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# The Effect of Potentialization after Electro-Stimulation Activation on Vertical Heel Performance

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## Abstract

**Introduction:** Post Activation Potentiation (PAP) is the effect caused by a conditioning exercise with maximum or submaximal loads that promotes increased explosive strength in the subsequent activity. This phenomenon is due to the phosphorylation of light chain regulatory myosin manifesting in fast-twitch type II fibers. Electro-stimulation is a method that uses electric currents to promote involuntary muscle contraction, and its higher incidence in type II fibers because they have thicker and more superficial nerve endings.

**Objective:** To compare the effects of an electro-stimulation protocol with a plyometric protocol to induce PAP on vertical jump performance.

**Methods:** Plyometric Protocol (PP) - 2 sets of 10 ankle hops, 3 sets of 5 hundle hops, and 5 cold jumps. Electro-stimulation Protocol (EP) - Protocol 32 Neurodyn device 4 channels, Russian current, 90% of pain threshold with 3 "rise, 12" on, 3 "decay and 18" off with 70Hz frequency burst during 5 'and control condition (CC). 5 'after each protocol the Jump Power Test (JPT) was performed and 3' after the jump resistance test (RS).

**Results:** Only the PP produced a significant effect when compared to the other protocols ($p \leq 0.05$) PP+EP (290,49 ± 14,28 e 280,36 ± 10,26) (p=0.016) and PP+CC (290,49 ± 14,28 e 280,18 ± 12,07) (p=0.006). Regarding the% fatigue, the PP protocol had indices higher than the EP protocol (p=0.054) and CC (p=0.050).

**Conclusion:** It was concluded that the electro-stimulation did not produce PAP effect nor in greater magnitude than the Plyometric protocol, but had the highest jump resistance compared to the control condition and plyometrics.

**Keywords:** Potentiation after activation; Electro-stimulation; Vertical jump; Plyometrics

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## Introduction

Post Activation Potentiation (PAP) is the effect generated by a conditioning exercise performed before the main activity that promotes an acute increase in explosive force [1,2]. Studies have shown that conditioning exercises of isometric, dynamic, and plyometric characteristics with maximum or almost maximum loads induce this state of PAP improving performance in the subsequent activity [3-5]. However, studies warn about the side effect on performance, as seen, that the process can generate early muscle fatigue [6,7].

One of the most applied conditioning exercises to induce PAP is plyometric training, where it consists of a concentric action immediately after an eccentric contraction, where there is an accumulation of elastic energy in the eccentric phase, being released in the concentric phase [8]. Another method of inducing PAP is electro-stimulation because it is a method that initially causes a contraction of fibers type II (rapid contraction), specific to induce PAP [9,10].

Electro-stimulation consists of a method that uses electric currents that stimulate the muscle externally and afferently through electrodes positioned on the belly of the target musculature, promoting involuntary contraction, which in turn occurs inversely to voluntary contraction, starting from type II fibers (rapid contraction), strength and power characteristics, for fiber type I (slow shrinkage), resistance characteristics, because they have axons of thicker caliber and more superficial the electrical impulse tends to reach the fiber type II first, besides producing considerable recruitment of motor units, causing no or almost no impact on the joints [10,11].

When observing the PAP method, it was identified the need to dose its prescription so that adverse effects do not occur throughout the competition, among these effects are the loss of efficiency of the yield, due to the decrease in energy bioavailability and/or changes in the potential of actions generated for specific muscle contraction [2,12]. Electro-stimulation can be a solution for self-performance because it does not bring this tension overload because of mechanical overload, nor metabolic, because of its exogenous and afferent stimulus. Therefore, this study aimed to investigate the effects of electro-stimulation compared to the plyometric protocol, on the PAP and the fatigue rate, during the performance in the vertical jump.

# Method

## Experimental design

The present study had a Quasi-Experimental character, in Crossover format. All the evaluators were selected by invitation, thus characterizing a sample for convenience. The study is following the provisions of the Declaration of Helsinki, met the Brazilian requirements recommended by resolution 466/2012, and approved by the Ethics and Research Committee of the Euro American University Center.

## Participants

The sample was composed of eleven young male university students, aged between 18 and 30 years old, physically active, who were ready to participate in the study duly confirmed by the signature of a Free and Informed Consent Term. They were included in the study physically active young men, without any joint problems and who had not undergone surgery on their lower limbs in the last 6 months. Before the tests were carried out, volunteers were submitted to the vertical impulse test and checked according to the staging Table if they were able to perform the protocols [13].

The procedure was held at the multi-sports court and at the Academia Escola do Centro Universitário Euro-Americano (Unieuro) in Brasília.

## Procedures

In the present study, we evaluated the muscular PAP induced by electro-stimulation compared to the PAP induced by plyometric protocol (independent variable) on the vertical jump and fatigue rate (dependent variables). Three experimental protocols were adopted: 1) Electro-stimulation Protocol; 2) Plyometric Protocol; 3) Control Session. The collections were performed with a minimum interval of 48 hours between each protocol.

On the first day, before the first experimental protocol was performed, data were collected to characterize the sample (i.e., age, body mass, height, BMI calculation, and heart rate). After the data was collected, the evaluated person was familiarized with the electro-stimulation device by measuring the pain threshold for quadriceps (QT) and gastrocnemius (GT) for the prescription of the electro-stimulation protocol by the EVA protocol (Visual Analog Scale) which consists of a horizontal line with facial expressions and enumerated from 0 to 10, where from 0 to 2 characterizes absence or almost no pain, from 3 to 7 characterizes moderate pain and from 8 to 10 characterizes a high degree of pain [14].

The warm-up was carried out in all the sessions on an ergometric bicycle at 60-70% of the maximum heart rate of the one evaluated with the aid of a heart rate meter (H-10, Polar, Finland) lasting 5 minutes. The Sargent Test [15] was performed 5 minutes after each protocol [4,15] and the jump resistance 5 minutes after the 45-second capacity test. For the jump's analysis, a cell phone camera was used to perform the filming and the Kinovea 0.8.15 software was used to measure the highest jump and its efficiency loss.

## Electro-stimulation protocol

For the intervention with electro-stimulation the 32 protocol adapted from the Neurodyn II 4-channel device was used, being 2 poles positive and 2 poles negative, the 5x5 electrodes were inserted in the rectus femoris, vast lateral quadriceps and the gastrocnemius muscle, 1 pole positive and 1 pole negative in the muscular belly of the rectus femoris, 1 pole positive and 1 pole negative in the lateral vast, 1 pole positive and 1 pole negative in the muscular belly of the gastrocnemius of both legs [11]. The device has a biphasic current, the Russian current was used with a frequency burst of 70Hz, the ramp rise time of 3 seconds, support time of 12 seconds, ramp downtime of 3 seconds, OFF time of 18 seconds, the intensity at 90% of the pain threshold of the evaluated, work cycle of 50% and the duration of the session of 5 minutes [16].

## Plyometric protocol

For the Plyometric protocol, it was composed of 3 exercises, ankle hops, hurdle hops, and drop jumps. 2 series of 10 repetitions of ankle hops keeping the shortest time of contact with the ground, 3 series of 5 hurdle hops, being these barriers placed 70cm away from each other with the shortest time of contact with the ground and 5 drop jumps of 50cm on top of a box with 15 seconds of interval keeping the shortest possible contact with the ground to complete a total of 40 jumps. This protocol was adapted from a study by reference [4].

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## Sargent test

To perform the explosive jump force (EJF) test, the evaluator positioned laterally the graduated surface, with the soles of the feet fully supported on the ground, and with an arm completely extended above the head, where the highest point reached with the middle finger was marked. From the orthostatic position, the execution consisted of flexing the legs and executing the impulse against the movement, with the help of the arms, and touching the highest possible point on the wall, the evaluator had 3 attempts and was computed the highest among them [15]. An adaptation was made to the Sargent Test to make a new jump resistance test (RS), where after 5 minutes of execution of the explosive force jumps, for 45 seconds the evaluator jumped as many times as possible and as high as possible, the highest height minus the lowest height was calculated and the value was given in percentage.

## Statistical analysis

The data were presented as mean and standard deviation. The statistical analysis was performed with the help of the statistical software package SPSS 19.0. The Shapiro Wilks statistical test was used to check the normal distribution of the analyzed variables. Because the data did not present normal distribution, comparisons between moments were made using the Mann Whitney test, with Wincoxon post hoc. For statistical differences, the significance value P ≤ 0.05.

# Results

The average age of the sample was 26.1 ± 5.5 years, the stature of 177 ± 07 cm, the body mass of 75.46 ± 5.55 kg, and BMI of 23.99 ± 1.93 kg/m². The variables used in the protocols are exposed in **Table 1.**

**Table 1** Characterization of samples when the prerequisite variables for starting protocols.

| Sample Characterization | |
|---|---|
| **Variables** | **Media ± SD** |
| HR Maximum (bpm) | 193 ± 5 |
| HR Rest (bpm) | 67 ± 8 |
| HR Maximum 60% (bpm) | 143 ± 4 |
| HR Maximum 70% (bpm) | 155 ± 3 |
| QT 100% (mA) | 156 ± 55 |
| GT 100% (mA) | 115 ± 48 |
| QT 90% (mA) | 140 ± 50 |
| GT 90% (mA) | 90 ± 18 |

HR=Heart Rate; BPM=Beats per Minute; QT=Quadriceps Threshold; GT=Gastrocnemical Threshold

After data analysis, a significant difference was observed in EJF between the PP moment, which produced a better performance, compared to the other moments (i.e., CC and EP) (PP=290.4 ± 14.2 cm; CC=280.1 ± 12.0 cm; EP=280.3 ± 10.2cm; p=0.01). At IF% a significant difference was demonstrated when comparing the moments (EP=9.57 ± 5.48%; PP=12.36 ± 4.36; CC=9.66 ± 5.46%; p=0.05). The number of jumps had no significant difference for any of the protocols. The performance of jumps in terms of jump magnitude and fatigue index is shown in **Figure 1.**

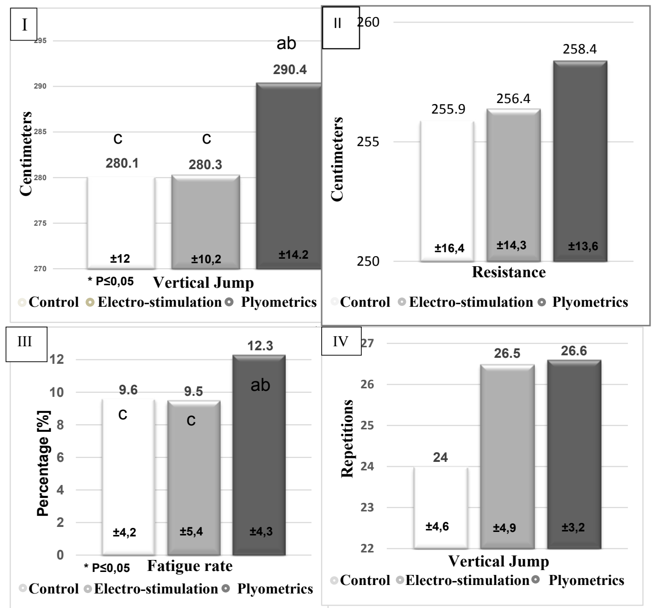


**Figure 1** Comparison of jump performance responses, between control moments, electro-stimulation, and Pliometry, presented by the mean and standard deviation.

Legend I: Comparison of the jump amplitude between the groups; II: Comparison of the lowest jump indexes along 45sec; III: Comparison of the jump fatigue indexes along 45sec; IV: Comparison of the number of jump repetitions along 45sec.

A: Statistical difference concerning control; b: Statistical difference concerning electro-stimulation; c: Statistical difference concerning pliometry.

For statistical differences p ≤ 0.05.

# Discussion

One of the justifications of this study is the low joint impact because it does not have any load implement, not even the bodyweight, which would be of great relevance for high-performance sports, besides a lower energetic expenditure since the stimulus is exogenous and does not have the participation of the central nervous system. However, there are few studies on this subject, allowing new studies that use varied protocols of electro-stimulation, both in the intensity of the stimulus and in the rest time for it.

Data analysis showed that there was a significant increase (p=0.006) in vertical jump height after the plyometric protocol (290.4 ± 14.2 cm) compared to control (280.1 ± 12.07 cm) and electro-stimulation (280.3 ± 10.2 cm) conditions, showing that the plyometric protocol is more effective in evoking the PAP state. Thus, rejecting the hypothesis initially raised. For the resistance test, the electro-stimulation protocol (9.5%) proved to be more efficient and had a smaller drop in the height of the jump concerning the plyometric protocol (12.3%), however, there was no significant difference in the number of jumps performed.

A previous study by Tobin et al. [4], from which the plyometric protocol of the present study was removed, also showed an increase in explosive force in the performance of the vertical jump thus contributing findings in the present research, as well as a study by [17] that showed a significant increase with a protocol that had a specific warm-up of volleyball composed of 25 repetitions of plyometric exercises promoted an increase in the height of the jump against the movement. However, other researchers showed no significant difference in the height of the vertical jump when used pliometry as a conditioning exercise [18,19]. Probably they have not been successful in producing the PAP effect because of the duration of the stimulus, generating a marked degree of fatigue [18] or with an inadequate volume (i.e., very low) making it impossible to generate a potentiation response [19].

One of the advantages of using pliometry to induce PAP is that it produces an effect with a magnitude similar to heavy training and with a shorter time between the conditioning exercise and the main activity (1-5 min for pliometry and 8 to 18 min for complex training) [4].

A study by Maffiuletti et al showed a significant increase in vertical jump performance with electro-stimulation combined with chronic pliometric training after 6 weeks, 3 sessions per week of intervention, however, this protocol evaluated a chronic intervention of 4 weeks and with electro-stimulation in different muscle groups [20].

Some theories explain the way this PAP process occurs, such as phosphorylation of light chain regulatory myosin that alters the conformation of cross bridges, positioning the globular myosin heads closer to the actin filaments, favoring the interaction between them, causing a greater number of connections, allowing a higher muscle torque than it would be without a conditioning exercise [2,12]. The effect of PAP is more expressive in muscles that are predominantly of type II fibers because they suffer greater phosphorylation of the regulatory myosin of the light chain than the fibers of type 1 [9].

The EP did not produce a potentiating effect in the execution of the vertical jump movement, and it can be explained because of the high intensity applied in mA, because it is not selective it probably recruited the maximum of fibers of type II [9] so that it would not be possible if it was executed voluntarily [10] and since the EP is an involuntary contraction it has no competence to generate the approximation of the myosin heads, However, fatigue levels were lower (9.5 ± 5.4%) than PAP (280.3 ± 10.2 cm), thus generating the perspective of applicability for the high sports performance field.

Another interesting finding in this study was the greater resistance presented by EP concerning the other moments (CC and PP). No studies were found that compared the fatigue rate acquired by inducing a muscle PAP after running a muscle endurance test. Perhaps the explanation for the greater resistance is due to the electrical impulse coming from the muscles [11], not occurring the depolarization of axons to send a response at the medullar level or to the central nervous system, thus saving energy that can be used for the development of the subsequent activity.

Studies showed several types of conditioning exercises previously performed in the main activity, such as the 5RM Back Squat exercises, where there was no significant difference in PAP compared to the control condition [7]; the maximum isometric voluntary contraction and the Electro-stimulation, where there was no significant difference [21]; the 80% M Squat Jump exercises. C and Drop Jump, where Squat Jump had a significant increase compared to Drop Jump in the main activity [22]; another study was performed with plyometric, isometric exercises and sprints with a change of direction, and plyometric was the one with the greatest significant difference compared to other protocols [23]. All findings were controlled with the presence of the Crossover group [21-23]. It is important to see in these studies that the more specific the conditioning exercise for the main activity, both biomechanically and the activation of the specific muscles, will lead to a greater positive probability in the results about the potentiation after activation.

## Conclusion

The PAP effect did not manifest itself significantly in the performance of the vertical jump with the electro-stimulation protocol. On the other hand, the pliometric protocol showed a significant difference compared to the electro-stimulation protocol and control condition showing to be more effective to evoke the muscular PAP improving the performance of the explosive force in the vertical jump. It is concluded that the plyometric protocol is the most effective to trigger PAP.

Although no significant gain was observed in the potentiation effect of the motor pattern investigated, the present study identified an important effect in the maintenance of optimal levels of jump resistance, attributed to lower levels of fatigue with the presence of the preactivation condition with the electro-stimulation.

It is suggested that new studies be carried out on the subject, where there is control of the interval variation between the conditioning action and the main activity, where there is variation in the intensity of the current and even the overlapping use of it with a traditional conditioning protocol.

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