

## Squat-based post-activation potentiation improves the vertical jump of elite female volleyball players

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### Abstract:

The purpose of this study was to confirm if a squat-based conditioning activity was effective in generating post-activation potentiation (PAP), and, as a consequence of this activation, improve the vertical jump (VJ) performance of national female volleyball players. Eleven trained volleyball players ( $22.6 \pm 3.5$  years) were randomly divided into two groups: an experimental group (N=6) and a control group (N=5). They completed 2 sessions. In the first session, a back squat one-repetition maximum (IRM) was determined for the experimental group by using an optoelectronic encoder and an incremental protocol until reaching the maximum load lifted for each subject. On the second day, the experimental group performed a PAP procedure consisting of three repetitions of 90% of IRM. Before and after performing the activation protocol, both groups completed a countermovement jump (CMJ) to verify whether any improvements were accomplished in the VJ. The height of the vertical jump was estimated by using a jump mat. The data obtained were analysed using an ANOVA test to determine the significant differences intra-group and between groups. The pre-PAP test did not establish any differences between the results of the control group ( $31.35 \pm 4.28$  cm) and that of the experimental group ( $34.08 \pm 3.98$  cm). Therefore, the groups were, at first, homogeneous. On the other hand, there were significant differences in the CMJ percentage of improvement between the experimental and control groups in the post-PAP test  $F_{(1,9)}=6.074$ ;  $p=0.036$ ;  $\eta^2=0.40$ . The control group presented a loss in jump height in the CMJ, thus obtaining negative values in the improvement percentage (-5.36%). The experimental group improved its jump height (4.11%). These differences between groups were statistically significant  $F_{(1,9)}=6.673$ ;  $p=0.030$ ;  $\eta^2=0.43$ . Finally, no significant differences were found intragroup between the pre and post-PAP test in both groups. To conclude, squat-based PAP protocols can generate positive effects on the vertical jump performance of elite female volleyball players. It may therefore be relevant to introduce these activation methods in the warm-up protocols of volleyball players.

**Key Words:** Back-squat, Countermovement jump, PAP, Sport performance, muscle potentiation

### Introduction

Vertical jump (VJ) can be bear in mind as one of the most determinant performance factors in volleyball. An improvement in VJ height allows obtaining improvements in technical actions such as sets, hits, services, or blocks (Rodríguez-Ruiz et al., 2011), which are decisive to achieve success in a volleyball game (Valadés, Palao, Femia, Padial, & Ureña, 2004).

One of the methods to improve VJ is the Post activation Potentiation (PAP), which refers to the increase of strength due to muscle contractile history (Robbins, 2005). Several authors have observed that PAP generates a rise in muscle power and, as a result, better sports performance (Chiu et al., 2003). This activation is achieved after a voluntary contraction, obtaining the best activation results with contractions near to the maximum (Dobbs, Toluoso, Fedewa, & Esco, 2018). It has been suggested that three mechanisms are responsible for PAP. One is related to myosin regulatory light chains, and the intensification in the phosphorylation of these, which renders actin-myosin more sensitive to submaximal  $Ca^{2+}$  concentrations (Blazevich & Babault, 2019; Sale, 2004; Tillin & Bishop, 2009). This activation occurs with more intensity in fibers with the isoform II, which are involved in high intensity and short duration actions, such as the VJ (Robbins, 2005). The second factor is an intensification in the excitability of high order motor units (Evetovich, Conley, & McCawley, 2015; Robbins, 2005). Both processes seem to be the main factors that explain the gain in muscle strength (Wallace, Shapiro, Wallace, Mark G., & Symons, 2019). Also, the reduction in the pennation angle after a maximal voluntary contraction is suggested as a possible mechanism of PAP (Mahlfeld, Franke, & Awiszus, 2004).

The way a stimulus can generate PAP and its magnitude of the activation will depend on the balance between fatigue and potentiation. Performance will be increased if the effect of the potentiation is larger than fatigue, whereas it will be null if both are similar and will decrease if the effect of the fatigue predominates

(Tillin & Bishop, 2009). This relationship is influenced by other factors, such as individual physiological characteristics of the subject, experience, age, distribution in the type of fibers, maximum strength, strength/power ratio, level of training, etc. (Xenofondos et al., 2010). The resting times between the activation and the action to study (Ah Sue, Adams, & DeBeliso, 2016), how intense the activation is, how much volume, with protocols are used to reach the activation charges (Suchomel, Lamont, & Moir, 2016) or the intensity of the jumps or displacements to be made after the activation are key factors in the magnitude of the PAP achieved too. It has also been suggested that the best increases in vertical jump are obtained with strength exercises such as squat (Choon Yeow Ng, Chen, & Lum, 2019), with protocols of 1 to 3 sets of 1 to 5 repetitions and loads greater than 80% 1RM, obtaining the best results in between 1 to 9 minutes after activation (Picón-Martínez, Chulvi-Medrano, Cortell-Tormo, & Cardozo, 2019). In the review carried out on vertical jump improvement, Suchomel et al. (Suchomel et al., 2016) came to similar conclusions adding as individual factors to those already mentioned the cumulative fatigue of the athlete and perceiving an improve in the jump both in squat jump (SJ) and in Countermovement jump (CMJ) after a sufficiently intense activation.

However, all of these studies have used both trained and untrained subjects as a sample (Dobbs et al., 2018). In this meta-analysis, it was observed that the greatest effects of PAP in trained subjects occur between 3 and 7 min, obtaining better results than studies for less than 3 min. Also, for studies carried out between 3 and 12 minutes or more, always for loads greater than 80% 1RM and in trained subjects, these same authors note that the longer times included in other meta-analysis are suitable for untrained subjects with smaller loads, where the effect of fatigue is greater.

Therefore, although there are studies that include trained subjects, there is still a lack of studies that include professional or semi-professional athletes, given that the behavior of a high-level athlete will be different from that of an amateur athlete or an untrained person after a PAP protocol (Xenofondos et al., 2010).

Moreover, if the problem is focused on the specific case of volleyball, the reviewed studies in which PAP protocols are applied to volleyball players show that the samples in all the studies are made up of university or college players (Ah Sue et al., 2016; Chen, Lo, Wang, Yu, & Peng, 2017; “Effect of Different Post-Activation Potentiation Intensities on Vertical Jump Performance in University Volleyball Players,” 2018; Quiroga Maraboli, Bustamante Garrido, Avendaño Hernández, Cáceres Guerra, & Urrea González, 2016), and just one with professional male players (De Villarreal, González-Badillo, & Izquierdo, 2007). Therefore, to the knowledge of the authors, no elite female players have participated in a PAP study, there is a lack of studies in professional volleyball players and more specific studies evaluating the effects of PAP on top woman players, a fact that, on the other hand, that usually occurs in the field of sports science, where most publications include samples formed only by men’s (Lopez & Alvariñas, 2015), and therefore do not take into account the physiological differences that exist between men’s and woman (Arabatzis, Patikas, Zafeiridis, & Kotzamanidis, 2014), and that can lead to different responses to similar activations.

This study is intended to observe the effects of a squat based PAP protocol in elite female volleyball players. The initial hypothesis is that the application of a squad based PAP protocol must product in the improvement of VJ height min after the application of the activation in female Spanish second division players.

## Material & methods

### Participants

Twelve Superliga 2 female players of Universidad de Alicante volleyball team volunteered to participate in this study. Participants read and gave consent before any action in the study was taken which had previously been approved by the research ethics committee of the University of Alicante (UA-2018-11-17).

Table 1. Characteristics of the experimental subjects (mean ± SD)

Group	N	Age (yrs)	Height (cm)	Body Mass (kg)	IMC (kg/m <sup>2</sup> )	Volleyball Experience (yrs)	Strength Experience (yrs)
<b>Total</b>	11	22.18±3.37	171.81±7.81	6.54±4.50	21.57±1.60	9.81±2.78	3.18±1.99
<b>Exper.</b>	6	21.33±3.01	171.33±7.76	6.40±5.33	21.80±5.30	8.83±2.71	3.17±1.83
<b>Control</b>	5	23.20±3.83	172.40±8.73	6.30±3.80	21.30±2.38	11.00±2.64	3.20±2.38

The inclusion criteria were to have at least 4 years of experience in the practice of volleyball in national competitions and to have previous knowledge in the strength half-squat exercise training. The exclusion criteria were not to participate in all the tests involved in the study, to suffer injury or illness that prevents the performance of the tests. A control group participant suffered an injury during the experimental process, therefore, she was considered as an experimental death.

### Instruments and data collection

For the determination of the force-velocity profile, an optoelectronic encoder (Velowin, Deportec, Murcia, Spain) was used. Vertical jump height was estimated with a jump mat (Chronojump - Boscossystem,

Barcelona, Spain), from which to measure the flight time and thus estimate the jump height (Pueo, Jimenez-Olmedo, Lipińska, Buško, & Penichet-Tomas, 2018)

### Procedure and design

#### Estimation of a maximum repetition in the squat exercise

To determine the load corresponding to the 1RM percentage in the half-squat exercise for the PAP protocol, the relationship between force and velocity was evaluated, since there is a proportionality between the speed of execution and the percentage of 1RM (Sanchez-Medina & González-Badillo, 2010). From the estimated 1RM of previous data, an incremental protocol was carried out (Courel-Ibáñez et al., 2019) with velocity data collection for the loads corresponding to 65%, 75%, 85%, 95%. The value of 1RM was considered as the load that is interpolated in the force-velocity profile with the average acceleration velocity value for the half-squat exercise of 0.31 m/s (Martínez-Cava, Morán-Navarro, Sánchez-Medina, González-Badillo, & Pallarés, 2019). To guarantee the absence of fatigue in the process, the athletes did not perform physical activity in the 48 hours before the test.

#### Vertical jump

To establish the effect of the PAP in the lower train, CMJ heights were measured with the use of jump mats that estimate jump height  $h$  from flight time  $t$  ( $h=1/8*g*t^2$ ). CMJ was held starting from the standing position with the hands in akimbo position and, after an auditory signal, each subject performs a knee flexion before jumping to reach the maximum height. Three attempts were carried out with 60 s between each attempt (De Villarreal et al., 2007). All jumps were considered as valid if they were executed inside the platform, with feet in extension and a simultaneous landing phase. The highest value of the three attempts was considered to be valid (Sanchez-Lopez & Rodriguez-Perez, 2018).

#### Post-activation potentiation protocol

The athletes were randomized and separated into two groups (experimental and control). Considering that the sample was composed of players with a minimum of 4 years of volleyball training experience, they can be considered as trained subjects, so the guidelines set by Dobbs et al. (2018) in their meta-analysis will be observed, as well as the corresponding 3-repetition PAP protocol at 90% intensity of 1RM (Oliveira et al., 2018; Quiroga Maraboli et al., 2016) with a rest time of 8 minutes. Such protocol follows the margins indicated by these authors (Dobbs et al., 2018) and also the rest of the studies consulted (McCann & Flanagan, 2010; Picón-Martínez et al., 2019; Quiroga Maraboli et al., 2016; Suchomel et al., 2016).

Before the PAP, a standardized warm-up was performed for both control and experimental groups, consisting of 4-min soft running followed by 4-min dynamic stretching. Then 2-min speed and changes of rhythm and direction were made inside the playground, 5 consecutive CMJ jumps to finish (Sanchez-Lopez & Rodriguez-Perez, 2018). After the warm-up, an active 2-min rest period was performed and an initial valuation of the jump height before activation was performed (Pre-PAP test).

The control group performed an 8-min rest, with no physical effort greater than walking, whereas the experimental group began the activation. To carry out the activation, a protocol for approaching activation was designed consisting of 12 repetitions with 20 kg, 3 min of rest, and followed by 5 repetitions with 50% of 1RM. After 3 minutes of rest, we proceeded to the PAP consisting of 3 repetitions at 90% of 1RM, afterward 8 exact min CMJ measurements are taken (Post-PAP test) to both groups with an identical methodology to the one followed in the pre-PAP data collection.

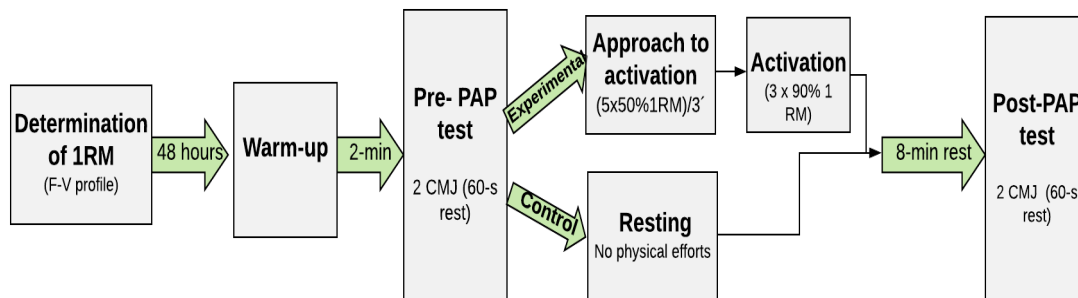


Figure 1. Experimental design of the study. RM: Repetition maximum; CMJ: Countermovement jump; PAP: Post-activation potentiation

#### Statistical analysis

A descriptive statistical analysis (mean  $\pm$  standard deviation) has been made to explore the subject characteristics of and dependent variable. Due to the small sample size, the Kolmogorov-Smirnov normality test

was run, resulted in a normal distribution. ANOVA tests were also performed to find intragroup differences between Pre-PAP and Post-PAP tests in control and experimental groups, and for determining intergroup differences between experimental and control group in CMJ and improvement percentage. The level of significance was set to  $p < 0.05$ . according to Cohen's criteria values of  $\eta^2$  were used to calculate the effect size (Cohen, 1998).

### Results

The results obtained in the jump within the Pre-PAP test did not establish differences between the results obtained from the control group ( $31.35 \pm 4.28$  cm) and the experimental group ( $34.08 \pm 3.98$  cm) with a minimum effect size between the two groups ( $\eta^2 = 0.12$ ) in jump height. Therefore, the sample was evenly distributed with similar means regarding the variable under test.

After performing the intervention of the PAP protocol in the experimental group, jump height values showed significant differences between post-test groups: the experimental group ( $35.40 \pm 3.69$  cm) and the control group ( $29.61 \pm 4.10$  cm) ( $p < 0.05$ ) with a high effect size ( $\eta^2 = 0.40$ ).

Thus, an improvement can be observed in the experimental group that increased their jumping height. On the contrary, the control group showed a slight decrease in the average jumping height of the players who did not perform the PAP protocol between the two jumping evaluations performed (Figure 2).

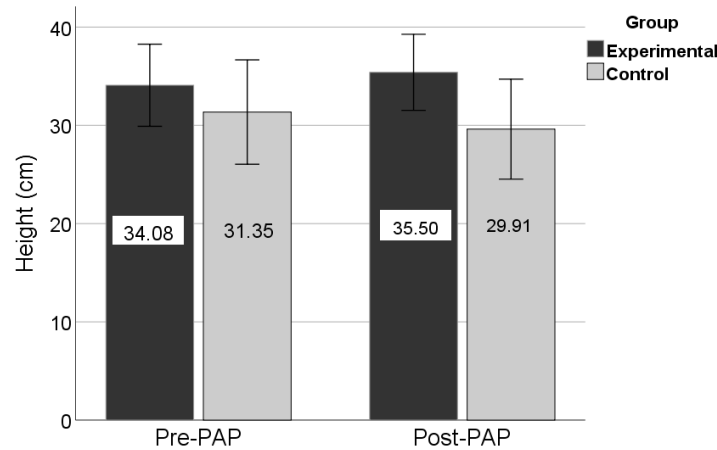


Figure 2. Comparison of CMJ height reached in the pre-PAP and post-PAP tests for the experimental and control groups.

Regarding the performance of each group between pre- and post-test, the control group showed a jump loss of 5.36%, while the experimental group obtained a jump improvement of 3.87% with a high effect size between the two groups ( $\eta^2 = 0.43$ ) (Figure 3).

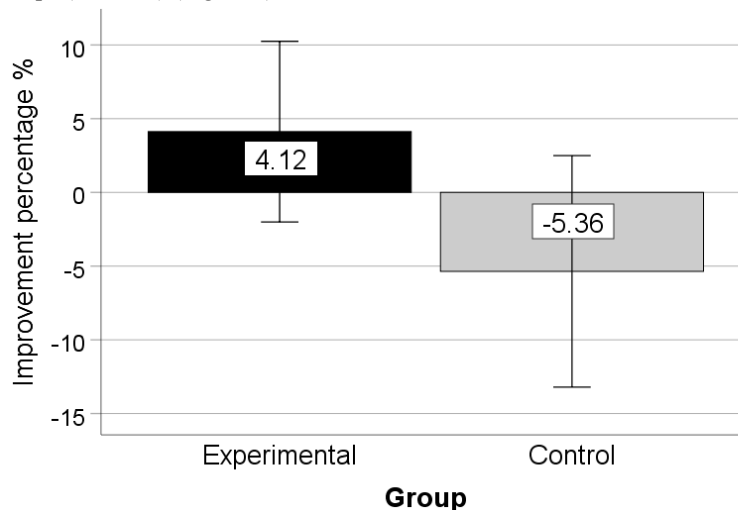


Figure 3. Comparison of the incremental percentage values obtained by the experimental and control groups

Therefore, the results suggest that a 90% 1 RM post-activation protocol in female volleyball players has positive effects on the improvement of jumping height.

## Discussion

To the knowledge of the authors, there are no publications in which that study the effect of a PAP protocol in elite woman volleyball players. This study aimed to verify if a conditioning activity consisting in 3 repetitions of 90% of 1 RM of the back-half squat was effective to generate PAP and thus, to increase the performance of CMJ height in elite female volleyball players.

Most of the studies found in the literature showed that a PAP protocol increased the performance in VJ in volleyball players (Chen et al., 2017; De Villarreal et al., 2007; “Effect of Different Post-Activation Potentiation Intensities on Vertical Jump Performance in University Volleyball Players,” 2018; McCann & Flanagan, 2010; Quiroga Maraboli et al., 2016). In this study, even though it can be observed that the PAP group displayed improvements in the VJ, and the control group gets lower values, such differences between Pre-PAP and Post-PAP tests are not statistically significant ( $p > 0.05$ ).

A first analysis of the data obtained from the volleyball players (Table 1) suggests that they can be classified as responders, according to the criteria of Seitz, Villareal, & Haff (Seitz et al., 2014). However, even though all players are subjects with extensive experience in volleyball training routines and at least one year in strength work, a deeper analysis of strength training shows that most of their routines include loads that oscillate from 40 to 70% of 1RM, a typical explosive strength workout (Gonzalez-Badillo.JJ & Gorostiaga-Ayestaran. E, 2018), and therefore the classification of trained subjects (Dobbs et al., 2018; Freitas et al., 2018) must be questioned.

Therefore, these workouts do not cause activations equal to those of 90% 1RM and consequently, subjects probably do not have the same improvement in VJ height than those familiarized with loads near 100% 1RM (Picón-Martínez et al., 2019; Wilson et al., 2013). As a consequence, it is necessary to individualize at maximum the PAP to adjust the activation loads to the individual characteristics of the subject.

On the other hand, if the incremental percentage values of both groups are compared, there are significant differences among control and experimental groups in the post-PAP tests, and there were no statistical differences between the two groups in the pre-PAP test. Positive incremental percentage values are observed for the experimental group (5.84%) and negative values for the control group (-5.36%). In addition, these statistically significant results are consistent with their effect sizes.

The practical significance for the improvement percentage and the height reached in the CMJ in the Post-test are supported by high effect size values, whereas minimum effect size values were observed for the differences in the height reached in the Pre-test, a sign of randomness of the sample. Therefore, as shown in this study, PAP would generate a positive effect on VJ performance, as a consequence of an increase in muscle strength obtained after an intervention (Boullosa, Abreu, Beltrame, & Behm, 2013; Evetovich et al., 2015; Freitas et al., 2018; Robbins, 2005). According to the incremental percentage values achieved, volleyball coaches can be recommended to include PAP protocols in their warm-up routines to improve the VJ height, and consequently, their players' sports performance (Rodríguez-Ruiz et al., 2011; Sale, 2004).

Although a limitation of this quasi-experimental study is the sample size, due to limited access to elite players, the present results can serve as a basis that can be generalized with larger populations.

## Conclusions

The use of PAP protocols consisting of 3 repetitions of 90% of 1 RM in the half-back squat exercise generates a significant increase in the CMJ heights expressed as a percentage of improvement between the control and experimental groups in the post-test. Therefore, the results of this study suggest that the use of the PAP protocols in elite female volleyball players may lead to a gain in the strength of the knee extensors that becomes an increase in performance in vertical jump, which would mean an enhancement in performance, since VJ is considered a performance factor in volleyball.

Furthermore, these improvements are more interesting in elite players, where the smallest changes represent very important competitive advantages. However, the activation must be fitted to the specific characteristics of each athlete to obtain the best improves. Therefore, even though the literature had already shown that PAP protocols may increase vertical jump, this study shows its applicability to the group of elite female volleyball players and therefore display the possible transfer of PAP to real competition environments.

Therefore, as it can see in the results of this and other studies, the coaches and physical trainers of the volleyball or related team sports should consider the inclusion of these protocols in pre-match volleyball warm-ups, or even between sets, aiming to obtain an acute improvement in vertical jump. However, additional research should be carried out, with a larger sample that allows us to generalize the results achieved in the present study.

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