THE POST ACTIVATION POTENTIATION EFFECT OF TWO DIFFERENT CONDITIONING STIMULI ON DROP JUMP PARAMETERS ON YOUNG FEMALE ARTISTIC GYMNASTS

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Abstract

The purpose of this study was to examine the post activation potentiation (PAP) effect of two different conditioning stimuli (CS) on drop jump (DJ) parameters on young female gymnasts. Thirty young female artistic gymnasts, aged 8 to 13 years old performed two protocols of either double tuck jumps (DTJ: 2 sets of 5 repetitions) or legs blocking action (LBA: 2 sets of 5 repetitions) in a within-subject randomized design. Before and immediately after the PAP treatment and 4, 8, 12, and 16 min after, jumping ability was measured by performing a drop jump (DJ). Statistical analysis revealed significant interaction effect between the two CS for DJ height ($p < 0.002$), time flight ($p < 0.002$) and take-off velocity ($p < 0.003$). Furthermore, significant main effect was found for protocol on DJ height ($p < 0.001$) and time flight ($p < 0.001$). It is recommended to the sports experts to include similar condition stimuli in the warm-up procedure, in order to improve their jumping performance. Conclusive both CS cause PAP phenomenon but the specialized CS produces higher rates of improvements in young female artistic gymnasts.

Key words: *plyometric exercise, artistic gymnasts, drop jump.*

INTRODUCTION

The majority of women gymnastics' routines are characterized by the use of lower limbs as in vaulting, balance beam and floor exercises. When training for these routines the gymnasts perform a great number of rebound jumps (more than 1000 per week) (Marina et al., 2012). Rebound jumps are characterised by the Stretch Shortening Cycle (SSC) and require high muscle strength and power**.** As Malisoux and colleagues stated, SSC exercises such as drop jumps can induce neuromuscular adaptations to the stretch reflex, elastic energy of the muscle and Golgi tendon

organ desensitization (Malisoux et al., 2006) and have been used as an intervention to examine the acute effect on muscle performance (Hilfiker et al., 2007; Masamoto et al., 2003). Furthermore, gymnasts, in order to improve their power production (Marina & Jemni, 2014) include in their warm-up skills that physically prepare them to perform the acrobatic series that will follow, such as forward/backward salto, acrobatic combinations etc.

A new technique used to induce a short-term increase in strength and power during training or competition is post activation potentiation (PAP) (Robbins, 2005). PAP is the phenomenon where previous intense muscle contractions increase subsequent force and power output over the baseline level (Sale, 2002). Special exercises included during warm-up, before training or competition may cause a PAP phenomenon that results in increased performance in the main activity as a result of strength conditioning exercises followed by dynamic exercises with similar motives of movement (Gouvea et al., 2013). Previous findings support that these plyometric exercises enhance muscle strength and power (Hilfiker et al., 2007; Masamoto et al., 2003) concluding that plyometric raise the motor unit efficiency (Esformes et al., 2010; Margaritopoulos et al., 2015; Saez Saez de Villareal, 2009) which in turn results in an increased neural stimulation of the muscle and improved subsequent power production (McBride et al., 2005). There are several proposed mechanisms responsible for the PAP phenomenon which are related a) to the phosphorylation of myosin regulatory light chains (Baudry & Duchateau, 2007; Ryder et al., 2007; Sale, 2002), b) the increase in the recruitment of motor units and the relative changes in muscle stiffness (Suchomel et al., 2016) and c) the changes that result in muscle's pennation angle (Mahlfield et al., 2004).

Previous findings support that several factors such as training status (Rixon et al., 2007), the type of the condition stimulus (CS) [maximum isometric contractions] (Tsolakis et al., 2011) and the type of muscle fibers (Sale, 2002), the exercise characteristics (intensity, specificity, volume) (Killduff et al., 2007; Steele et al., 2013; Tillin & Bishop, 2009) and the duration of rest intervals (Gouvea et al., 2013) may affect the magnitude of the PAP effect. Different types of muscle contraction at maximal or sub-maximal (Chatzopoulos et al., 2007; Killduff et al., 2007) levels have been used as potentiating exercises to improve lower limbs performance in various tasks (Hilficker et al., 2007; Till & Cooke, 2009).

Marina et al. (2012) examined the factors influencing drop jump (DJ) performance between well-trained gymnasts and a control group (aged 9-20 years) using different DJ heights from 20 up to 100 cm and found that the best performances were obtained between 40 cm and 60 cm drop height for both groups. However, the control group revealed a trend towards a continuing decline in DJ performance with the increase of the drop height. Dallas and Kirialanis (2013) who examined the effect of different conditions of Whole Body Vibration (WBV) with or without stretching on squat jump (SJ) and counter movement jump (CMJ) performance of well-trained artistic gymnasts with a mean age of 21.88 years, found no significant differences in jumping performance. However, the percentage improvement of WBV was greater in SJ and CMJ variables compared to WBV combined with static stretching (WBVSS condition immediately after the CS with this effect lasting up to 15 min in SJ performance. Furthermore, Dallas et al... (2014) investigated the acute effect of a single bout of WBV on SJ, CMJ and single leg explosive strength of young gymnasts with a mean age of 9.22 years. Results showed an improvement in SJ performance immediately after the end of the intervention stimulus with this effect lasting for about 15 min following the end of the intervention stimulus. Tsopani et al. (2014) who examined the effect of WBV on balance, flexibility and jumping performance on elite rhythmic gymnasts found an improvement

in SJ, CMJ and single leg jump performance immediately after the end of the stimuli which in turn became greater 15 min later. However, no study has investigated the acute effect of specific CS on PAP. Thus, it is not clear which athletes may benefit from this phenomenon. If PAP depends primarily on muscle strength, then subjects with similar muscle strength but different CS should experience the same effect of PAP on performance.

A limited number of studies (Arampatzi et al., 2014; Hilfiker et al., 2007; Marina et al., 2012) examined the PAP phenomenon on gymnastics with most of them using as CS the DJ or CMJ. Their findings were contradictory. Specifically, the results of Hilfiker et al. (2007) who examined the effect of 5 modified drop jumps on SJ and CMJ performance in athletes of various sports (ski & gymnastics) with a mean age of 22 years, showed a consistent tendency for improvement when adding drop jumps to a warm-up routine compared to a warm-up without drop jumps, and of Marina et al. (2012) who investigated the factors influencing plyometric jumping performance and also showed improvement in DJ height. However, data of Arampatzi et al.. (2014) who examined male and female participants of three different age groups (pre-adolescents: 10-12, adolescents: 14-15, and adults: 20-25 years old), using maximum half-squat isometric contractions, revealed that the conditioning stimulus significantly increased SJ performance in men but has no effect on jumping performance in teen-males, boys and in females irrespective of age. However, none of them used the plyometric exercises that gymnasts incorporate in their training sessions. Taking into consideration the results of the above mentioned studies it remains unknown whether the CS may improve the performance of jumping ability in pre-adolescent female gymnasts. There are no scientific findings comparing plyometric exercises of different forms (typical - specific). So, it is not certain which form of plyometric stimulus (PS) causes the greatest PAP effect. Thus, the purpose of this study was to examine the acute effect of a specific (leg blocking action: LBA) and a typical (double tuck jumps: DTJs) conditioning stimulus immediately after the PAP treatment and following 4, 8, 12, and 16 min, on explosive strength of lower limbs on drop jump (DJ) performance in young female gymnasts. It was hypothesized that specific form of CS would have a greater PAP effect.

METHODS

Thirty moderate trained female artistic gymnasts, aged 8 to 13 years old (Tanner stage 1-2) (Tanner, 1962) (age = 10.10 ± 2.17 years, body weight = 33.99 ± 8.91 Kg, body height = 135.93 ± 11.69 cm, body mass index [BMI] = 18.06 ± 2.23, training experience = 17.53 ± 11.92 months) volunteered to participate in this study. All subjects were familiar with the exercises used (LBA, DTJ, DJ) as they were part of their daily training practice. Institutional Ethics Board, and all procedures were in accordance with the ethics of University of Athens approval was obtained and all subjects' parents gave written informed consent before participating in any of the testing. The subjects were informed extensively about the experiment procedures and the possible risks or benefits of the project, had no musculoskeletal injuries in the previous 6 months.

This study was designed to investigate the effect of PAP on lower limbs explosive strength in young female gymnasts. More specifically, a repeated measure, within subject randomized design, involved 2 different CS: a typical CS (double tuck jumps: DTJs) and a specialized CS (legs blocking action [LBA]) was used to evaluate the effects of PAP on jumping performance. Furthermore, in order to evaluate the fatigue and PAP interactions on lower power output, the performance tests were executed immediately following the interventions and were repeated every 4 min up to 16 min.

All testing sessions took place during a 2-week period. The subjects were examined

in their training hall during three different sessions. During the 1st session the anthropometric characteristics of subjects (age, body mass, body height) were measured and a familiarization session was performed to get acquainted with the proper technique for the execution of LBA and DTJ. On the 2nd and 3rd session, following a five-minute warm-up that included low intensity running with callisthenic exercises the subjects performed DJ baseline performance tests (Pretest) using the Chrono jump mat (Bosco et al., 1983). Two trials were performed and the best score was considered for statistical analysis. Drop Jump height (DJH), Flight Time (FT), and take-off velocity (V) of the DJ were considered as the dependent variables and were used in the subsequent analysis. The rise of the centre of gravity above the ground (h in m) was measured (Bosco et al., 1998) from flight time (tf in seconds) applying ballistic laws: h = tf2 . g . 8-1 (m), where g is the acceleration of gravity (9.81 m . s-2). The subjects performed two DJ from a 33-cm box with hands placed on their hips throughout the test and they were instructed to jump, as soon as possible, trying to minimize the time of contact with the floor. Thirty seconds recovery was given between each DJ. Their knees and ankles had to be fully extended when leaving the box. The reliability for the DJ height was estimated to be 0.96 ($p < .001$).

Following the warm-up and baseline measures, each subject performed a conditioning protocol (PAP) that consisted either of 2 sets of 5 repetitions of the legs blocking action on the feet or 2 sets of 5 double tuck jumps with a 30 seconds interval between sets. The DTJ were performed by explosively jumping upward while quickly pulling the knees to the chest. In the LBA, each subject, from standing position, performed a step forward followed by a leap and a rebound with two feet after landing (stop jump), an action which is similar to that used by gymnasts in order to perform a forward salto on the floor event following the preparatory running phase. In order to evaluate the fatigue and PAP interactions on DJ output the performance tests were executed immediately after the interventions and were repeated every 4 min up to 16 min with a rest period of 30 sec between trials. All testing was conducted at the same time of the day (18.00-20.00) to eliminate a possible time-of-day effect, and a minimum of 72 hours was provided between hall visits. Subjects were familiar with the PAP condition stimuli (LBA & DTJ].

For the measurement of lower-body performance subjects performed a DJ. The Intraclass correlation (ICC) for the peak power output during the DJ tests was 0.97 ($p < 0.001$). The plyometric PAP activities were the DTJ and LBA. Subjects performed 2 set of 5 repetitions of these drills with 30 sec rest between each effort. These plyometric drills which result in high muscle fiber recruitment (Till & Cooke, 2009) are empirically used by gymnasts as part of their warm-up to improve their performance during training.

The IBM Statistical Package for the Social Science (SPSS) (version 21) was used for the statistical analysis. The arithmetic mean, standard deviation, and range were calculated for each variable and trial. Raw data were checked for normality using a Shapiro–Wilk test as the sample size was < 50. To explore the impact of time (pre, post1, post4, post8, post12, and post16) and CS (LBA, DTJ) on the dependent variables, a two-way (group x time) ANOVA with repeated measures on the second factor was used for the statistical analysis. Sphericity was checked using Mauchly's test, and the Greenhouse-Geisser's correction on degrees of freedom was applied when necessary. Levene's test of equality of error variances was used to check the assumption of homogeneity of variances. In cases where interaction between time and group was detected, the simple effects were investigated, and Bonferonni's correction was used. In the absence of interaction, the main effects of the two factors (measurement and protocol) on the dependent variables were

investigated. All statistical significances were tested at $\alpha = 0.05$.

RESULTS

The Drop jump height (DJH) results indicated a significant interaction effect between the two factors ($F_{(5)} = 5.379$, $p < 0.002$, $\eta^2 = 0.518$). Furthermore, significant main effect was found for protocol ($F_{(1)} = 21.476$, $p < 0.001$, $\eta^2 = 0.291$). The post hoc analysis revealed that there was significant difference in the LBA protocol between post 1 (immediately after), post 8 and post 12 compared to baseline values. On the contrary, significant differences were found in the DTJ protocol between post 1 (immediately after), and post 8 compared to baseline values (table 1).

Table 1

Time course comparative analysis between interventions (LBA - DTJ) in drop jump height (DJH), time flight (TF) and take-off velocity (V) performance on gymnasts (n = 30).

		Time					
		PRE	POST 1	POST 4	POST 8	POST 12	POST 16
DJH (cm)	LBA	20.03±5.09	22.39±5.47*	20.89±5.38#	21.34±4.75*#	21.46±5.07*	20.80±5.03#
	DTJ	19.67±4.94	22.28±5.23*	20.69±5.11#	20.70±4.52*#	20.64±4.83#	20.20±4.73#
TF (ms)	LBA	0.40±0.05	0.42±0.05*	0.41±0.06#	0.41±0.04*	0.41±0.05*	0.41±0.05#
	DTJ	0.40±0.05	0.42±0.05*	0.40±0.05#	0.41±0.04*#	0.41±0.05*#	0.40±0.05#
V (m/sec)	LBA	1.97±0.25	2.08±0.25*	2.01±0.25#	2.03±0.22*	2.04±0.24*	2.00±0.24#
	DTJ	1.95±0.25	2.07±0.25*	2.00±0.24#	2.00±0.22*#	1.99±0.23*	1.98±0.23#

Significant differences from baseline, p = 0.05; # Significant differences from post 1, p=0.05; LBA :Leg blocking action, DTJ: Double tuck jumps.

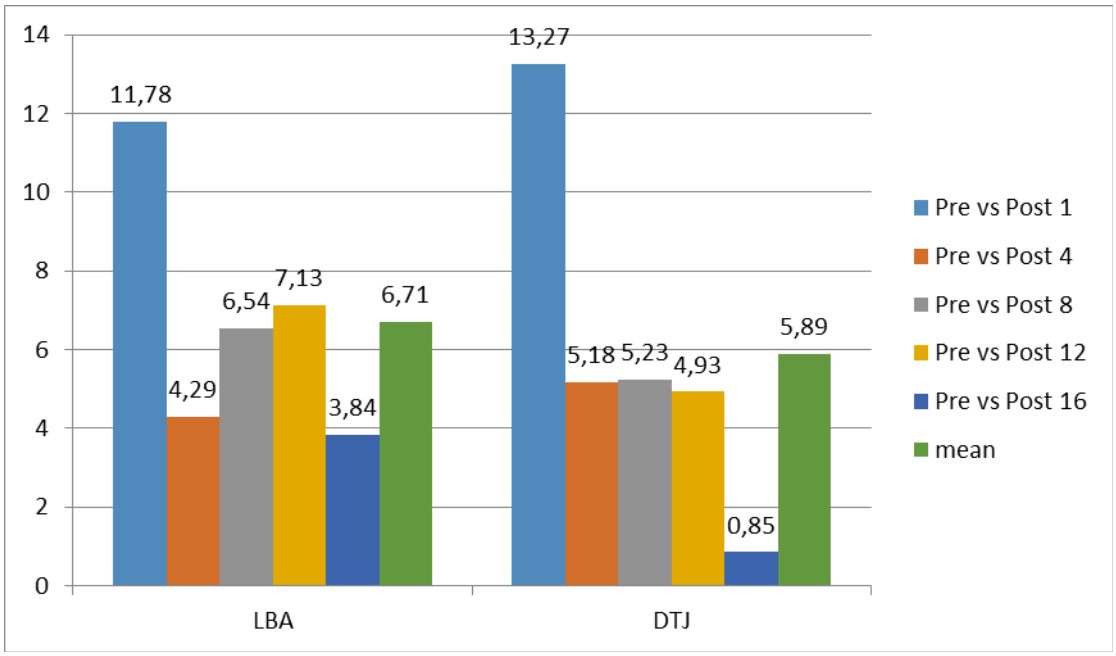

Figure 1. Percentage (%) improvement in post measurements compared to baseline values (pre) in gymnast's drop jump height between two different condition stimuli.

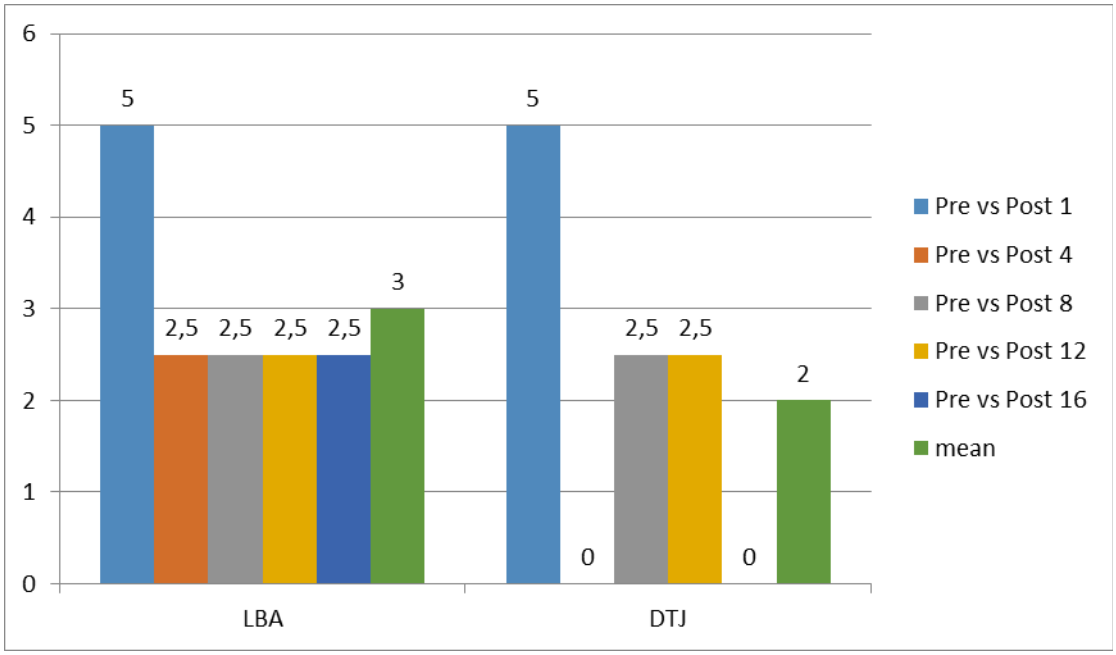

Figure 2. Percentage (%) improvement in post measurements compared to baseline (pre) values in gymnast's time flight between two different condition stimuli.

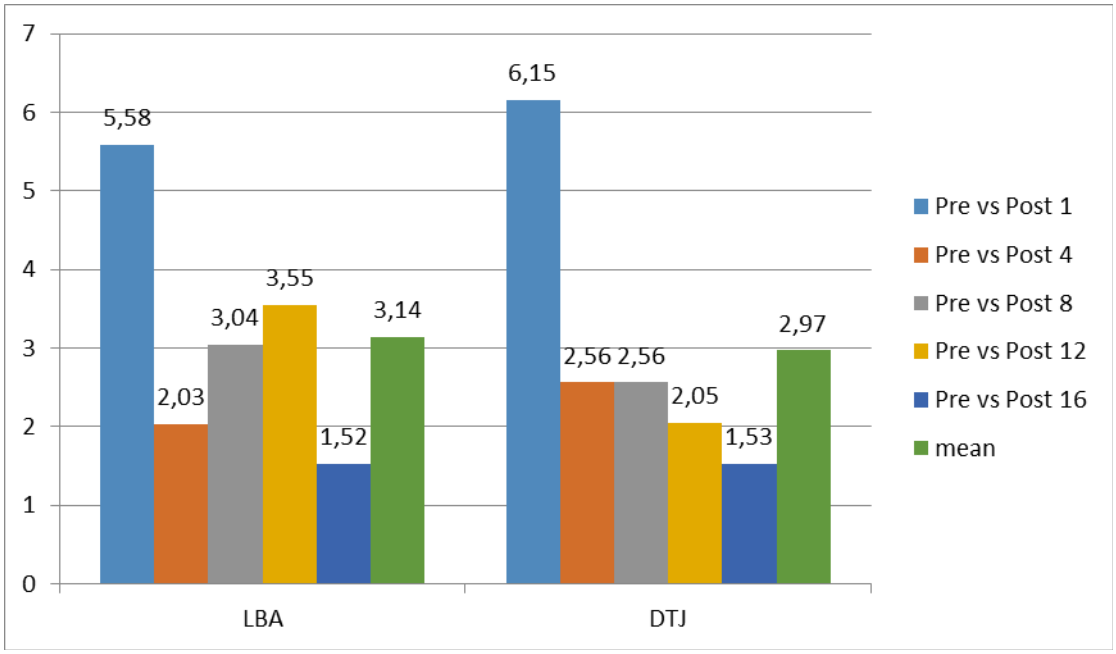

Figure 3. Percentage (%) improvement in post measurements compared to baseline (pre) values in gymnast's take-off velocity between two different condition stimuli

Moreover, the mean percentage improvements compared to baseline values (pre) in gymnast's drop jump height was greater in the LBA protocol compared to the DTJ protocol (figure 1).

Significant interaction effect was found for flight time (TF) ($F(5) = 5.219$, $p < 0.002$, $\eta 2 = 0.511$). Furthermore, significant main effect was found for protocol ($F(1) = 24.903$, $p < 0.001$, $\eta 2 = 0.462$). The post

hoc analysis revealed that there was significant difference in the LBA protocol and DTJ protocol in post 1 (immediately after), post 8 and post 12 compared to baseline values ($p < .05$) (table 1). Moreover, the mean percentage improvements (%) compared to baseline values (pre) in gymnast's drop jump flight time was greater in the LBA protocol compared to the DTJ protocol (figure 2).

There was significant interaction effect between time and protocol for take-off velocity (V) ($F(5) = 4.969$, $p < 0.003$, $\eta 2 = 0.498$). Significant main effect was found for protocol ($F(1) = 18.187$, $p < 0.001$, $\eta 2 = 0.385$). The post hoc analysis revealed that there was significant difference in the LBA and DTJ protocol in post 1 (immediately after), post 8 and post 12 compared to baseline values ($p < .05$) (table 1). Furthermore, the mean percentage improvements compared to baseline values (pre) in gymnast's take-off velocity was greater in the LBA protocol compared to the DTJ protocol (figure 3).

DISCUSSION

This is the first study that examined the effect of a specific (LBA) or a typical (DTJ) CS on drop jump parameters (height, flight time, take-off velocity) at recovery times of 15 sec – 16 min on young female gymnasts. The main finding of the present study was that: (i) both protocols revealed a trend for increased positive effects on DJ parameters; ii) there was a trend for different pattern of CS-time effect on DJ performance between the LBA (specialized) and DTJs (typical) protocol. Our results revealed that short-duration and high intensity dynamic exercise (LBA) elicits a different drop jump height post-activation potentiation (PAP) effect when compared to the typical DTJs (medium-intensity contractions). The volume of the CS applied in our study (2 set per 5 repetitions) may increase the excitability of motor units (Kilduff et al., 2007; Masamoto et al., 2003) and further offer sufficient recruitment of fast-twitch muscle fibers, thereby improving DJ performance in young female gymnasts (Sale, 2004; Till & Cook 2009; Tsolakis et al., 2011).

LBA intervention resulted in greater improvement in DJ parameters in post measurements (15 sec – 16 min) after the end of intervention compared to DTJs intervention. The magnitude of improvement in DJ height by the LBA (3.84 % - 11.78%) and the DTJs (0.85 % - 13.27 %) suggests that explosive-typing loading used in our study facilitates the function of the neuromuscular system without causing undue fatigue resulting to the improvement of the fast-twitch units (Linnamo et al., 1998). Nevertheless, it is underlined that the average increase in post measurements in each parameter considered was the largest specialized stimulus compared to the typical. In our study, the improvement in DJ parameters (height, flight time, take-off velocity) suggests that a series of plyometric exercises, 10 repetitions, appears to be an efficient method of taking advantage of the PAP phenomenon and supports other findings (Arampatzi et al., 2014; Lowery et al., 2012) that examined the effect of plyometric exercises on explosive strength of lower limbs. Furthermore, previous studies found that 5 DTJs (Till & Cooke, 2009) have no significant differences between the conditions in sprint and vertical jump performance or multiple sets of DTJs 3x3 (Turki et al., 2011) or 3x5 (Tsolakis et al., 2011) have no effect on subsequent plyometric performance over 12 - 20 min respectively. In contrast, other findings revealed that 3-10 single repetitions of DJs can improve lower extremity power performance by 2.4% up to 3.5% (Hilfiker et al., 2007; Masamoto et al., 2003). It seems that the level of intensity of the stimulus affects the interaction between fatigue and PAP, thus determining subsequent performance (Suchomel et al., 2016). Post activation potentiation is defined as a phenomenon by which previous muscle activity contributes to enhancing the muscle power and the performance of subsequent activity (Hamada et al., 2000). Following multiple sets of potentiating

exercises, recovery periods of more than 3 min are necessary to elicit a PAP effect and to increase subsequent performance (Wilson et al., 2013).

Immediately following both interventions, the percentage performance improvement of the present study suggests that using high-intensity contractions such as LBA, or medium-intensity contractions such as DTJs during a warm-up, elicit a PAP effect that may positively affect jumping performance (Ebben 1998; Gullich & Schmidtbleicher, 1996). LBA is a specific competitive explosive activity that may load various large muscle groups to a greater degree than DTJs which are considered to be medium-intensity exercises. The percentage improvement found in our study is comparable with data of Tobin and Delahunt (2014) who reported an improvement by 4.8%, 3.9%, and 3.5% at 1, 3 and 5 minutes post-plyometric exercise respectively on CMJ performance on rugby athletes aged 22.4 ± 3.4 years. However, our results oppose previous data of Bassa et al.. (2012) who examined prepubertal trained and untrained boys and girls, aged 9-11 years, and found no performance gain, during SJ, CMJ and DJ from height up to 50 cm, although trained children (irrespective of gender) showed a higher performance compared with the untrained ones. Several factors such as the volume of the preload stimulus, gender, duration of the rest intervals between the consecutive sets and before execution, may be responsible for the equivocal findings among the aforementioned studies. These plyometric stimuli were chosen because they are empirically used by young gymnasts as part of their warm-up and strength programs. In a meta-analysis, Wilson et al.. (2013) have noted that windows of approximately 3-7 min reveal significantly greater potentiating effects compared to intervals longer than 10 min. The results of our study concerning the DTJs protocol revealed a PAP effect immediately after and up to 16 min of rest, a finding that verify data of previous studies that found PAP effect immediately after and up to 12 min (Chen et al., 2013). Ebben and colleagues reported that fast-twitch muscle fibers should be sufficiently recruited during the plyometric stimulus (LBA or DTJs) (Ebben et al., 2008). The intensity of the CS used in our study may increase the excitability of motor units (Kilduff et al., 2007) resulting in improved DJ performance and, in addition, provide adequate recruitment of fast-twitch muscle fibers (Sale, 2004).

CONCLUSIONS

In conclusion, the findings of the present study indicated that different forms of plyometric drills (specialized [LBA] or typical [DTJs]) that are used as part of warm-up exercises provide an advantage in DJ performance in the acute phase (15 sec – 16 min) after the completion of the CS exercises in young female gymnasts. Furthermore, taking into consideration that specialized plyometric exercises may produce a greater PAP effect, it is useful to incorporate them into the warm-up especially prior to competitions in order to retain this PAP effect for as long as possible. Our study has some limitations. We examined thirty moderately trained female gymnasts; therefore, generalizations should be treated with caution. Furthermore, DJ height and take-off velocity (V) were calculated based on the flight time measurement.

The findings of this study have significant implications when considering the application of plyometric exercises to exploit the PAP phenomenon. The results support that the utilization of a specific (LBA) or a typical (DTJ) plyometric exercise causes an immediate improvement on DJ parameters (height, flight time, take-off velocity). Hence, for gymnasts competing in floor exercises or in vaulting, events that incorporate a specialized warm-up motor skill are likely to lead to a potentiating effect on performance with minimal fatigue. Condition stimuli exercises may be performed by pre-adolescent gymnasts, however, the intensity of these

exercises should vary depending on the level of their muscular strength.

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