Effects of an Electrostimulation Training Program on Strength, Jumping, and Kicking Capacities in Soccer Players

Maxime Billot,[1] Alain Martin,[1] Christos Paizis,[1,2] Carole Cometti,[2] and Nicolas Babault[2]

[1]Laboratory INSERM U887 Motricity-Plasticity, Faculty of Sport Science, University of Burgundy, Dijon, France; and [2]Performance Expertise Center, Faculty of Sport Science, University of Burgundy, Dijon, France

Abstract

Billot, M, Martin, A, Paizis, C, Cometti, C, and Babault, N. Effects of an electrostimulation training program on strength, jumping, and kicking capacities in soccer players. *J Strength Cond Res* 24(5): 1407–1413, 2010—The present study investigated the influence of a 5-week electrostimulation (EMS) training program on muscular strength, kicking velocity, sprint, and vertical jump performance in soccer players. Twenty amateur soccer players participated in the study, 10 in the electrostimulated group and the remaining 10 in a control group. Electrostimulation was applied on the quadriceps muscles over 5 weeks. Subjects were tested before, during (wk-3), and after (wk-5) the EMS training program. Maximal voluntary contraction using different contraction mode (i.e., eccentric, concentric, and isometric), vertical jump height, sprint running for 10 m, and ball speed were examined. We observed an increase in isometric and eccentric maximal knee extension torques and also a gain in ball speed performance without run up at wk-3. After 5 weeks of EMS training, eccentric, isometric, and concentric torques and ball speed had significantly improved. It appeared *appropriate* to conduct EMS training during at least 3 weeks to observe beneficial effects in specific soccer skills such as ball speed.

Key Words ball speed, knee extensors, isokinetic dynamometer, isometric and eccentric strength

Introduction

Soccer necessitates explosive-type efforts such as tackling, jumping, kicking, and sprinting (32). It has previously been demonstrated that 10-m sprint performance was higher in elite than in amateur soccer players (4,9), and it is generally accepted that muscles of the thigh play an important role in running (35), jumping, and ball kicking (2,14,30). Some studies, such as that of Narici et al. (27), demonstrated a positive correlation between quadriceps maximal voluntary contraction (MVC) and maximal ball velocity. Furthermore, Wisloff et al. (35) reported a positive correlation between maximal squat strength, sprinting, and jumping in elite soccer players. A correlation has also been observed between sprinting and jumping abilities and torque at concentric velocities normalized to subjects' body mass (10). Quadriceps muscles seem important for soccer players. Training of these specific muscles could therefore induce positive modifications in soccer performance.

It has been reported that a 12-week (4 days a week) voluntary isometric training program induced a significant increase in squat jump (SJ)–height performance in young adults (20). In the specific case of soccer, previous studies have found that voluntary strength training improved performance in a specific kicking ball task in soccer (8,11). Therefore, voluntary strength training induces benefits in specific soccer abilities. Among the different training methods, the electrostimulation (EMS) method could improve muscle strength production (5,12,13,21). Indeed, enhancement in strength production was evident in many muscular groups after EMS training ranging from 10 to 41% for quadriceps muscles (3,7,15,16,23,25). Some authors have tested the effects of EMS training on sport performance. After 4 weeks of EMS training on quadriceps and triceps surae muscles, Malatesta et al. (23) reported the positive effects on vertical jump performance in volleyball players. Furthermore, Maffiuletti et al. (23) found that SJ performance in basketball players was improved by 14% after 4 weeks of EMS training on quadriceps muscles. Similarly, it was reported that 3 weeks of EMS on latissimus dorsi and quadriceps muscles decreased stroke and sliding sprint time in swimming and ice hockey, respectively (7,31). On the other hand, Babault et al. (3) measured an increment in squat performance after 6 and 12 weeks of quadriceps EMS training, but observed no significant change on specific scrumming tasks in rugby players.

It thus appeared that EMS training may enhance specific sports movements such as stroke and sliding sprint (3,7,23–25,31),

Address correspondence to Maxime Billot, maxime.billot@u-bourgogne.fr.

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whereas improvements in others, such as jump height and sprint time, remain unclear in the literature. To date, no study has investigated the evolution of specific performance in soccer after an EMS training program. Indeed, analysis of the physiological profile of soccer players reveals the importance of anaerobic power in most decisive skills such as jump, sprint, and ball-kicking ability (4). It was also reported that quadriceps femoris muscles are important for specific soccer abilities. Thus, the aim of this study was to test the effects of a 5-week EMS training program on the quadriceps femoris of soccer players. With this intention, strength was measured in different contractile conditions (i.e., isometric, concentric, and eccentric). Moreover, special interest was given to the evaluation of specific soccer tasks such as vertical jump, sprint, and ball speed during kicking. We hypothesized that a 5-week EMS training program on the quadriceps femoris improved muscle strength and sport performance in soccer players.

Methods

Experimental Approach to the Problem

This study was designed to determine the beneficial effects of a 5- weeks EMS training program in soccer players. Strength adaptations were investigated by measuring the isokinetic torque during maximal voluntary eccentric, isometric, and concentric knee extensions. Sport performance adaptations were investigated using ball speed after kicking, vertical jumps, and sprinting. These variables were tested before, 3 weeks (wk-3) and 5 weeks (wk-5) after the beginning of training. Two groups of soccer players were considered. During the 5-week period, the first group (control, C) only followed soccer trainings. The second group (electrostimulated, EMS), in addition to the same soccer training, underwent a 5-week EMS training on the knee extensors. During the 5 weeks, the EMS training program consisted of 3 sessions a week. Statistical analyses allowed us to evaluate the effect of EMS training on physical performances of soccer players. Independent variables were time (before, wk-3, and wk-5) and groups (EMS and C). Values obtained for the different tests were used as dependent variables.

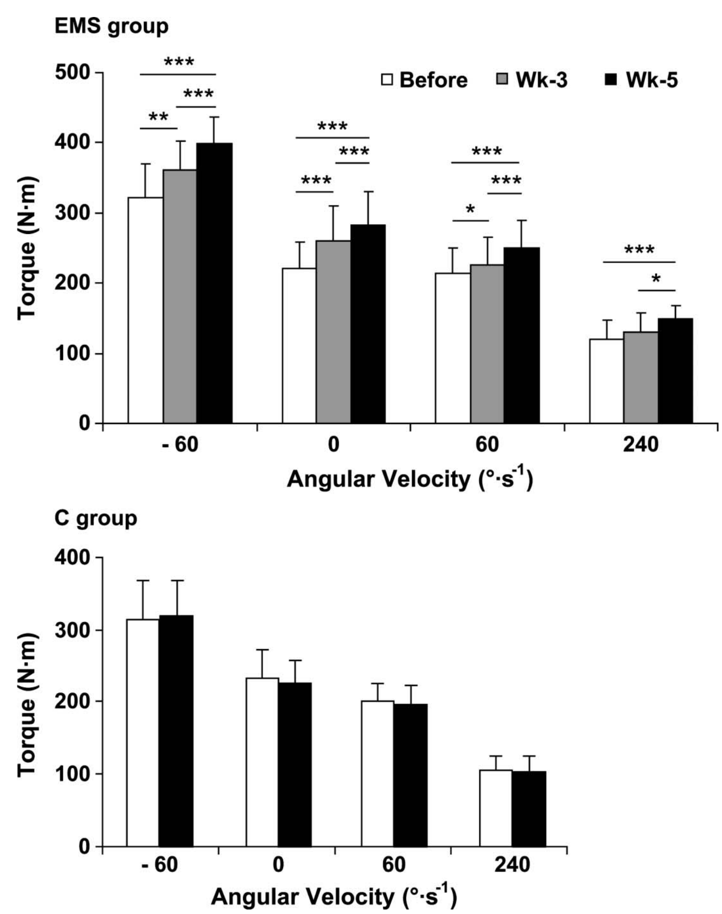

Figure 1. Torque-angular velocity of knee extensors in electrostimulation group and control group. Values measured before and after wk-3 and wk-5 are means ± *SD*. *,**, and ***Significant differences at $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively.

Subjects

Twenty male soccer players from the faculty of sport science competing at least in the regional division of the French Football Federation voluntarily participated in this study. They were randomly assigned to an electrostimulated group (EMS, $n = 10$; age 20.1 ± 2.1 years; height 1.76 ± 0.06 m; mass 69.5 ± 7.4 kg) or control group (C, $n = 10$; age 21.7 ± 3.4 years; height 1.80 ± 0.05 m; mass 70.7 ± 11.0 kg). All players technically trained twice a week (without physical training) and competed once a week for a total of practical soccer averaging 5 hours a week. They were asked to maintain their usual training, food intake, and hydration. The experiment was conducted during March, corresponding to the last part of the championship. None of them had previously engaged in systematic strength or EMS training. Written informed consent was obtained. All experimental procedures conformed to the standards set by the Declaration of Helsinki and were approved by the local Committee on Human Research.

Procedures

The EMS group participated in a 5-week training program that consisted of 12-minute EMS sessions, at a rate of 3 sessions per week. Electrostimulation was performed on both quadriceps femoris muscles. During the stimulation, subjects were seated on a machine used for strength quadriceps strength training (Multi-form, La Roque D'anthéron, France) with the knee fixed at a 60° angle (0° corresponding to the full extension of the leg). A portable battery-powered stimulator (Compex-Energy, Medicompex SA, Ecublens, Switzerland) was used. Three 2-mm-thick self-adhesive electrodes were placed over each thigh. The positive electrodes, measuring 25 cm^2 (5 cm × 5 cm), which had membrane-depolarizing properties, were placed as close as possible to motor points of vastus medialis and vastus lateralis muscles. Negative electrodes, measuring 50 cm^2 (10 cm × 5 cm), were placed near the proximal insertion of rectus femoris muscle. Rectangular wave pulsed currents (100 Hz) lasting 400 μs were used. Electrical stimulation was 3-second long and was followed by a rest period of 17-second (duty cycle 15%). This program was adapted from Compex commercially strength programs. During the training sessions, 36 contractions were performed. Stimulation intensity was determined by the pain tolerance of the subject. The maximally tolerated intensity varied between 60 and 120 mA. The level of force produced by EMS was measured with a myostatic type dynamometer (Allegro, Sallanches, France), and it was verified by the examiner to produce a force higher than 60% of MVC during each training session. For both EMS and C groups, similar soccer training was conducted twice a week.

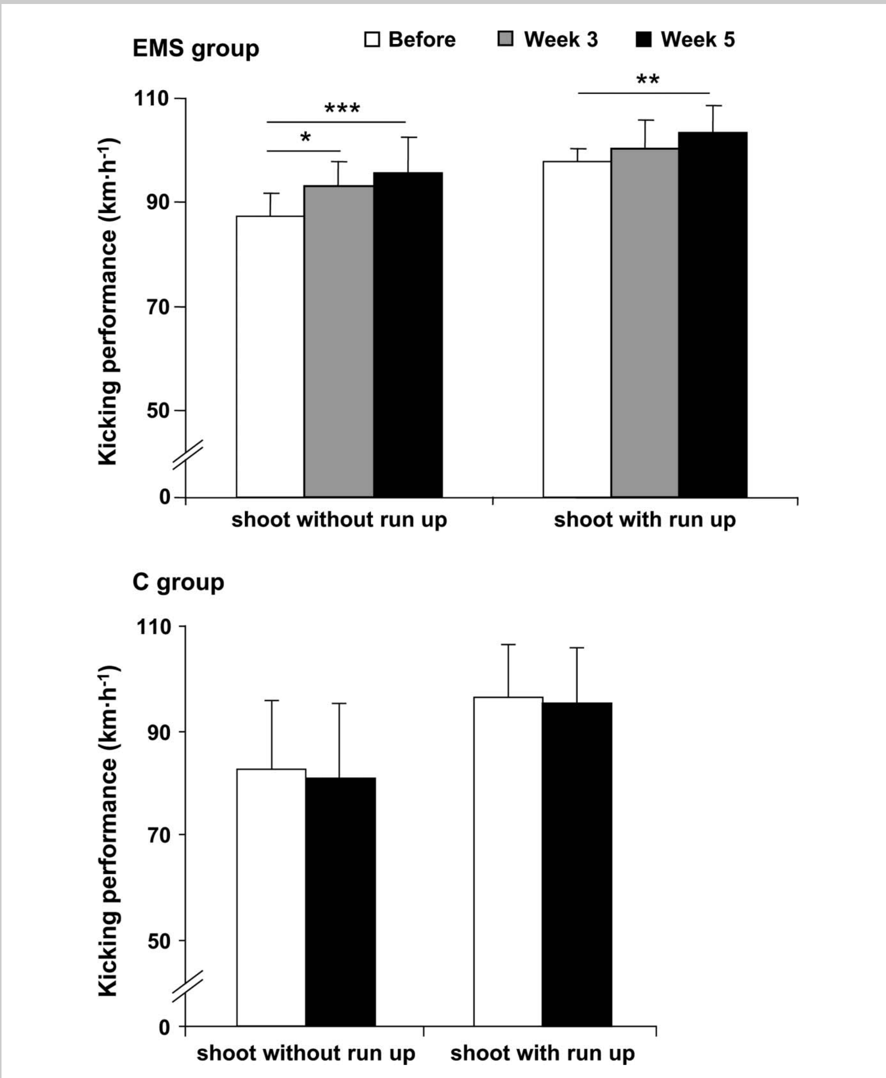

Figure 2. Ball speed during soccer kicking in electrostimulation group and control group. Measured values before and after a wk-3 and a wk-5 period are means ± *SD*. *,**, and ***Significant difference between before, wk-3, and wk-5 at $p < 0.05$, $p < 0.01$, and $p < 0.001$, respectively.

Testing

Strength Tests. Tests were performed before and after a 3-week (wk-3) and 5-week (wk-5) period. We used an isokinetic dynamometer (Biodex Corporation, Shirley, NY, USA) to test the strength of the dominant leg (i.e., kicking leg) of each subject. The reliability of strength measurements of the isokinetic dynamometer was previously validated (34). Before the test, a warm-up was carried out by means of 2 series of 10 concentric actions ($30°\cdot s^{-1}$) with increasing intensities. Subjects were seated with the hip at a 90° angle. To minimize hip and thigh motion during the contractions, straps were applied across the chest and pelvis and at midthigh. Another strap secured the leg to the Biodex lever arm, and the alignment between the center of rotation of the dynamometer shaft and the axis of the knee joint was checked at the beginning of each trial. The arms were positioned across the chest with each hand clasping the opposite shoulder. Strength measurements consisted of 2 series of 4 consecutive maximal knee extensions and flexions from 90° of flexion to full extension (0°). Contractions were performed at 3 *randomized* angular velocities (concentric: +60 and +240°·s^{-1}; and eccentric: −60°·s^{-1}), then 3 MVCs were performed in isometric conditions at 60°. A 3-minute rest period was allowed between series to eliminate the effects of fatigue. The peak torque was directly measured by the Biodex software. For each condition, only the best trial was included in the analysis. Torques were gravity corrected at each joint angle, using the resistive torque of the weight of the limb obtained at the joint angle where the gravity effect was greatest.

Kicking Tests. Kicking performance was determined from maximal ball speed during shots. The speed, was measured with 44 Check Speed Radars (Tibar Industries, Downview, Ontario, Canada). Check Speed Radars operate with 10.25-GHz frequency, and the frame of the signal is approximately 60° vertical by 40° horizontal. Radars were positioned in both upper and lower corners, behind the goal. This goal was materialized on a net by means of an adhesive strip (3 m wide and 2 m high). The soccer ball was placed at a distance of 9 m. For speed values, we retained speed from the radar nearest the ball impact. The ball characteristics were in accordance with Fédération Internationale de Football Association approval (size: 5, weight: 440 g, circumference: 69 cm, and pressure: 1,000 g·cm^{-2}), and the pressure was verified before each testing session. Shots were effectuated using the dominant leg without run-up (one step before kicking) and with run-up (3 steps before kicking). The best of 3 trials was analyzed for each subject.

Vertical Jump Tests. Each subject performed vertical jumps on an Optojump system (Optojump, Microgate, Bolzano, Italy). A digital timer was connected to the system to measure the flight times of the jumps. The SJ was measured starting from a static semisquatting position (knee angle 90°) and without any preliminary movement. The countermovement jump (CMJ) was performed starting from a standing position, then squatting down to a knee angle of 90 ± 5° and then extending the knee in one continuous movement. During these tests, the arms were kept close to the hips to minimize their contribution. The third jump was a CMJ in which the movement of the arms was free (CMJf). The position of the upper body was also controlled so as to minimize trunk flexion and extension. Subjects were asked to jump as high as they could 3 times, and the best performance was reported.

Sprint Test. Subjects performed 3 10-m sprints, separated by 3-minute recovery periods. Speed was measured with infrared photoelectric cells positioned at 1 m from the floor and 10 m from the start line and controlled by TAC (Test Atletici Computerizzati, TEL.SI. s.r.l. Vignola, Italy) software. After a visual signal, the players started from a standing position and ran the 10-m distance as fast as possible. Performances did not include reaction time. The fastest of 3 trials was used for subsequent analysis.

Statistical Analyses

Standard statistical techniques were used to calculate means and *SD*s. A 2-way analysis of variance (group × time) with repeated measures was used to compare MVC, jump height, sprint, and ball speed. When significant effects occurred, Tukey post hoc analyses were used to test significant differences among values. Statistical power values were calculated for various significant differences. The level of significance was set at $p \leq 0.05$ for all procedures. All statistical tests were performed with Statistica software (version 6.1, StatSoft, Tulsa, OK, USA).

Results

Reliability of measurement showed that the statistical power values for various significant differences ranged from 0.64 to 0.99.

Before training, EMS and C groups were similar in physical characteristics, knee extensor strength, ball speed, vertical jump, or sprint performance ($p > 0.05$). No significant time effect was observed for the C group in all tests ($p > 0.05$).

Concerning the EMS group, eccentric torque increased significantly at wk-3 (+11.5 ± 10.4%, $p < 0.01$) and wk-5 (+22.1 ± 16.4%, $p < 0.001$) as compared with before. A further increase was observed from wk-3 to wk-5 (+9.6 ± 8.1%, $p < 0.01$) (Figure 1). A similar significant increase was obtained in isometric conditions from before to wk-3 and wk-5 (+16.3 ± 21.3, $p < 0.01$ and +27.1 ± 22.6%, $p < 0.001$, respectively) and from wk-3 to wk-5 (+9.2 ± 7.4%, $p < 0.05$). We observed no significant increment between before and wk-3 for both concentric conditions. However, we observed a significant increment between before and wk-5 (+14.0 ± 9.9% at 60°·s^{-1} and +23.2 ± 18.9% at 240°·s^{-1}, $p < 0.001$)

Table 1. Vertical jump performance during SJ, CMJ, and CMJf in EMS and C groups, mean values ± *SD*.*

	SJ (cm)	CMJ (cm)	CMJf (cm)
EMS group			
Before	32.0 ± 6.4	35.1 ± 6.5	40.9 ± 6.1
wk-3	31.7 ± 5.9	33.7 ± 6.3	39.7 ± 6.1
wk-5	33.1 ± 6.2	35.9 ± 5.9†	41.6 ± 5.1
C group			
Before	29.7 ± 4.4	34.4 ± 4.7	40.5 ± 5.8
wk-5	29.3 ± 4.1	33.9 ± 4.8	40.8 ± 5.8

*SJ = squat jump; CMJ= countermovement jump; CMJf = countermovement jump free; C = control; EMS = electrostimulation.

†Significant difference between wk-3 and wk-5 ($p < 0.05$).

TABLE 2. Sprint time and velocity at 10 m in EMS and C groups before, after wk-3, and after wk-5.*

	10-m Sprint time (s)	Velocity at 10 m ($m \cdot s^{-1}$)
EMS group		
Before	1.91 ± 0.06	6.83 ± 0.37
wk-3	1.91 ± 0.07	6.95 ± 0.56
wk-5	1.90 ± 0.05	6.83 ± 0.29
C group		
Before	1.91 ± 0.06	7.24 ± 0.70
wk-5	1.93 ± 0.07	7.37 ± 0.61

*EMS = electrostimulation; C = control.
Values are means ± *SD*.

and from wk-3 to wk-5 (+10.0 ± 9.6% at $60° \cdot s^{-1}$ and +14.2 ± 16.5% at $240° \cdot s^{-1}$, $p < 0.01$). Our measurements showed that ball speed without run-up improved significantly at wk-3 (+6.6 ± 8.7%, $p < 0.05$) and wk-5 (+9.6 ± 10.6%, $p < 0.001$) compared with measurements taken before the program. Ball speed with run-up improved significantly at wk-5 (+5.6 ± 4.0%, $p < 0.05$) (Figure 2).

For jump performance, we observed a significant increase from wk-3 and wk-5 in CMJ condition for the EMS group (+6.7 ± 6.3%, $p < 0.05$) (Table 1). However, no significant difference was observed in SJ, CMJ, and CMJf conditions at wk-3 or wk-5 compared with before. Moreover, no significant time effect was observed *either* in sprint time *or* velocity after the wk-3 and wk-5 period in either group (Table 2).

Discussion

The main finding of this study was that in addition to the well-known strength increase, EMS training could lead to benefits in more specific attributes such as kicking speed, with and without run-up. However, strength gains were not directly transferable to jumping ability or sprint performance in our soccer players.

The results of the present study showed smaller strength increases than those previously observed in elite ice hockey players in eccentric conditions (12 vs. 24% in soccer players and ice hockey players, respectively) after 3 weeks of EMS training (7). However, these authors also found a significant increase in the C group and explained gains in eccentric conditions by noting the fact that subjects were more accustomed to performing isokinetic contractions at pretests. Furthermore, it was suggested that fast-twitch fibers might be preferentially recruited during eccentric submaximal contractions (22,33) and that total recruitment may take place during eccentric maximal contractions (19). In addition, Jubeau et al. (19) reported that EMS contractions may result in neither motor unit recruitment according to Henneman's size principle nor in a reversal in this voluntary recruitment order. Thus, a random recruitment of motor units during EMS training may activate easily fast fibers in comparison with voluntary contraction during submaximal level of force. In our study, we suggested that eccentric adaptations may be because of the result of motor unit recruitment. In fact, Nardone et Schieppati (26) reported a greater fast MUs recruitment during eccentric contraction.

The enhancements we observed in isometric conditions corroborated the existing literature. For example, Gondin et al. (16) observed an increment of 15% in the isometric MVC of quadriceps muscles after 4 weeks of EMS training. Early progress in strength production after wk-3 in isometric but not in concentric conditions may be explained by the fact that the angular position during EMS sessions was the same as the isometric test position (i.e., 60°) (16). We also observed that 2 additional weeks of EMS training induced significant enhancements in MVCs in eccentric, isometric, and concentric conditions. We would suggest that benefits observed after 3 and 5 weeks of EMS training were mainly because of neural adaptation. Indeed, it has been previously reported that adaptations observed after 4 weeks of EMS training on quadriceps muscles were mainly because of neural adaptations, whereas changes in muscle mass and architecture became significant between the fourth and the eighth weeks (16). However, our measurements could not confirm these previous adaptive mechanisms.

Research dealing with EMS training and kicking has until now not been undertaken. This study reported an increase in kicking performance without run-up after 3 weeks of EMS training on the quadriceps muscle. Increments were higher and significant after 5 weeks of EMS training in both conditions (with and without run-up). We can thus suggest that strength improvements are transferable to a specific movement such as kicking in soccer players. This finding confirms that quadriceps muscles play an important role during kicking movements (2,28–30). Other studies have found that EMS training could improve specific movements in sports. Indeed, a beneficial effect in swimming sprint and skating performance has previously been reported after 3 weeks of EMS training on latissimus dorsi and quadriceps muscles, respectively (7,31). Conversely, Babault et al. (3) found no improvement in a scrumming task after 6 weeks of EMS training in elite rugby players. These authors explained that the lack of gains in the scrum test may be partly attributed to technical and motivational factors. Technical considerations cannot, therefore, be excluded from criteria of specific performance. Our results, therefore, suggest that EMS training appears to be a viable approach for developing specific attributes used in soccer.

We observed no significant increase in vertical jump performance after 3 or 5 weeks of our EMS training program. These results were in contradiction with Maffiuletti et al. (23) who observed an increment of 14% in SJ after 4 weeks of

EMS training on quadriceps femoris. These different results could be explained by the fact that fewer contractions were performed in our study for each training session. However, some previous studies were in accordance with our results and reported no significant increase in vertical jump performance. In fact, Malatesta et al. (25) and Herrero et al. (17) reported no significant increase in SJ and CMJ after 4 weeks of EMS training on knee extensors. In addition, a decrease in jumping ability after 3 weeks of EMS training in ice hockey players has been reported (7). The lack of increment or even decline in vertical jump performance might be explained by fatigue or overtraining induced by short EMS training programs. Some studies have reported that a recovery period after EMS or resistance training is necessary to allow an enhancement in jumping performance (1,23–25). Furthermore, it has been previously demonstrated that SJ and CMJ involve not only knee extensor muscles but also plantar flexors (6,18). In this way, Malatesta et al. (25) found a significant increase in mean height during consecutive CMJs after 4 weeks of EMS training of the quadriceps femoris and triceps surae muscles. An increment in jump performance may therefore necessitate training of more than just the quadriceps femoris muscles. It has also been previously reported that EMS training coupled with specific training such as plyometric training induced gains in jump ability (17). Indeed, plyometric training solicits quadriceps muscles in the same way as jumping. Thus, an increase in strength production of quadriceps muscles by EMS and the specificity of plyometric training could induce an enhancement in jumping ability.

Electrostimulation training induced adaptations on explosive type movements such as sprint performance. In this study, sprint time and velocity at 10 m did not change significantly after 3 and 5 weeks of EMS training. These findings are contradictory to those of a previous study. Indeed, Herrero et al. (17) reported a significant improvement in 20-m sprint performance after 4 weeks of EMS training on quadriceps muscles. The lack of gain in sprint performance in our study could be explained by the complexity of the running task in which many muscles are involved and by the technical level of the amateur soccer players tested here. The transfer of strength gains after EMS training appeared more difficult for nonspecific sport performance (i.e., vertical jump and sprint) than specific sport performance (i.e., kicking) in soccer players.

Practical Applications

In summary, soccer necessitates not only technical and strategic training, but also physical conditioning. Three weeks of EMS training programs seems appropriate to improve knee extensors muscle strength in eccentric and isometric conditions in soccer players. However, 2 additional weeks appears necessary to observe increments in all contractile conditions. Moreover, EMS training leads to an improvement in specific soccer tasks such as ball speed performance after kicking. Exclusive EMS training of the quadriceps femoris muscles may be of limited value for improving jumping performance in amateur soccer players. However, some of the following might provide a significant training effect for jumping including (a) the concurrent training of the triceps surae, gluteus maximus, and hamstrings, (b) the inclusion of an optimal recovery period, and (c) the coupling of EMS training with plyometric training. Additionally to traditional soccer training, an EMS training program of 3- or 5-week period appears *to represent a viable means for improving* force and specific soccer tasks at preseason and during the season. In fact, this original method might be used to complement traditional training for soccer. It would infuse variability into the training program, which might enhance the motivation of some players. Furthermore, EMS might also be used for injured athletes to attenuate or eliminate detraining effects.

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