J SPORTS MED PHYS FITNESS 2013;53:387-95

Effect of combined electrostimulation and plyometric training on 30 meters dash and triple jump

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***Aim*. The aim of this paper was to analyze the effects of training combining plyometrics (PT) and neuromuscular electrostimulation (ES) on speed training and triple jump. The study consisted on the application of an electrostimulation protocol and plyometric jumps to four groups of young athletes (Control, G II, G III and G IV).**
***Methods*. Eighty-four young athletes took part in the study (40 girls and 44 boys). All of them were sprinters (100 and 200 meters dash, and 100 and 110 hurdles meters), their mean age, weight and height being 15.9±1.4 years old, 58.53±8.05 kg, and 1.68±0.07 m, respectively. After 8 weeks of training, a 30-meter sprint launched test –time being measured by photoelectric cells – and a triple jump test from static position were completed. Repeated measures ANCOVA were used.**
***Results*. The only group that improved significantly in the speed test (P<0.001) relative to the control group was G IV. In the triple jump test, improvements were significant, (P<0.05) and (P<0.01), in G II and G IV, respectively, relative to the control group. The results of ES + PT combined training offered no significant differences in either speed test and triple jump by gender.**
***Conclusion*. The most effective training aimed at improving the speed of 30 m is simultaneous combined training. Regarding triple jump, the results showed significant improvements in the performance of athletes who used both simultaneous combined training and used ES followed by plyometrics. However, no significant improvement was observed after PT training prior to ES.**

KEY WORDS: Transcutaneous electric nerve stimulation - Athletes - Training.

Neuromuscular electrostimulation (ES) consists on applying an electric current on the muscle or peripheral nerve to provoke involuntary contraction.[1]

Although in the beginning it was only used either in injury rehabilitation [2] or as a strength measuring method,[3] in the last decades this technique has been focused on the training of healthy athletes to improve their performance. Particularly after Russian researcher Yadou Kots obtained 40% increases in muscle strength in young athletes. No reproduction has ever obtained such positive results again, perhaps due to linguistic-related problems, yet some authors have come close.[4]

The search for an ideal protocol for this kind of training eventually ended up in the use of a wide variety of electric current parameters.[2] These include the current frequency used in different settings depending on the type of manifestation of muscular strength to be improved; for example, using 120-to-150 Hertz (Hz) intervals to increase the explosive-elastic-reactive manifestation.[5] The choice of pulse width was based on the fact that most authors relate values close to 300 milliseconds (ms),[6-8] as well as applied current intensity, measured by the percentage of maximal isometric voluntary contraction, where intensities from 50% [9] up to 100%,[10] or even maximum athlete-tolerated intensities have been used.[11-14]

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Continuing with the previous range of parameters, three aspects stand out. Firstly, that ES involves different muscle fiber recruitment. That is, while in voluntary contraction type I and afterwards type II fibers contract, the opposite sequence is observed in ES. This leads to greater energy consumption and therefore demands longer recovery time.[15, 16] In spite of the foregoing, recovery times substantially varied among different authors; thus, Benito *et al.*(2010) [17] set 3:15 s of contraction, while Cigdem *et al.* (2002) used a lower proportion, 1:4,[11] and Brocherie *et al.*, (2005), Gondin *et al.* (2005), Maffiuletti *et al.* (2000) and Holcomb (2005) used 1:3.[13, 14, 18, 19] Secondly, increased strength requires 8 to 12 min [7, 13, 20, 21] of training time. Finally, there is broad consensus on the convenient weekly frequency of ES application: mostly three days a week.[7, 13, 18]

Last, there is a parameter that has been researched to a lower extent but could represent a significant difference in strength training effectiveness: the type of exercise to be combined to ES. Although Maffiuletti *et al.* (2000) [18] argue that current application must be combined with voluntary exercise to improve muscular strength, this consideration has been generally ignored and outshone by focus on the configuration of the first parameters previously indicated in this article. Nevertheless, some authors such as Basas (2003) [22] - who structured a protocol for high level jumpers in which a voluntary plyometric exercise was completed while the athlete was applied the electric current - or Herrero *et al.* (2006) [23] - who studied the differences between plyometrics-based training, electrostimulation-based training, and combining both training methods at different times – opened a research line that demands concrete results in the determination of the type of voluntary exercise that proves the most suitable to be coupled to ES and the precise time when both methods should become compatible to obtain the athlete's maximum performance.

On the one hand, review of previous research showed that plyometrics (PT) is defined as "the specific capacity to develop an elevated impulse of force immediately after sudden muscle mechanic stretching",[24] and confirmed that plyometrics is a very useful method for strength-specific preparation, since it favors reactive and explosive strength.[17, 24, 25, 26] On the other hand, the studies on athlete-applied ES are mainly focused on increasing muscular power. Therefore, its effect when applied combined (PT & ES) remains unknown, as well as its specific performance in athletic events such as jumping or speed.

The present study poses a hypothesis: simultaneous development of ES+PT combined training leads to over 30-m improvements in throw and triple jump relative to other ES+PT combinations. The main aim was analyzing the effect of a training program including different ES+PT combinations on 30-m throw and triple-jump tests. We also attempted to determine whether the order of application of ES and PT may influence the results in these tests.

Materials and methods

This quantitative and quasi-experimental study lasted 8 weeks, including two result measurements (pre- and post-training). An ES protocol and PT jumps were applied to 4 groups of young athletes. Different training application orders were applied to these groups.

Participants

A total number of 84 national-level, young athletes (42 girls and 40 boys) took part in this study, but only 78 completed it. Six participants (3 from each group III and group IV) abandoned the program: five due to personal reasons, and another one due to ES-training incompatibility. All of them practiced speed disciplines (100 and 200 m dash, and 100 and 110 m hurdles). These were the features of the group: average age was 15.9±1.4, average weight was 58.53±8.05 kg, and average height was 1.68±0.07 m (Table I). Their average training time in their discipline was 5.64±2.13 years. No athlete had previously experimented electrostimulation training. A voluntary written consent form was signed by all athletes and their parents or guardians.

Instruments

Participants' weight and height were measured with a 100-milligram sensitivity scale and a 1-milimeter SECA sensitivity tape-measure (SECA Ltd, Germany). Two photoelectric cells ELEIKO SPORT RS 232 MAT (Sweden) were used to record the time in the 30 m dash launched test, and a tape measure

TABLE I.—*Means and standard deviation (±) in baseline according to age, antropometryc variables, 30-meter sprint launched, and triple jump. Values split in groups: Control, G II (ES + PT), G III (PT + ES), and G IV (Simultaneous). P-values denote comparison between groups. * P<0.05 and ** P<0.01.*

All	Control (N.=20)	Group II (N.=20)	Group III (N.=19)	Group IV (N.=19)	P value
Age (years)	16.80 ± 1.54	16.95 ± 1.43	16.94 ± 1.47	17.05 ± 1.45	0.962
Weight (kg)	57.25 ± 8.88	58.30 ± 6.22	57.68 ± 8.13	60.94 ± 8.81	0.493
Height (cm)	1.68 ± 0.07	1.66 ± 0.05	1.67 ± 0.06	1.71 ± 0.07	0.208
Speed: 30 m (s)	4.03 ± 0.38	4.02 ±0.40	4.13 ±0.44	3.84 ±0.29	0.132
Triple Jump Length (m)	6.11 ± 0.65	6.55 ±0.68	6.51 ±0.76	6.71 ±0.80	0.064
Boys	**Control (N.=11)**	**Group II (N.=9)**	**Group III (N.=9)**	**Group IV (N.=9)**	**P value**
Age (years)	16.72 ±1.61	16.88 ±1.53	16.88 ±1.53	17.11 ±1.53	0.960
Weight (kg)	61.0 ±10.03	63.6 ±4.12	59.8 ±10.62	68.6 ±5.78	0.125
Height (cm)	1.72 ± 0.077	1.71 ± 0.041	1.68 ±0.07	1.77 ±0.034	0.031*
Speed: 30 m (s)	3.82 ± 0.27	3.78 ± 0.43	3.86 ±0.42	3.65 ±0.212	0.614
Triple Jump Length (m)	6.40 ± 0.65	6.63 ± 0.82	7.05 ±0.65	7.44 ±0.12	0.004**
Girls	**Control (N.=9)**	**Group II (N.=11)**	**Group III (N.=10)**	**Group IV (N.=10)**	**P value**
Age (years)	16.88 ±1.53	17.00 ±1.41	17.00 ±1.49	17.00 ±1.49	0.998
Weight (kg)	52.55 ±4.06	53.90 ±3.59	55.70 ±4.78	54.00 ±3.52	0.411
Height (cm)	1.63 ±0.052	1.62 ±0.031	1.66 ±0.043	1.65 ±0.035	0.324
Speed: 30 m (s)	4.29 ±0.33	4.20 ±0.26	4.37 ±0.322	4.00 ±0.241	0.044*
Triple jump length (m)	5.75 ±0.46	6.48 ±0.56	6.02 ±0.43	6.06 ±0.53	0.023*

was used to measure triple jump length statically. Besides, an electrostimulator MEGASONIC 314 P4 SPORT (MEDICARIM) (France) was used for the ES protocol.

Procedures

The study met the standards of the Declaration of Helsinki (rev. 2008). Young athletes were distributed in a simple random probability sampling. The distribution and training of the four groups were as follows:

— Group 1 (Control): it included 9 girls and 11 boys. These athletes performed the planned plyometric jumps for 8 weeks (2 days/week × 12 min/day), and received a Type TENS analgesic current as a placebo. The athletes were never informed about the current type applied to eliminate potential mistakes derived from this fact. These were current parameters used: 350 ms, and 50 Hz. Both ES and TENS were applied through the same electrotherapy device and the TENS current was applied in a pulsating way to obtain muscular contraction. This way, although the ES current was meant to develop strength, the TENS current was merely analgesic. However, the athletes perceived muscular contraction in both cases, thus avoiding any potential mistakes derived from their awareness of the type of current applied;

— Group 2 (G II): it comprised 11 girls and 9 boys. Firstly, this group received ES training and later, after a 10-minute rest period, it completed the plyometric jumps protocol (ES + PT).

— Group 3 (G III): it consisted of 10 girls and 9 boys. In this case, the young athletes completed the plyometric jumps first and, after 10 min, the ES was applied (PT + ES).

— Group 4 (Simultaneous): it included 10 girls and 9 boys. This group completed combined training, which consisted on doing the same protocol of plyometric jumps as the other groups, together with simultaneous ES application. This group performed a total number of 48 jumps in every single session. These 48 jumps concurred with the 48 cycles of ES current. The young athletes performed the last set of the last plyometric jumps when the ES had already finished (Figure 1).

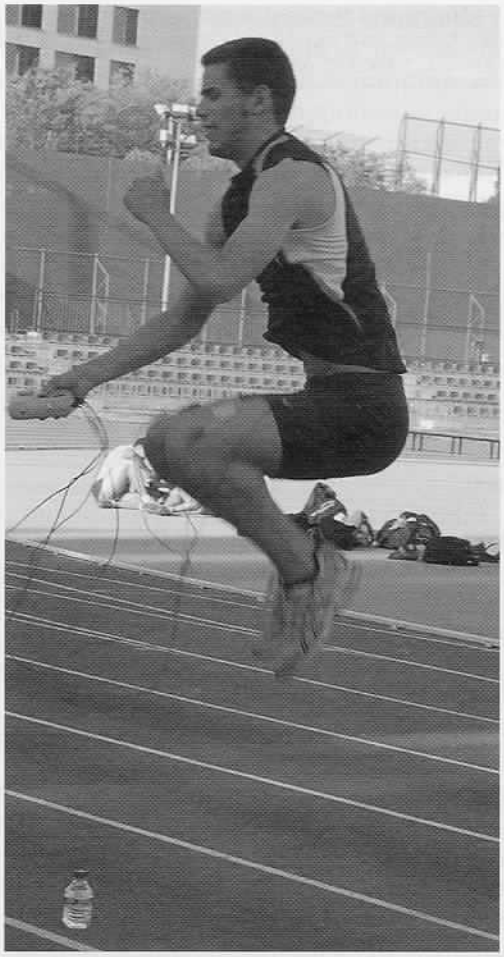

Figure 1.—Simultaneous training with plyometric jumps and electrostimulation.

Electrostimulation protocol

The ES groups took part in a 8-week training program. Three positive (5×5 cm^2) and one negative (10×5 cm^2) self-adhesive electrodes were placed by three well-trained professionals on each thigh in two different channels: channel 1 for vastus lateralis and channel 2 for the vastus medialis and rectus femoris muscles. The active electrodes were placed as close as possible to muscles' motor point [7, 17, 28] and the negative electrode was placed on the femo-

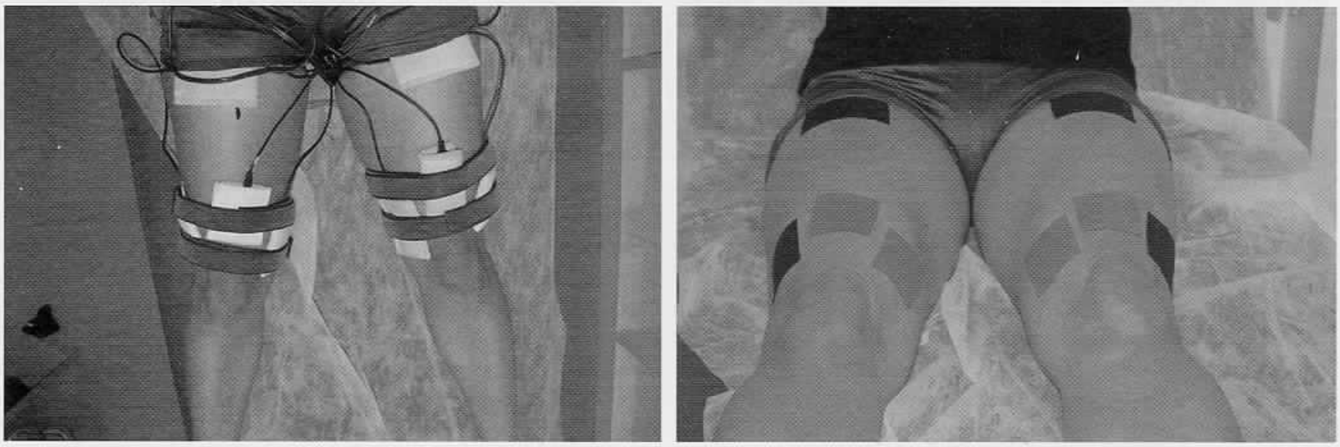

Figure 2.—Electrode location on the athlete's lower limbs during the electrostimulation protocol.

ral triangle.[6, 19] The motor point was located with a stimulation pen electrode (Figure 2). These were the electrostimulation parameters used in G II and G III: 150 Hz frequency, 350 Hz pulse width, 3-12 s contraction-rest time, 2 days/week × 12 min/day dosage. Thirty-six contractions were performed during the training sessions. The exercise combined with ES was based on plyometric exercises and the maximally athlete-tolerated intensity was applied, varying between 60 and 130 mili ampere (mA).

Plyometric protocol

Plyometric training consisted of performing three exercises involving vertical jump with different execution. Two series of 8 repetitions were completed in each exercise. The athletes performed a familiarization period prior to training, where the plyometric jump technique was shown visually and repeatedly explained until correct performance. The first exercise consisted on several knee-to-chest vertical jumps at maximum intensity (Figure 3A). The second began in the squat position (flexed knees and hips keeping knee bent over 100º). Three small jumps preceded the maximum jump in the first exercise (Figure 3B). Finally, the third exercise started in the same position as the second, but the landing jump was done with a leg in an advanced position. In addition, after the first little bounce, the feet recovered parallel position to complete the other two bounces from that position (Figure 3C). In all jumps G IV received electrical impulse during maximum jump performance.

Fig. 3a. Plyometry: Exercise 1. 2 x 8 repetitions. Knees to the chest maximal effort jumps with 3 minutes rest between sets. No small jumps were allowed when landing.

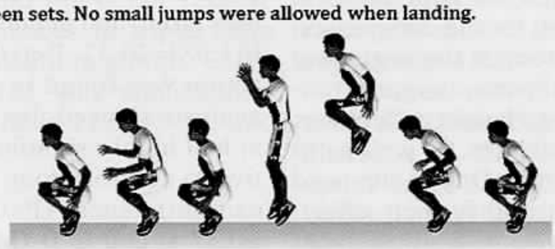

Fig. 3b. Plyometry: Exercise 2. 2 x 8 repetitions, starting in a squat position, with three small jumps preceding a fourth maximal effort jump. There was a 3 minutes rest between sets.

Fig. 3c. Plyometry: Exercise 3. 2 x 8 repetitions. It was performed in the same way as exercise 2, but the athlete landed with one leg ahead of the other, which was alternating in every jump.

Figure 3.—Programmed plyometric exercises.

Triple jump protocol

After the previously planned warm-up – consisting of 10 min of continuous running, 15 min of stretching, 10 technical exercises, and 2 progressive 80 m sprints – the athletes performed triple jump in the sandpit. For this purpose, the jumping line was placed 3 and 4 m far from the sandpit. The jump was as follows: athletes had to begin standing with their feet together and gather momentum with trunk flex-oxtension and arm swinging, then perform two two-feet landings, and fall into the sandpit. A rest period of 120 s separated consecutive jumps.

Thirty meter sprint protocol

Two photocells, placed 10 and 40 m from the start, respectively. Athletes were advised to run as fast as possible from the track line that marked the first cell (10 m) to the second cell. Each athlete performed the distance twice and their personal best mark was recorded. The athletes were given a 3 min recovery time between races.

Statistical analysis

Statistical analysis was completed with SPSS v. 19. A one-way ANOVA was used for the comparison of variables depending on the group at the beginning of the study. Although groups were assigned randomly, (pre) data analysis showed height differences between the groups of young athletes, as well as in 30 m and triple jump performance. Due to the need to adjust these values so as to nullify their effect, analysis of covariance (ANCOVA) with adjustement using Bonferroni confidence interval was completed, where the covariate was the baseline measurement of each athlete's test (pretraining) and height. The time used to run the 30 m as well as triple jump length from a standing position, were used as a dependent variable, and the type of training and gender as an independent variable. The rejection criterion chosen to set both correlations and significant differences was P≤0.05.

Results

We performed a descriptive analysis of all variables across the distribution of absolute frecuencies (N) and summary measures such as mean, standard deviation, and standard mean error. All variables followed normal patterns. Mean 30 m speed and triple jump in the participating athletes was 4.01±0.38 s and 6.46±0.74 m, respectively. (Pre) data analysis showed differences among groups in boys' height (P=0.031) and 30 m performance (P=0.044, only in girls) and triple jump (P=0.004 for boys and P=0.023 for girls). No height or age differences were found between the athletes in each group (P>0.05). Participant's baseline features are provided in Table I.

Time used to run the 30 m distance in each group is shown in Table II. A 4 (group) × 2 (gender) ANCOVA of the 30 m sprint found a main effect between variables group and gender (F[3.68]=12.37, P<0.001; and F[1.68]=20.32, P<0.001, respectively), but no interaction was found in group × gender (F<1). Further analysis showed that group G IV (mean=3.57±0.21 s) had highly significant differences (P<0.001) relative to control group (M=4.05 ±0.42 s), and significant differences (P<0.01) relative to G III (M=3.95 ±0.37 s) and G II (M=3.87±0.36 s). No differences were found in the 30 m launched test's initial and final time between control group and the rest of the groups. Mean time in the 30-meter launched test was

TABLE II.—*Means and standard deviation (±) of the time obtained by each group of athletes in the 30 m sprint launched after 8 weeks of training. Control, G II (ES + PT), G III (PT + ES), and G IV (Simultaneous). Diff.: differences between groups. **P<0.01; *** P<0.001.*

Speed: 30 – meter sprint test (s)	All (N.=78)	Boys (N.=38)	Girls (N.=40)	Diff. (all)			
				Control	G II	G III	G IV
Control	4.05±0.42	3.82±0.31	4.33±0.39	-	0.090	0.168	<0.001***
G II	3.87±0.36	3.67±0.34	4.03±0.31		-	0.996	0.002**
G III	3.95±0.37	3.70±0.28	4.17±0.29			-	0.001**
G IV	3.57±0.21	3.41±0.20	4.16±0.12				-

TABLE III.—*Means and standard deviation (±) of the time obtained by each group of athletes in the length of the standing triple jump after 8 weeks of training. Control, G II (ES + PT), G III (PT + ES), and G IV (Simultaneous). Diff.: differences between groups. * P<0.05; ** P<0.01.*

Length of triple jump (m)	All (N.=78)	Boys (N.=38)	Girls (N.=40)	Diff. (all)			
				Control	G II	G III	G IV
Control	6.21±0.72	6.65±0.54	5.69±0.54	-	0.019*	0.121	0.003**
G II	6.84±0.67	7.17±0.67	6.57±0.57		-	0.999	0.996
G III	6.75±0.80	7.36±0.67	6.21±0.44			-	0.845
G IV	7.06±0.81	7.81±0.16	6.38±0.48				-

significant higher ($P<0.001$) in girls than in boys ($M=4.17\pm0.27$s, and $M=3.65\pm0.28$ s, respectively).

Triple jump length from a stationary position in each group of athletes is shown in Table III. A 4 (group) × 2 (sex) ANCOVA of the triple jump measurement found a main effect between variables group and gender ($F[3.68]=5.06$, $P=0.003$, y $F[1.68]=2.08$, $P<0.001$, respectively), but showed no group × gender interaction ($F<1$). Further analysis showed that G IV (mean=7.06±0.81 m) showed the most significant differences ($P=0.01$) relative to Control ($M=6.21\pm0.72$ m). Besides, G II (mean=6.84±0.67 m) increased ($P<0.05$) jump distance significantly relative to Control, yet this did not occur relative to G III ($P=0.121$). No differences in triple jump were observed between the remaining groups. Girl's average jump distance in girls was significantly lower ($P<0.001$) than boys' ($M=6.21\pm0.50$ m, and $M=7.24\pm0.51$ m, respectively).

Discussion

The present study was aimed at analyzing the effect of a training program including different ES+PT combinations on 30 m launched tests and triple jump. It was also meant to determine whether ES+PT order of application could influence results in these tests. Results suggest that the most effective training aimed at improving 30 m speed is simultaneously combined training. Regarding triple jump, the results showed significant improvement in the performance of athletes who used both simultaneously-combined training and used ES followed by plyometrics. The 30 m sprint launched test was chosen to carry out the research due to its extensive referencing in traditional scientific literature as a strict test for speed assessment.[26] Secondly, the present paper was sought to justify the use of the triple jump test as a control test of exclusive participation of the momentum power in the final effect of speed.[27]

The athletes who simultaneously combined both training types (G IV) obtained 6.78% improvement in the 30 m sprint launched test. This outperforms those in others studies that report 2.4 and 3.3% improvement, respectively.[23, 28] Possible explanations for this increased performance can be: first, the current frequency used in this study exceeds that used by Maffiuletti (150 Hz *vs.* 85 Hz);[29] and, second, current application time was lower than that applied by Herrero *et al.*[23] (3 to 12 s *vs.* 3 to 30 s), which could reserve to muscle depletion caused by increased energy demand ES.[6, 16]

However, not all results are documented in the same direction. Babault *et al.*, Billot *et al.* and Brocherie *et al.* found no significant improvement in sprint times after ES training. One possible explanation is that the first two trained ES in isolation, with the consequent loss of agonist-antagonist coordination achieved when combined with voluntary exercise.[19] In addition, the increase in the number of muscle fibers recruited in each contraction due to the reverse order of recruitment (voluntary contraction and ES) between the two techniques is lost when a voluntary contraction is not made to complement ES.[15, 16, 20] Similar studies showed that both exclusive plyometric training [30-32] and isolated ES training [33-35] does not improve speed, which justifies the need to use ES as a complementary technique to other voluntary training methods to improve speed.

Regarding the results of improvement in triple jump, substantial improvement in jump was observed when ES was used prior to PT, being even higher in the group that combined ES+PT simultaneously, reaching 5.21% increase in jump distance. Similar improvements were achieved with unique training plyometric jumps (5.6%) [36] and to a lesser extent-based training sprint (3.2%).[31] In addition, high correlation between triple jump and jump countermovement (CMJ) and drop jump (DJ) (r=848 and r=805, P_s<0.01) [31] allows comparing the results of this study with others that use ES to improve jumps, some of which obtained similar results to ours and others'. Therefore, Babault *et al.* obtained percentages of improvement of 6.60% and 2.82% for DJ and CMJ, respectively, and Maffiuletti *et al.*[29] and Billot *et al.*[36] made gains of 6.4% and 2.27%, respectively, in CMJ. However, other studies reached no improvement after a training jump with ES,[28] or even negative rates of 5.5% relative to initial marks.[5] This could be due to, on the one hand, the low frequency of current used,[28] or short recovery time between sessions,[5] which prevents the athlete's recovery by requiring ES greater metabolic demand than conventional training.[6, 16, 23]

The results of the speed test and triple jump showed no significant gender differences. Other studies that worked ES similarly found no gender differences,[38-41] but there are opposite research findings, in which the percentage of force thus increasing ES is gender-dependent. So, Alon's [42] results showed that women need more sessions to accommodate the current intensity necessary to achieve optimal training threshold. Maffiuletti [18] found significant gender differences, as girls needed lower current intensity to reach the supramotor threshold. This may be due to the difference in the quadriceps area between boys and girls. On the threshold emotor, Maffiuletti found no significant gender differences.

Speed and triple jump results revealed that simultaneous ES+PT training renders the most significant improvement by ES+PT training, while PT training + ES is unprofitable on the athlete's jump and speed. The high correlation between triple jump and speed tests (r=0.814, P<0.01) [27] justifies the fact that both tests achieve the best results with the same training (simultaneous ES+PT combination), since both tests are based on the development of the same strength expression (explosive-elastic-reactive).[17] Therefore, it would be reasonable to think that both improve with the same type of training. Nevertheless, authors fail to consider the order of ES and PT application as a study variable. Only Basas took this factor into account to increase exercise difficulty in a training protocol for patellar tendinopathy, where the application of both techniques in simultaneous combination involved greater difficulty than those involving one of both techniques or both yet not simultaneously. However, no data were collected on muscle strength improvement.

Conclusions

The results of the present study suggest that ES+PT combination and their order of application is a key factor in athletic speed and triple jump tests. The simultaneous combination of both techniques in training renders the best results in the 30 m speed launched test. Both the simultaneous ES+PT combination and the application of ES prior to PT significantly improve triple jump athletes' performance. However, no significant improvement is obtained in any of both tests — 30 m launched and triple jump — when PT precedes ES in training. Finally, gender does not prove a determining factor in speed results or jumping capacity when ES and PT are trained in young athletes.

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Conflicts of interest.—None.

Acknowledgements.—The authors wish to express their gratitude to Medicarim Centro Company for their logistic support; to Mr Agustín Pérez-Barroso for his help in both technical and practical issues; to Dr Valentín Rocandio-Cilveti for his collaboration in the theoretical framework of this study; and to every athlete who has taken part in the research. In addition, the authors would like to thank Spanish translator and interpreter Andrea Pérez-Arduña for English translation and style correction of the present paper.