferred to MT performance. However, fencers need time to transfer the gains.

Key Words fencing performance, weightlifting, plyometric training

Address correspondence to Juan C. Redondo, jc.castan@unileon.es.

28(12)/3375–3384

Journal of Strength and Conditioning Research
© 2014 National Strength and Conditioning Association

Introduction

Fencing could be qualified as an agility sport (33) in which whole-body change of direction, rapid movement and direction change of limbs, temporal or spatial uncertainty, rapidly accelerates or decelerates in a straight line to evade an opponent are included together with open skills that involve physical and cognitive components. Therefore, according to the universal agility components outlined by Young et al. (43), we must focus on reaction time (RT) and movement time (MT) as important variables on fencing performance (30).

The fencing lunge is an offensive movement in which the success of the action depends on the speed of execution (40). Consequently, it is necessary to have a high-strength development to generate high power outputs. In fact, Sedano et al. (32) have reported a link between the different manifestations of speed and the explosive strength in athletes. Moreover, Tsolakis and Vagenas (39) outlined that during the execution of actions in fencing, muscle strength and neuromuscular coordination are important parameters to maximize the features of functional power of the lower extremities. Thus, one of the most important capacities in fencing might be explosive strength (8), which could be defined as the ability to generate the greatest strength in the shortest time. These rapid movements with loads <25% of 1 repetition maximum (RM), similar to those made in fencing, are determined by the ratio of increase in strength per unit of time (21), that is, the rate of expression of force (3) in the initial part of the force-time curve, which is the initial force. Therefore, one could conclude that explosive strength is one of the performance factors in fencers.

The effects of physical activity on RT and MT have been analyzed in different sports, but these studies used measurement devices in RT not directly related to the sporting activity studied (7). In some studies (34), fencers underwent isometric contractions at 50% of 1RM with the brachial triceps to exhaustion, and contrary to their expectations, no deterioration was observed in the motor time after the isometric contraction. Therefore, Borysiuk (5) compared RT and MT with visual, tactile, and auditory stimuli among elite

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

and novice fencers and found differences in both RT and MT. For elite fencers, the most important differences were registered in the RT, specifically to visual stimuli. In addition, other studies about the effect of a high-intensity effort on visual RT outlined significant increases in time both for men and women (11) and when fencing athletes were compared with other athletes, concluded that the experience in fencing coupled with better fitness level, making it more effective (9).

Research on fencing have focused mainly on comparing and analyzing physical capacities (40,42). Nevertheless, technical and tactical aspects of matches have also been investigated (17), even considering potential differences between competition levels (36,41). However, no study has focused on the analysis of a specific strength training program implemented in-season to enhance the performance of experimented fencers.

Because of the lack of related studies, more research into the effect of different strength training programs on experimented fencers' performance is necessary. Consequently, the purpose of this study was to determine the effects of a 12-week 2-part (maximal and explosive) strength training program on body mass, body fat, muscle mass, maximal strength, jumping ability, RT, and MT in experimented fencers. We hypothesized that with the strength training program implemented during the competitive season, which partially replaced the regular fencing conditioning program, the experimental group of experimented fencers would demonstrate greater increases in maximal and explosive strength, and these could be transferred to a specific fencing movement, the lunge, in terms of reaction and MT.

Methods

Experimental Approach to the Problem

The research experiment followed a repeated-measures design to assess the effects of a 2-part strength training program on experimented fencers' performance, and the adaptations of this type of training were compared with a regular standard physical conditioning program for fencing. Participants were selected regarding their national-level competition to ensure similar levels of technical execution. Subjects participated in a prescribed number of monitored training sessions over the course of 12 weeks. They were evaluated on 4 occasions: 1 week before the start of the training program, after 6 and 12 weeks of training, and 4 weeks after the end of the program (detraining period). The participants undertook the strength training program exercises and test between 1800 and 2130 hours, and they were also instructed to avoid any strenuous physical activity and to maintain their usual dietary habits for the duration of the study. Throughout the testing sessions, all fencers were encouraged to drink water regularly to maintain their hydration status. They were also required to abstain from taking any stimulants or depressants, including caffeine for at least 6 hours and alcohol for at least 24 hours before the testing sessions.

The independent variables were the type of physical conditioning program and the time of dependent variables assessment. Dependent variables were body mass, fat mass, muscle mass, squat jump (SJ) height, countermovement jump (CMJ) height, RT, MT, and maximal strength. Subjects were restricted from participating in any other exercise programs during the training period. Two-way analysis of variance (ANOVA) with repeated measures was conducted to assess the effects.

Subjects

Twelve national-level male fencers (all of them reported positions among the top 12 in their respective national rankings) agreed to participate in the study and were randomly divided into 2 groups: the control group (CG) and the treatment group (TG). Their demographic and anthropometric data are shown in Table 1. The CG and TG fencers have 10.3 ± 2.5 and 9.7 ± 6.4 years of experience, respectively. This limit was set to minimize the variability of the technique. Players averaged 11.3 ± 3.1 hours of training per week. Informed consent was obtained from all participants, in keeping with the guidelines established by the University of León (Spain) Ethics Committee that approved the author's study.

Procedures

Training Protocols. The specific training program was implemented during the competitive season (i.e., February, March and April, May). Before the start of the intervention, both groups performed the same regular standard physical conditioning program for 2 months.

During the intervention, all players participated in the regular fencing training program, which included 5 training sessions a week and a real or simulate competition. The physical conditioning program was different for the 2 groups. The CG players followed the regular standard physical conditioning program for fencing, which was

Table 1. Demographic and anthropometric data of the players.*

Group	Age (y)†	Height (cm)	Mass (kg)
Control group ($n = 6$)	22.3 ± 8.1	179.5 ± 5.2	77.1 ± 10.1
Treatment group ($n = 6$)	24.8 ± 7.2	173.3 ± 7.8	70.4 ± 10.5

*Values are given as mean ± *SD*.
†All older than 18 years.

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

partially altered in the TG to improve the strength in the upper and lower limbs.

The training regimen of the fencers during the study is shown in Table 2. After the 12 weeks, TG and CG participants continued with the same regular standard physical conditioning program together. During the study, fencers were not allowed to perform any other training that might influence the results, and they were previously informed about hydration, rest, and nutrition patterns. All training sessions were supervised by the lead researcher with careful attention to proper exercise technique.

Control Group Training. During the 12-week intervention, the CG fencers followed the training regimen set out subsequently: (a) Monday and Wednesday: Fencers practiced specific fencing movements for 10 minutes, tactical exercises in pairs for 60 minutes at competition intensity, in which specific actions of fencing were previously agreed (obligation or prohibition to do certain measures such as attack, counterattack, or defense), simulated competition for 30 minutes, individual training for 30 minutes, and flexibility exercises aimed at the lower limbs for 15 minutes; (b) Tuesday: Fencers practiced individual training for 30 minutes and flexibility exercises aimed at the lower limbs for 15 minutes; (c) Thursday: Fencers practiced individual training for 30 minutes, simulated competition for 120 minutes and flexibility exercises aimed at the lower limbs for 15 minutes; (d) Friday: Fencers practiced individual training for 30 minutes and flexibility exercises aimed at the lower limbs for 15 minutes; (e) Saturday: If there was no official competition, a simulated competition was performed with the same characteristics of Thursday and flexibility exercises aimed at the lower limbs for 15 minutes.

Treatment Group Training. The TG, in addition to the previously outlined, participated in a 12-week supervised strength training program divided into 2 parts. All players had previous experience on this type of training. Details are given in Table 3 (2,4,13).

Maximal Strength Training (6 Weeks). The TG fencers followed the same training regimen as CG fencers except that on Mondays and Wednesdays, and they had a maximal strength training session instead of the exercises in pairs described previously. It included 1 upper-extremity exercise (horizontal bench press) and 2 lower-extremity exercises (i.e., barbell squat and seated calf extension). Exercises were performed using 3 sets of 6 repetitions with 75% of the maximal load with a 3-minute rest between sets (4). The general order of the maximal strength training routine was a seated calf extension, horizontal bench press, and barbell squat.

Explosive Strength Training. On Mondays and Wednesdays, TG participants had explosive strength training sessions instead of the sessions described previously, completing a combined weights and plyometrics program. Sessions included the exercises detailed previously in the same order. They were performed with 3 sets of 3 repetitions with 70% of the maximal load (4). These characteristics aimed at performing the movements in an explosive manner. Each resistance exercise was combined with a plyometric exercise to mimic the stretch-shortening movement performed by the muscles involved in the fencing lunge. The rests between sets were 3 minutes to guarantee the explosive manner in the execution.

Testing Protocols

Before the initial testing session, each fencer was familiarized with the testing protocol. All participants were required to attend 2 trial sessions. In the first, we assessed anthropometric profile, RT, MT, and explosive strength of the lower limbs. Two days later, in the second session, maximal strength was measured. To standardize testing procedures,

TABLE 2. General training regimen of the fencers during the study.

Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
10 min: specific fencing movements 60 min: exercises in pairs 30 min: simulated competition 30 min: individual training 15 min: flexibility	30 min: individual training 15 min: flexibility	10 min: specific fencing movements 60 min: exercises in pairs 30 min: simulated competition 30 min: individual training 15 min: flexibility	30 min: individual training 120 min: simulated competition 15 min: flexibility	30 min: individual training 15 min: flexibility	Official competition or 120 min: simulated competition 15 min: flexibility	Rest

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

TABLE 3. Strength training details.*

Exercises	Muscle action	Sets/repetitions/load/rest between sets	Repetition velocity
Maximal strength training			
Seated calf extension	ECC:CON:ISO	3 sets × 6 repetitions × 75%/3 min	1:1:1
Horizontal bench press	ECC:CON:ISO	3 sets × 6 repetitions × 75%/3 min	1:1:1
Barbell squat	ECC:CON:ISO	3 sets × 6 repetitions × 75%/3 min	1:1:1

Combined exercises	Muscle action	Sets/repetitions/load/rest between sets	Repetition velocity
Explosive strength training			
Seated calf extension + vertical jumps with straight legs	ECC:CON + PLY	3 sets × (3 repetitions × 70% + 6 repetitions)/3 min	Explosive
Horizontal bench press + repetitions with the bar only	ECC:CON + PLY	3 sets × (3 repetitions × 70% + 6 repetitions)/3 min	Explosive
Barbell squat + vertical jumps with flexed legs	ECC:CON + PLY	3 sets × (3 repetitions × 70% + 6 repetitions)/3 min	Explosive

*CON = concentric; ECC = eccentric; ISO = isometric; PLY = plyometric.

the same trained test leaders performed the entire test procedure using an identical order and protocol. All players were tested on 4 separate occasions: T1, 1 week before the start of the training program; T2 and T3, after 6 and 12 weeks of the training program, respectively; and T4, 4 weeks after the end of the program (detraining period).

Anthropometric Data. Anthropometric testing followed the protocols of the International Society for the Advancement of Kinanthropometry (ISAK) (28) and was performed by an ISAK level 2 anthropometrist. Testing was performed in a standardized order after a proper calibration of the measuring instruments. Height and body mass were measured using a stadiometer (Holtain Ltd., Crymych, United Kingdom) and a SECA Atrax 770 electronic scale (Seca, Hamburg, Germany), respectively. To estimate body composition, 6 skinfold (triceps, subscapular, suprailial, abdomen, front thigh, and medial calf) and 2 diameter (wrist and femur) measurements were taken using a Holtain skinfold caliper (Holtain Ltd.) and a Lafayette caliper (Lafayette Instrument Company, Lafayette, IN, USA). Each skinfold and diameter were measured 3 times with the median result used in data analyses. Subsequently, fat mass, muscle mass, and their respective percentages were calculated to evaluate body composition using the formulas of Faulkner (12) and Matiegka (25), respectively.

Explosive Strength of Lower Limbs. Before the start of the test session, fencers went through a standardized 20-minute warm-up period. Fencers' jumping ability was assessed using a jumping mat (SportJUMP System; DSD, Inc., León, Spain), which showed positive significant correlations (RXY = 0.998, $p < 0.001$) with the Bosco Ergo Jump System (Globus, Treviso, Italy) and with a Dinascan 600M (IBV, Valencia, Spain) force plate (RXY = 0.994, $p < 0.001$) (15). Fencers performed 2 different jumps: an SJ and a CMJ, both with hands on hips, each one 3 times. The best result was used for the statistical analysis. The rest between trials was 60 seconds.

Fencing Performance: Reaction Time and Movement Time Assessment. All participants were required to wear the specific suit of fencing. According to the requirements of Williams and Walmsley (41), the test presented in Figure 1 begins with the master's signal (movement from 1 to 2) and it ends when the tip of the sword makes contact with the master's chest (movement from 3 to 4). The RT and MT, expressed in milliseconds, were measured with a telemetry timing system (DSD Laser System, León, Spain) with a laser photocell that was composed of 3 peripherals (Figure 1): Peripheral "A": Laser barrier with an accuracy of 500 Hz that performs the function of crossing detector that sends the signal to the central telemetry module; peripheral "B": Metal rod that rotates in the horizontal plane and when sword's cup takes contact with it a signal is transmitted to the central module by wire; and peripheral "C": Fencers used their personal swords equipped with a digital 1/1,000-second stopwatch interfaced with their wiring system where the tip of the sword was acting as a button.

The reliability of the results offered by this test with the current measuring protocol was previously validated using 7 VICON-460 infrared video cameras at 100 Hz (Vicon Peak, Oxford, United Kingdom). The study revealed that the system used did not influence either the measurement of the RT ($F = 0.007$, $p > 0.001$), the MT ($F = 2.620$, $p > 0.001$), or the matching time (intraclass correlation

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

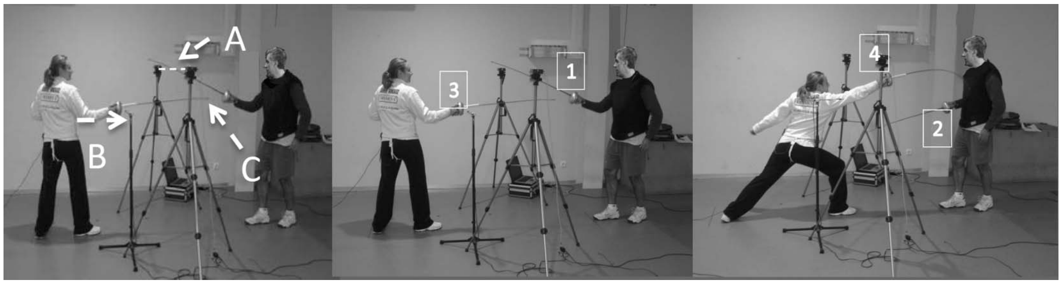

Figure 1. System for movement time assessment with initial and final position in test. A, B, and C = peripherals; 1, 2, 3, and 4 = actions.

coefficient [ICC] = 0.997 and 0.998 for RT and MT, respectively), which associated with effect size (ES) (0.000 and 0.102 respectably) indicates a high degree of relationship between the 2 measurement systems.

Each participant performed 3 fencing lunges using his own sword. Participants were instructed to do maximally during each trial. The rest period between trials was of 1-minute duration, and the highest speed was used in data analysis.

Maximal Strength. Before the start of the second test session, participants went through a standardized 20-minute warm-up. A 1RM test following the protocol established by the National Strength and Conditioning Association was performed to measure maximal strength. First, fencers were instructed to warm-up with a light resistance that easily allowed 5–10 repetitions. After a 1-minute rest period, we estimated a warm-up load that would allow them to complete 3–5 repetitions by adding 5–10% for upper-body exercises and 10–20% for lower-body exercises. After a 2-minute rest period, we estimated a near-maximum load that would allow for 2–3 repetitions by adding 5–10% for upper-body exercises and 10–20% for lower-body exercises. Then, we introduced a 3-minute rest before consecutive load increases of 5–10% for upper-body exercises and 10–20% for lower-body exercises until the player could complete only 1 repetition with a proper exercise technique. The 1RM test was calculated for the same exercises used in the training program, which were always performed in the same order: seated calf extension, horizontal bench press, and barbell squat. A 5-minute rest was taken between exercises.

Statistical Analyses

The SPSS statistical software package (version 18.0; SPSS, Inc., Chicago, IL, USA) was used to analyze all data. Normality of distribution was tested by means of the Kolmogorov-Smirnov test. Standard statistical methods were used for the calculations of the mean and *SD*. Student's *t*-tests were performed to determine differences in the initial values among the members of the 2 groups in all variables analyzed. Training-related effects and the differences between groups were assessed using 2-way ANOVA with repeated measures (group × time). When a significant F value was achieved by means of Wilks' lambda, Scheffe's post hoc procedures were performed to locate the pairwise differences. The Bonferroni correction for multiple comparisons was applied. The significance level was set at $p \le 0.05$. Effect size (ES) statistics was assessed using Cohen's d (27). Cohen classified ES into "small" (0.2–0.3), "medium" (0.4–0.7), and "large" (>0.8). In addition, the reliability of measurements was calculated using the ICC.

Results

The Kolmogorov-Smirnov test suggested that all variables were distributed normally ($p > 0.05$). Results of Student's *t*-test between CG and TG at baseline revealed that there were no statistically significant differences before the start of

Table 4. Comparative analysis between CG ($n = 6$) and TG ($n = 6$) in all the variables at baseline.*

	F†	*P*
Body mass (kg)	0.05	0.29
Percent fat	1.21	0.19
Percent muscle	2.26	0.66
SJ (cm)	1.84	0.20
CMJ (cm)	2.25	0.16
Reaction time (s)	1.95	0.20
Movement time (s)	1.23	0.30
1RM horizontal bench press (kg)	3.40	0.17
1RM barbell squat (kg)	0.14	0.62
1RM seated calf extension (kg)	0.07	0.73

*Student's *t*-test (unpaired samples); F ratios and p values; significant differences at $p \le 0.05$.
†CG = control group; TG = treatment group; SJ = squat jump; CMJ = countermovement jump; RM = repetition maximum.

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

TABLE 5. Descriptive data for anthropometric features and reaction time for the CG and the TG for each test occasion.*

Variable	Group	Time T1	Time T2	Time T3	Time T4	Group *F*	Time *F*	Group × time *F*	*d*
Body mass (kg)	CG†	70.43 ± 10.49	71.5 ± 10.01	71.75 ± 10.03	72.4 ± 9.77	0.57	0.27	9.18	0.05
	TG	77.13 ± 10.20	75.95 ± 8.75	75.267 ± 9.70	74.700 ± 8.76				
Body fat (%)	CG	14.12 ± 22.66	14.14 ± 2.62	14.12 ± 2.79	14.18 ± 2.64	0.10	0.59	6.51	0.01
	TG	13.89 ± 2.54	13.72 ± 2.40	13.46 ± 2.43	13.63 ± 2.48				
Muscle mass (%)	CG	42.25 ± 3.97	42.50 ± 3.84	42.53 ± 3.87	42.61 ± 3.76	0.00	1.39	3.04	0.05
	TG	42.46 ± 2.57	42.48 ± 2.39	42.56 ± 2.63	42.25 ± 2.46				
SJ (cm)	CG	31.10 ± 3.68	30.70 ± 2.45	33.48 ± 2.48	33.02 ± 2.49	12.854‡	20.706‡	7.074‡	0.897
	TG	33.92 ± 1.83a	36.10 ± 1.55b	38.15 ± 1.60a,b,c	36.80 ± 1.50a,c				
CMJ (cm)	CG	32.15 ± 3.40	32.20 ± 4.07	31.42 ± 3.49	31.43 ± 4.00	13.888‡	7.108‡	15.995‡	0.918
	TG	36.02 ± 1.84$_{a}$	38.08 ± 1.46$_{a}$	40.23 ± 1.97$_{a}$	38.58 ± 2.28$_{a}$				
1RM horizontal bench press (kg)	CG	41.93 ± 11.22	42.03 ± 11.59	42.02 ± 11.08	42.37 ± 10.84	3.239	20.825‡	20.350‡	0.363
	TG	55.10 ± 18.33a	58.85 ± 16.66b	61.52 ± 17.89a,b	60.33 ± 17.24a				
1RM barbell squat (kg)	CG	80.27 ± 25.63	80.07 ± 25.45	81.12 ± 25.91	80.60 ± 25.02	1.690	29.154‡	23.973‡	0.218
	TG	88.60 ± 30.74$_{a}$	105.57 ± 34.37$_{a}$	111.22 ± 34.75$_{a,b}$	105.35 ± 33.02$_{a,b}$				
1RM seated calf extension (kg)	CG	89.43 ± 10.35	90.62 ± 10.55	91.33 ± 8.94	90.78 ± 9.75	13.283‡	18.884‡	14.493‡	0.906
	TG	91.43 ± 9.33$_{a}$	109.60 ± 8.85$_{a,b}$	120.13 ± 10.44$_{a,b,c}$	113.70 ± 8.77$_{a,c}$				
RT (s)	CG	0.41 ± 0.12	0.38 ± 0.19	0.34 ± 0.10	0.34 ± 0.08	8.57	0.54	0.39	0.46
	TG	0.31 ± 0.10	0.26 ± 0.06	0.27 ± 0.07	0.32 ± 0.08				
MT (s)	CG	0.304 ± 0.068	0.302 ± 0.068	0.305 ± 0.064	0.319 ± 0.050	6.575‡	9.964‡	10.764‡	0.638
	TG	0.263 ± 0.049$_{a}$	0.248 ± 0.032$_{b}$	0.216 ± 0.025$_{a,b}$	0.220 ± 0.027				

*Values are given as mean ± *SD*.
†CG = control group; TG = treatment group; SJ = squat jump; CMJ = countermovement jump; RM = repetition maximum.
‡$p \leq 0.05$. Mean values in the same row for the same variable having the same subscript are significantly different at $p \leq 0.05$.

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

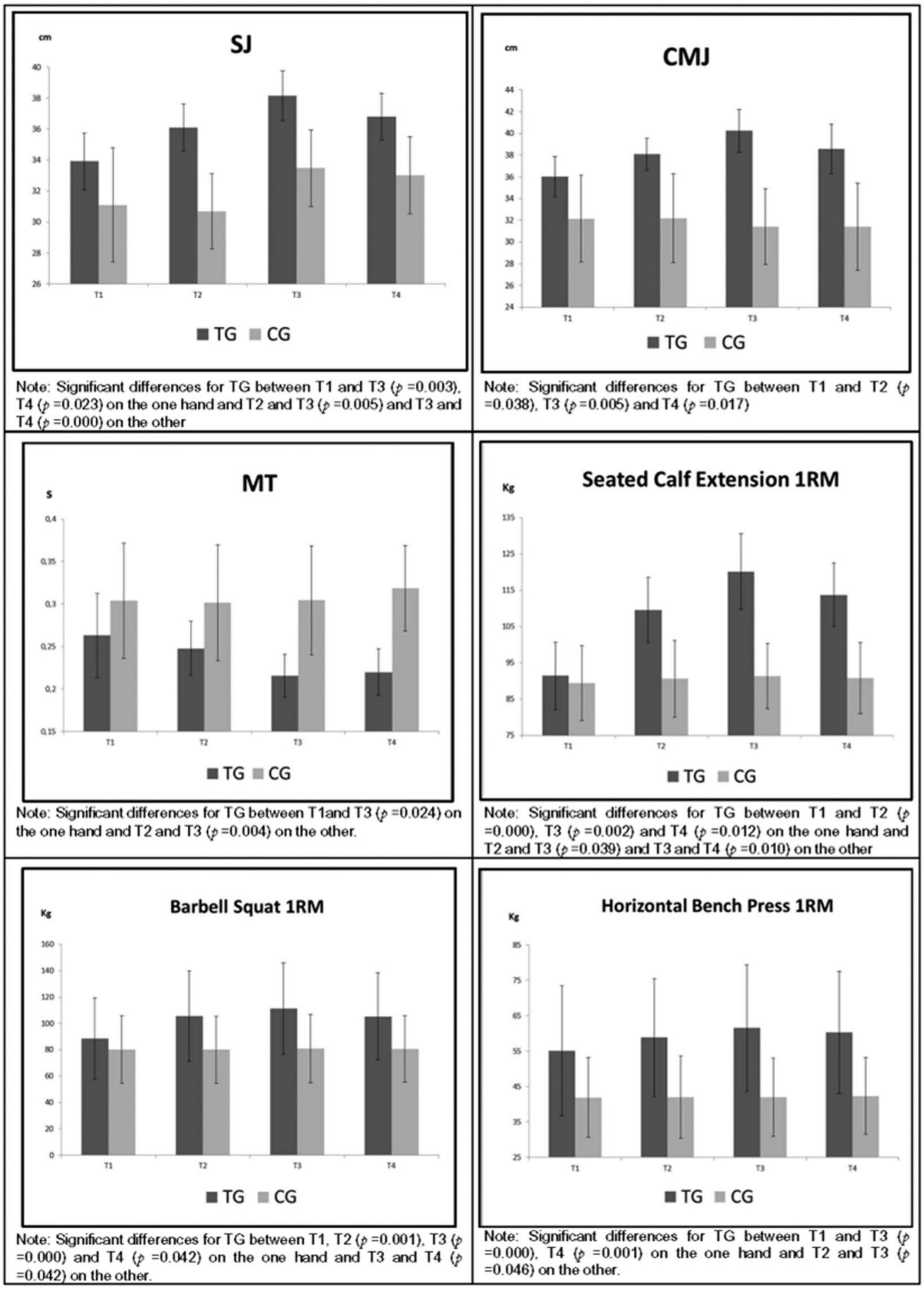

Figure 2. Graphic display of the evolution in variables were the significant time × group significant interaction effects given by analysis of variance. SJ = squat jump; CMJ = countermovement jump; RT = reaction time; MT = movement time; and RM = variables related to maximal strength.

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

the training program (Table 4). Table 5 shows the data for all variables on every test occasion (T1, T2, T3, and T4). A graphic display of other variables with statistically significant differences is shown in Figure 2.

Anthropometric Data

Analysis of variance revealed no significant time × group interaction effects for body mass, muscle mass, and body fat. All anthropometric measures were highly reliable with ICC of 0.93–0.97 for skinfolds and 0.91–0.97 for diameters.

Explosive Strength of Lower Limbs

For explosive strength, ANOVA showed that there were significant interaction effects both for SJ ($p = 0.001$, ES = 0.562) and CMJ ($p = 0.004$, ES = 0.581). For TG, Scheffe's post hoc tests found the differences between T1 and T3 ($p = 0.003$, ES = 0.93), T4 ($p = 0.023$, ES = 0.83), and between T2 and T3 ($p = 0.005$, ES = 0.71) and T3 and T4 ($p = 0.000$, ES = 0.71), and for SJ and CMJ the differences were registered between T1 and T2 ($p = 0.038$, ES = 0.71), T3 ($p = 0.005$, ES = 0.89), and T4 ($p = 0.017$, ES = 0.53). The ICC was 0.95 for SJ and 0.97 for CMJ.

Maximal Strength

Analysis of variance located significant interaction effects for all the variables related to maximal strength (horizontal bench press 1RM [$p = 0.001$, ES = 0.265], barbell squat 1RM [$p = 0.002$, ES = 0.145], and seated calf extension 1RM [$p = 0.001$, ES =0.570]). For all the exercises related to maximal strength, Scheffe's post hoc tests located the differences between T1 and T3 ($p = 0.000$, ES = 0.15) and T4 ($p = 0.001$, ES = 0.13) and between T2 and T3 ($p = 0.046$, ES = 0.08) for horizontal bench press 1RM; T1 and T2 ($p = 0.001$, ES = 0.26), T3 ($p = 0.000$, ES = 0.34), T4 ($p = 0.042$, ES = 0.26), and between T3 and T4 ($p = 0.042$, ES = 0.09) for barbell squat 1RM; and for seated calf extension 1RM, the differences were registered between T1 and T2 ($p = 0.000$, ES = 0.72), T3 ($p = 0.002$, ES = 0.84) and T4 ($p = 0.012$, ES = 0.79) and between T2 and T3 ($p = 0.039$, ES = 0.52) and T3 and T4 ($p = 0.010$, ES = 0.36). The measurements were highly reliable with the ICC ranging from 0.91 to 0.99, indicating excellent trial-to-trial reliability.

Fencing Performance

Analysis of variance reflected significant time × group interaction effects just for MT ($p = 0.029$, ES = 0.397). For TG, Scheffe's post hoc tests located the differences between T1 and T3 ($p = 0.024$, ES = 0.53) and T2 and T3 ($p = 0.004$, ES = 0.49) for MT. All lunge performance measurements were highly reliable with ICC of 0.98 for RT and 0.99 for MT.

Discussion

As a result of the lack of studies on high-level competitive fencers, the primary aim of this study was to determine whether experimented fencers could enhance maximal and explosive strength and other qualities critical to fencing performance (jumping abilities or the lunge) by a 12-week strength training program. As mentioned previously, fencing is a sport in which speed is a crucial component of performance (37). Therefore, bearing in mind the relationship between speed and explosive strength, training these athletes to increase strength values must be one the objectives for fencing performance (39). Consequently, one of the most important aims of training programs for fencers should be to increase fencing-specific strength. In agreement with our hypothesis, the main findings showed that this training program, in addition to the regular fencing training exercises, increased maximal strength in both upper and lower limbs, explosive strength of lower limbs, and fencing performance, in terms of a lower MT (Figure 2).

Our data revealed that 6-week maximal strength training was enough time to produce significant improvements in maximal strength (19.47 ± 9.05% in barbell squat and 20.27 ± 9.90% in seated calf extension), explosive strength (6.56 ± 4.40% in SJ and 5.81 ± 2.57% in CMJ), and MT (4.97 ± 6.76%). However, our findings indicate that 6 weeks later, including complex training with plyometric exercises, fencers convert these strength gains in more efficient results of MT (12.78 ± 4.05%).

Several authors (23,32) have suggested that in other sports, in which the technical movement depends on the precisely coordinated action of different muscles, is important to combine strength training with technical training to transfer the gains. They have also emphasized that the specific nature of the exercises performed and the fact that athletes combined strength and technical training could be considered as key factors in the successful transfer of the strength gains to a specific movement.

Studies about RT and MT in fencing have been carried out by different authors (6,16,26,29,41,42) but because of the fact that they use different methods and experimental conditions the comparison among them is not easy. So, we can find different stimuli on single or elective reactions and also perform different actions for RT, and the major differences lie in the distance between the performer and the objective for MT.

Although maximal strength data in fencing are reported by several researchers (35,36,38,40), in none of their studies the relationship of these variables with strength training programs arises. However, consistent with the assertions of Ronnestad et al. (31) our results revealed maximal strength improvements, with a very low increase in muscle mass, which may be because of alterations in training intensity factors (18) or neural adaptations by subject (19,20,31).

Results of this study showed significant increases in vertical jump ability values for TG, whereas there were no differences for CG. Markovic (24) suggested in a meta-analytical study that there may be a positive transfer of the effects of plyometric training on vertical jump ability to other athletic performance, which could include lunge fencing. Although we have not found specific references to connect vertical jump ability improvements in fencing athletes

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

because of specific training programs, authors like Tsolakis and Tsiganos (38) and Tsolakis et al. (37), with elite and nonelite Greek fencers, revealed data similar to those obtained in our study for SJ and CMJ. However, these results are hardly comparable in terms of the relationship between these factors and performance in fencing. The TG improved 12.62 ± 4.74% and 11.77 ± 3.66% for SJ and CMJ, respectively, in our study where all the exercises used in the strength program were chosen on the basis that major agonists were highly active in fencing-specific movements. Consequently, neural adaptations such as a greater activation and synchronization of the recruitment of higher-threshold motor units and an enhanced inhibition of antagonist muscle activity may have an important impact on the gains (10). However, further studies that focus on neuromuscular factors are needed to determine the role of each factor in the improvements.

It is important to highlight the positive effect of this type of training to maintain the gains previously achieved. This could be related to the fact that the detraining period did not affect the changes recorded during the 12-week strength training program in maximal strength, explosive strength, and MT. These results are in agreement with those of Alvarez et al. (1), Sedano et al. (32), and Maffiuletti et al. (22), who found that a detraining period, in which the regular training of a specific sport is maintained, made it possible to maintain the gains previously achieved, which is also a key factor in planning the season.

Finally, with regard to anthropometric variables, the program had no significant effects that might be partially explained by the findings of Tsolakis et al. (37) because they concluded that these variables cannot be identified as factors of performance in fencing.

In conclusion, the results of this study show for the first time that a 12-week 2-part (maximal and explosive) strength training program that partially replaced the regular fencing conditioning program can improve maximal and explosive strength, and these can be transferred to the lunge, in terms of MT. However, it must be taken into consideration that our sample is not as wide as to claim that results previously mentioned could easily be extrapolated. Therefore, further studies with a greater sample must be developed.

Practical Applications

This article contains information about the beneficial effects of a 2-part strength training program on fencers' performance. We have clearly demonstrated that experimented fencers by undertaking a 6-week maximal strength training program can improve maximal and explosive strength and create a basis for more specific strength exercises (1,14). It has proven that these gains can be transferred to MT, which has practical importance because this factor is a significant factor for fencing performance. Other authors have found a similar benefit of strength training programs in other sports, but this is the first involving experimented fencers. Lunge fencing is a complex dynamic movement that depends on the precisely coordinated action of different muscles. On this point, fencing coaches must take into account that strength exercises should be combined with technical training to transfer the gains in strength to the kinematic parameters of the lunge and must take into account that regular fencing training can maintain the gains for several weeks after the 12-week program.

It is recommended that fencing coaches implement physical training, especially strength training, such as an integral component of elite fencers' practice regimen because of its potential to improve the performance.

Acknowledgments

The authors acknowledge the fencers of Dismeva Club (Valladolid, Spain) for their collaboration in this study. The authors have no professional relationships with companies or manufacturers that might benefit from the results of this study. There is no financial support for this project. No funds were received for this study from National Institutes of Health.

References

1. Alvarez, M, Sedano, S, Cuadrado, G, and Redondo, JC. Effects of an 18-week strength training program on low-handicap golfers' performance. *J Strength Cond Res* 26: 1110–1121, 2012.
2. American College of Sports Medicine. American College of Sports Medicine position stand. Progression models in resistance training for healthy adults. *Med Sci Sports Exerc* 41: 687–708, 2009.
3. Behm, DG and Sale, DG. Velocity specificity of resistance training. *Sports Med* 15: 374–388, 1993.
4. Bird, S, Tarpenning, K, and Marino, F. Designing resistance training programmes to enhance muscular fitness–A review of the acute programme variables. *Sports Med* 35: 841–851, 2005.
5. Borysiuk, Z. Complex evaluation of fencers predisposition in three stages of sport development. *Biol Sport* 23: 41–53, 2006.
6. Borysiuk, Z. The significance of sensorimotor response components and EMG signals depending on stimuli type in fencing. *Acta Univ Palacki Olomuc Gymn* 38: 43–51, 2009.
7. Brunet, R, Keller, D, and Moreaux, A. Effect of physical exercise on the simple and choice reaction time in a fencing situation. *Sci Sports* 10: 215–217, 1995.
8. Caldarone, G, Pelliccia, A, and Gambuli, N. *Values anthropometric, dietary habits and blood chemistry parameters in a group of fencers of high competitive level. Studies and research of Sports Medicine Applied to fencing*. Pisa: Giardini Editore, 1983. pp. 51–63.
9. Chan, JSY, Wong, ACN, Liu, Y, Yu, J, and Yan, JH. Fencing expertise and physical fitness enhance action inhibition. *Psychol Sport Exerc* 12: 509–514, 2011.
10. Doan, BK, Newton, RU, Kwon, YH, and Kraemer, WJ. Effects of physical conditioning on intercollegiate golfer performance. *J Strength Cond Res* 20: 62–72, 2006.
11. Duvan, A, Şenel, Ö, and Toros, T. Effects of maximum exercise intensity on visual reaction time of elite fencers. *Nigde Univ J Phys Education Sport Sci* 4: 146–151, 2010.
12. Faulkner, JA. Physiology of swimming. *Res Q* 37: 41–54, 1966.
13. Fleck, S and Kraemer, W. Resistance training–Basic Principles 1. *Phys Sportsmed.* 16: 160–171, 1988.

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.

14. Fletcher, IM and Hartwell, M. Effect of an 8-week combined weights and plyometrics training program on golf drive performance. *J Strength Cond Res* 18: 59–62, 2004.

15. Garcia-Lopez, J, Peleteiro, J, Rodgriguez-Marroyo, JA, Morante, JC, Herrero, JA, and Villa, JG. The validation of a new method that measures contact and flight times during vertical jump. *Int J Sports Med* 26: 294–302, 2005.

16. Gutierrez-Davila, M, Javier Rojas, F, Antonio, R, and Navarro, E. Effect of uncertainty on the reaction response in fencing. *Res Q Exerc Sport* 84: 16–23, 2013.

17. Gutierrez-Davila, M, Javier Rojas, F, Caletti, M, Antonio, R, and Navarro, E. Effect of target change during the simple attack in fencing. *J Sports Sci* 31: 1100–1107, 2013.

18. Häkkinen, K, Pakarinen, A, Alen, M, Kauhanen, H, and Komi, PV. Neuromuscular and Hormonal adaptations in athletes to strength training in 2 years. *J Appl Physiol* 65: 2406–2412, 1988.

19. Hermassi, S, Chelly, MS, Fathloun, M, and Shephard, RJ. The effect of heavy-vs. moderate-load training on the development of strength, power, and throwing ball velocity in male handball players. *J Strength Cond Res* 24: 2408–2418, 2010.

20. Hoffman, JR, Wendell, M, Cooper, J, and Kang, J. Comparison between linear and nonlinear in-season training programs in freshman football players. *J Strength Cond Res* 17: 561–565, 2003.

21. Kawamori, N and Haff, G. The optimal training load for the development of muscular power. *J Strength Cond Res* 18: 675–684, 2004.

22. Maffiuletti, NA, Dugnani, S, Folz, M, Di Pierno, E, and Mauro, F. Effect of combined electrostimulation and plyometric training on vertical jump height. *Med Sci Sports Exerc* 34: 1638–1644, 2002.

23. Manolopoulos, E, Papadopoulos, C, Salonikidis, K, Katartzi, E, and Poluha, S. Strength training effects on physical conditioning and instep kick kinematics in young amateur soccer players during preseason. *Percept Mot Skills* 99: 701–710, 2004.

24. Markovic, G. Does plyometric training improve vertical jump height? A meta-analytical review. *Br J Sports Med* 41: 349–355, 2007.

25. Matiegka, J. The testing of physical efficiency. *Am J Phys Anthropol* 4: 223–230, 1921.

26. Mickevičienė, D, Motiejūnaitė, K, Skurvydas, A, Darbutas, T, and Karanauskienė, D. How do reaction time and movement speed depend on the complexity of the task? *Ugdymas Kûno Kultûra Sportas* 2: 57–62, 2008.

27. Nakagawa, S and Cuthill, IC. Effect size, confidence interval and statistical significance: A practical guide for biologists. *Biol Rev Camb Philos Soc* 82: 591–605, 2007.

28. Norton, K, Olds, T, Olive, S, and Craig, N. *Anthropometrica: A Textbook of Body Measurement for Sports and Health Courses.* Marrickville, New South Wales, Australia: UNSW Press, 1996.

29. Poliszczuk, T, Poliszczuk, D, Dąbrowska-Perzyna, A, and Johne, M. Asymmetry of complex reaction time in female Épée fencers of different sports classes. *Polish J Sport Tourism* 20: 25–29, 2013.

30. Roi, GS and Bianchedi, D. The science of fencing–Implications for performance and injury prevention. *Sports Med* 38: 465–481, 2008.

31. Ronnestad, BR, Kvamme, NH, Sunde, A, and Raastad, T. Short-term effects of strength and plyometric training on Sprint and jump performance in professional soccer players. *J Strength Cond Res* 22: 773–780, 2008.

32. Sedano, S, Vaeyens, R, Philippaerts, RM, Redondo, JC, de Benito, AM, and Cuadrado, G. Effects of lower-limb plyometric training on body composition, explosive strength, and kicking speed in female soccer players. *J Strength Cond Res* 23: 1714–1722, 2009.

33. Sheppard, JM and Young, WB. Agility literature review: Classifications, training and testing. *J Sports Sci* 24: 919–932, 2006.

34. Stull, GA and Kearney, JT. Effects of variable fatigue levels on reaction-time components. *J Mot Behav* 10: 223–231, 1978.

35. Tsolakis, C, Bogdanis, GC, Nikolaou, A, and Zacharogiannis, E. Influence of type of muscle contraction and gender on postactivation potentiation of upper and lower limb explosive performance in elite fencers. *J Sports Sci Med* 10: 577–583, 2011.

36. Tsolakis, C, Douvis, A, Tsigganos, G, Zacharogiannis, E, and Smirniotou, A. Acute effects of stretching on flexibility, power and sport specific performance in fencers. *J Hum Kinetics* 26: 105–114, 2010.

37. Tsolakis, C, Kostaki, E, and Vagenas, G. Anthropometric, flexibility, strength-power, and sport-specific Correlates in elite fencing. *Percept Mot Skills* 110: 1015–1028, 2010.

38. Tsolakis, C and Tsiganos, G. The influence of training on neuromuscular factors in elite and non elite fencers. *Serbian J Sports Sci* 2: 59–65, 2008.

39. Tsolakis, C and Vagenas, G. Anthropometric, physiological and performance characteristics of elite and sub-elite fencers. *J Hum Kinetics* 23: 89–95, 2010.

40. Turner, A, Miller, S, Stewart, P, Cree, J, Ingram, R, Dimitriou, L, Moody, J, and Kilduff, L. Strength and conditioning for fencing. *Strength Cond. J* 35: 1–9, 2013.

41. Williams, LR and Walmsley, A. Response timing and muscular coordination in fencing: A comparison of elite and novice fencers. *J Sci Med Sport* 3: 460–475, 2000.

42. Yiou, E and Do, MC. In fencing, does intensive practice equally improve the speed performance of the touche when it is performed alone and in combination with the Lunge? *Int J Sports Med* 21: 122–126, 2000.

43. Young, WB, James, R, and Montgomery, I. Is muscle power related to running speed with changes of direction? *J Sports Med Phys Fitness* 42: 282–288, 2002.

Copyright © National Strength and Conditioning Association Unauthorized reproduction of this article is prohibited.