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Original Article

The post-activation effect with two different conditioning stimuli on drop jump performance in pre-adolescent female gymnasts

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Abstract:
The purpose of this study was to examine the post-activation potentiation effects of two different conditioning stimuli (Rondat and double tuck jumps) on drop jump height, Contact time, and Power; and to determine whether strong gymnasts are able to elicit post activation potentiation earlier than weaker gymnasts during a drop jump test in pre-adolescent female gymnasts. Twenty-nine moderately trained female gymnasts, aged 9 to 13 years old (age = 11.75 ± 1.31 years, body weight = 40.40 ± 10.84 Kg, body height = 147.87 ± 11.22 cm,) volunteered to participate in this study. Each subject performed a drop jump before, immediately after and 3, 6, and 9 minutes after two different conditioning stimuli; the first consisted of 10 repetitions of Rondat exercise and the second consisted of 2 set x 5 repetitions of double tuck jumps. According to the results both conditioning stimuli revealed consistent tendency for greater jump heights during the drop jump condition. The applied conditioning stimuli were not adequate to produce post-activation potentiation effect due to their low volume. The researchers therefore suggested that both conditioning stimuli could be added to a warm-up prior to either training efforts or prior to competitions in order to increase explosive power and jumping ability in preadolescent female gymnasts. However, changes must reach a certain threshold considering the exercises intensity and volume in order to lead to a beneficial outcome even to preadolescent gymnasts.
Key words: artistic gymnastics, **potentiation, jumping ability**

Introduction

Athletes in artistic gymnastics (AG) often use various exercises in their training sessions to improve power production (Marina and Jemni, 2014) or high intensity specific contractions during warm up, in order to maximize performance. Specific warm-up exercises before training or competition may induce PAP phenomenon causing increased power performance in the main activity as a result of strength conditioning exercises followed by dynamic exercises with similar movement patterns a (Gouvea et al., 2013). There are several proposed mechanisms responsible for the PAP phenomenon related a) to the phosphorylation of myosin regulatory light chains (Baudry and 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) (Tsolakis et al., 2011), and the type of muscle fibers (Sale, 2002), exercise characteristics (intensity, specificity, volume) (Killduff et al., 2007; Steele et al., 2013; Tillin & Bishop, 2009), duration of rest intervals (Gouvea et al., 2013) may affect the magnitude of PAP effect.

The effects of plyometric exercises, carried out as a part of the warm-up procedures have been recently studied by other authors who concluded that plyometrics raise the motor unit efficiency (Esformes et al., 2010; Margaritopoulos et al., 2015; Saez Saez de Villareal, 2009) which in turn result in an increased neural stimulation of the muscle and improved subsequent power production (McBride et al., 2005), however their applicability in competitive conditions remain inconclusive (Davies et al., 2015).

The examination of PAP effect on performance in preadolescents gymnasts is very important, since plyometric stimulus have been widely used in sport settings for increasing muscular strength (French et al., 2003) and jumping ability (Smilios et al., 2005). Limited number of studies on gymnastics that referred on PAP phenomenon (Arampatzi et al., 2014; Hilfiker et al., 2007; Marina et al., 2012) and the most of them use as condition stimulus (CS) the drop jump (DJ) or counter movement jump (CMJ). The results of Hilfiker et al. (2007) and Marina et al. (2012) showed improvement in DJ height since data of Arampatzi et al. (2014) revealed no effect on CJ on female moderately preadolescent subjects. Furthermore, findings by Dallas et al. (2018) refer improvement in Squat Jump (SJ) performance of young gymnasts after a single bout of Whole-Body-Vibration (WBV), immediately after the end of the intervention stimulus with this effect lasting for about 15 minutes following the end of the intervention stimulus. In another study, Dallas and Kirialanis (2013) investigated the

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effect of WBV with and without stretching on well artistic gymnasts and found increment in SJ and CMJ performance in both protocols. However, this improvement was greater in WBV protocol without stretching. In addition, Tsopani et al. (2014), who examined the effect of WBV on balance, flexibility, and jumping performance on 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. Neither of them has been using plyometric exercises that gymnasts incorporate in their training sessions. To the authors knowledge there is only one study that examined the PAP effect applying the legs blocking action (LBA) as plyometric stimulus (PS) on young gymnasts founding a trend for increased positive effects on DJ parameters. Taking into consideration the results of the above mentioned studies it remains, unknown whether the CS may improve the performance of jumping ability in preadolescent female gymnasts. Thus, the purpose of this study was to examine the acute effect of a specific (Rondat exercise) and typical (double tuck jumps: DTJ) plyometric contractions on jumping ability on pre-adolescent female artistic gymnasts. A secondary purpose was to determine the optimal time between the CS (PAP effect) and the DJ performance in this gymnast's group.

Material and Methods
Participants

Twenty-nine female moderate-trained gymnasts, aged 9 to 13 years old (age = 11.75 ± 1.31 years, body weight = 40.40 ± 10.84 Kg, body height = 147.87 ± 11.22 cm,) volunteered to participate in this study. Nine subjects excluded in the second condition protocol (DTJ) due to illness. All subjects were familiar with the exercises used (Rondat, DTJ, DJ) as they were part of their training program. Gymnasts trained a minimum of $5h{\cdot}w^{-1}$ with an average of 3 sessions, with training experience 2 to 4 years and they participated in local competition for beginners' gymnasts. Institutional ethics 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, and written consent was obtained before participation. None of the subjects reported subjective evidence of musculoskeletal injuries. The study was approved by the local institutional Review Board, and all procedures were in accordance with the ethics of University of Athens.

Procedures

All testing sessions took place during a 2-week period. The subjects visited laboratory for three different sessions. During the 1st session the anthropometric characteristics of subjects (age, body mass, body height) were measured and a familiarization session to get acquainted with the proper technique for the execution of Squat Jump and DJ, were performed. In addition the subjects' leg explosiveness under concentric conditions was evaluated each subject performing two trials of squat jump test to separate gymnasts in strong and weak group (Argus et al., 2011).

On the 2nd and 3rd session, each subject after a 5-min standardized warm-up on a motorized treadmill (*Technogym Runrace 1200, Gambettola, Italy*) at a self paced speed (approximately 2.22 $m{\cdot}s^{-1}$) performed DJ baseline performance tests (Pre test) 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), Contact Time of DJ (DJCT), and Power DJ (DJP) were calculated as the dependent variables and were used in the subsequent analysis.

The subjects performed two DJ from a 43.2-cm box (*Technique boxes, Power Lift*) (Bobbert et al., 2006), with hands placed on their hips throughout the test. Upon landing they immediately jumped vertically as explosively as possible Thirty seconds recovery was given between each DJ. Due to possible initial upward propulsion the subjects were requested to use their leading leg and to keep their hands on their hip while stepping off the box. Their knees and ankles had to be fully extended when leaving the box. The reliability for the DJ height was estimated to be 0.93 ($p< .001$). The height of rise of the centre of mass in all jump tests was determined by the flight time according to the method of Asmussen and Bonde-Petersen (1974) and used in order to analyze the explosive strength characteristics of the leg muscles as reported elsewhere (Bosco et al., 1998). Jump height, was calculated using $h = g\ tf2/8$, Where tf is the flight time and g is the acceleration due to gravity ($9.81\ m\cdot s^{-2}$).

Following the warm-up and baseline measures, each subject performed a conditioning protocol (PAP) that consisted either of 10 repetitions of the Rondat exercise rebounding at the landing phase with 15 seconds pause between each repetition or 2 sets of 5 double tuck jumps (DTJ) with a 30 seconds interval between sets and 15 sec pause between each repetition. The DTJ performed by explosively jumping upward while quickly pulling the knees to the chest. 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 3 min up to 9 min with a rest period of 30 sec between trials. All subjects were asked to refrain from extraneous exercise proceeding the testing sessions in order to exclude fatigue effect (Gullich and Schmidtbleicher, 1996). All testing was conducted at the same time of the day (17.00-19.00) to eliminate a possible time-of-day effect (Thun et al., 2015), and a minimum of 72 hours was provided between laboratory visits. Subjects were familiar with the PAP conditioning activities (Rondat and DTJ] as they reflect the typical exercises performed in their strength and conditioning program throughout training sessions.

Statistical analysis

All statistical analyses were performed using the SPSS for Windows version 22.0 (SPCC Inc., Chicago, IL). Data were presented as means and standard deviations. A 3-way repeated measures ANOVA (intervention x level x time) was used to examine possible differences in drop jump height, contact time and power output (immediately after (15sec) and at 3, 6 and 9 min). Moreover, 2-way repeated measures ANOVA (type of intervention x time) were used to compare changes in performance after the two PAP interventions and (level x time) in SG and WG, separately. A Bonfferroni post – hoc test was performed whenever appropriate ($p < 0.05$) to locate differences between means. According to Richardson (2011), partial eta squared is classified as small (0.01 to 0.059), moderate (0.06 to 0.137) and large (≥0.138). Test–retest reliability for all the dependent variables measured in this investigation was determined in separate experiments by calculating the intraclass correlation coefficient (ICC) using a 2-way mixed model (Shrout and Fleis, 1979). Statistical significance was accepted at $p < 0.05$.

Results

The 3-way ANOVA, revealed significant DJ height main effects between interventions ($F = 5.689$, $p = 0.018$, $n^2 = 0.031$). Moreover, significant DJ power main effects were observed between levels ($F = 12.737$, $p = 0.000$, $n^2 = 0.066$). Significant interactions were not observed. Post - hoc analysis to locate possible differences were not observed due to the severe Bonferroni correction ($p = 0.0125$)

Table 1 *Time course comparative analysis between interventions (Rondat - TJ) in drop jump height (DJH), contact time (CT) and power performance (PP)*

Time

	Intervention	Pre	Post 1	Post 3	Post 6	Post 9
DJH	DTJ	13.00 ± 3.38	13.90 ± 3.27	13.36 ± 3.24	14.52 ± 3.08	14.98 ± 3.05
	Rondat	11.82 ± 3.00	12.97 ± 2.48	13.42 ± 3.03	12.61 ± 2.76	13.45 ± 2.78
CT	DTJ	0.27 ± 0.05	0.27 ± 0.04	0.28 ± 0.05	0.26 ± 0.03	0.28 ± 0.05
	Rondat	0.27 ± 0.05	0.45 ± 0.81	0.28 ± 0.05	0.28 ± 0.06	0.26 ± 0.04
PP	DTJ	382.79±104.02	378.94±103.14	372.62±101.29	387.70±108.84	385.37±114.89
	Rondat	365.15±94.50	351.34±122.50	358.76±89.69	357.58±95.81	356.10±93.72

Table 2 *Time course comparative analysis between strong (SG) and weak gymnasts (WG) in drop jump height (DJH), contact time (CT) and power performance (PP)*

Time

	Level	Pre	Post 1	Post 3	Post 6	Post 9
DJ	SG	13.53 ± 3.42	13.73 ± 3.09	13.14 ± 2.78	13.53 ± 3.35	14.11 ± 2.69
	WG	11.78 ± 2.98	13.24 ± 2.82	13.56 ± 3.34	13.59 ± 2.89	14.28 ± 3.22
CT	SG	0.26 ± 0.03	0.27 ± 0.03	0.28 ± 0.05	0.27 ± 0.06	0.27 ± 0.05
	WG	0.27 ± 0.05	0.41 ± 0.74	0.28 ± 0.06	0.27 ± 0.05	0.27 ± 0.04
PP	SG	343.07±80.53	336.24±76.89	332.00±82.92	341.38±90.97	337.00±84.92
	WG	394.58±105.43	384.41±121.19	387.00±97.21	393.48±105.99	393.22±111.85

Figure 1 *Drop jump height baseline value (pre), immediately after (post) and following 3, 6 and 9 min of recovery after two different plyometric interventions*

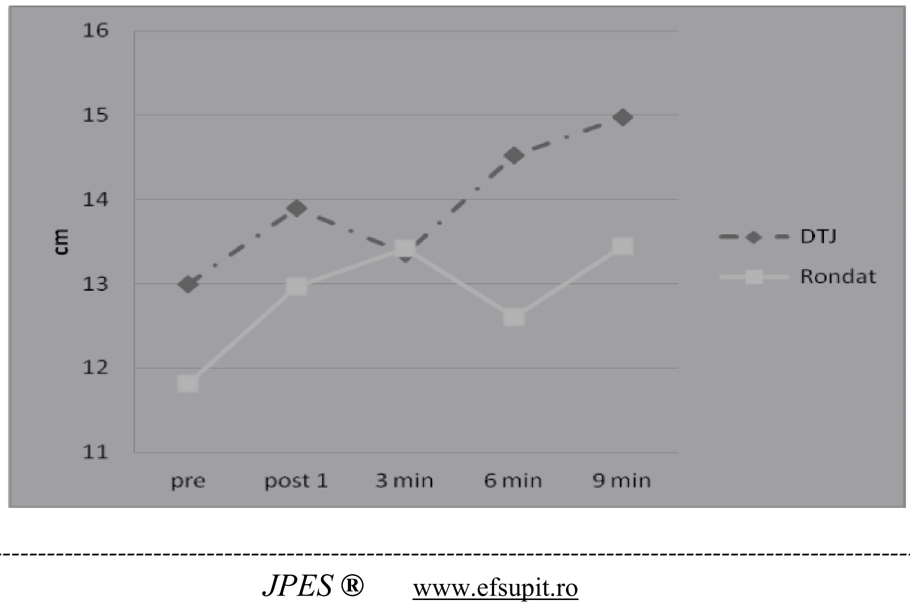
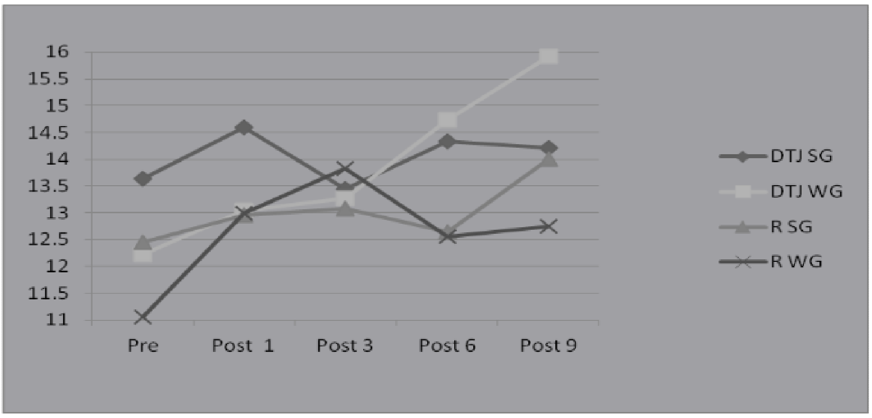


Figure 2 *Drop jump height baseline value (pre), immediately after (post) and following 3, 6 and 9 min of recovery after two different plyometric interventions between strong gymnasts (SG) and weak gymnasts (WG)*



Discussion

The study was designed to investigate different PAP effects in drop jump (DJ) after either Rondat or DTJ at recovery times of 15 sec – 9 min on pre-adolescent moderately trained female gymnasts. The main findings of the study are showing that: (i) there is a trend for increased positive effects on DJ performance irrespective of the high-intensity contractions [Rondat] or the medium-intensity contractions [DTJ]) applied; b) there was also a trend for different pattern of CS-time effect on DJ performance between SG and WG. Practically, our results found that high-intensity contractions of Rondat elicit a similar drop jump height post-activation potentiation (PAP) effect when compared to the typical medium-intensity contractions of DTJs. Rondat intervention resulted in enhanced jumping performance 3 min after intervention, while increased jumping performance related to DTJ were observed after 6 min, reaching the highest values 9 min after intervention. The weak gymnasts while performing DTJ are more favored because the intensity and the volume of CS is low, so it is better to highlight the PAP the weak gymnasts. The outcome isn't the same in strong gymnasts because they didn't overcome the necessary threshold intensity required to cause a difference; it just equalize the decrease that appears at 3 min. The Rondat in the SG tends to cause PAP at 9 min compared to the WG that the difference appears earlier (immediately after and 3 min later). As Suchomel et al. (2016) reported the interaction between fatigue and PAP determines subsequent performance and is affected by different factors such as the intensity and the volume of the preload exercise, the duration of the rest intervals between sets and the recovery time after a stimulus.

Post activation potentiation is defined as a phenomenon by which previous muscle activity contributes to improving 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). The volume of the present study was not equalized. However, 2 set of 5 DTJs or 10 single Rondat failed to produce a PAP effect in DJ performance on pre-adolescent moderately trained female gymnasts. The results concerning the plyometric volume of potentiating exercises still appear to be inconclusive. One set of 3-5 DTJs is not adequate to cause a PAP effect (Till and Cook 2009; Tsolakis et al., 2011). Moreover multiple sets of DTJs 3x3 (Turki et al., 2011) or 3x5 (Tsolakis et al., 2011) have shown no effect on subsequent plyometric performance over 12 - 20 min respectively. On the other hand, other previous studies have indicated 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).

Studies aiming at evaluating the optimal recovery period use different periods between the exercise stimulus and the plyometric performance and indicate potentiating effects after and up to 20 min of rest (Comyns et al., 2006; Jensen and Ebben, 2003; Kilduff et al., 2007; Terzis et al., 2009). Recently 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 regardless the strength level of the subjects revealed a PAP effect immediately after up to 9 min of rest, a finding that verify data of other studies (Chen et al., 2013; Comyns et al., 2006; Jensen and Ebben, 2003; Kilduff et al., 2007; Terzis et al., 2009; Wilson et al., 2013).

Similar % improvement were observed in the present study after both interventions, suggesting that using high-intensity contractions, such as Rondat or medium-intensity contractions such as DTJ performed during a warm-up elicit PAP effect that may positively affect jumping performance (Ebben 1998; Gullich and Schmidtbleicher, 1996). Rondat is a specific competitive explosive activity that may load various large muscle groups to a greater degree than tuck jumps which are considered to be medium-intensity exercises. The magnitude of improvement in DJ height by Rondat (9.72%, -13.70%) and DTJ (6.92%-15.23%) suggest 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). The fact that Rondat has similar effect on PAP compared to DTJ may be attributed to the rest interval between each trial (15 sec) whereas DTJ performed without rest between trials on each set. Concerning the temporal profile the difference in the performance between SG and WG is the result of the intensity of the CS which favors the WG compared to the SG.

Performing a series of plyometric exercises 5 – 10 repetitions appears to be an efficient method of taking advantage of the PAP phenomenon. In our study, the improvement in DJ verify previous results (Arampatzi et al,, 2014; Lowery et al,, 2012) that examined the effect of plyometric exercises on explosive strength of lower limbs. Ebben and colleagues stated the fast-twitch muscle fibers have to be sufficiently recruited during the plyometric stimulus (CMJ) (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 to the improvement of DJ performance, and further offer sufficient recruitment of fast-twitch muscle fibers (Sale, 2004). Furthermore, it is well documented that a higher degree of potentiation may be expressed by stronger individuals (Ruben et al,, 2010; Tillin and Bishop, 2009) due to higher type 2 fiber content which has been linked to a greater expression of PAP (Tillin and Bishop, 2009) and possibly a more rapid recovery after a CA (Jo et al., 2010). In general, although in the first couple of minutes of recovery performance may decrease, then following a recovery period of 3 (Kilduff et al., 2007) to 18.5 minutes (Chiu et al., 2003), PAP may be induced and performance may be increased. The results of our study in contrast with the literature (Kilduff et al., 2007), showed that WG expressed a PAP earlier in comparison to SG. It is possible that the intensity and the volume of the CS are low and this is the reason that SG could not appear a PAP effect.

Conclusions

The findings of the present study demonstrate that incorporating a general (DTJ) or a specific (Rondat) task as a condition stimulus induce a PAP response resulting in an improvement in DJ height in the acute phase (15 sec – 9 min) after the completion of the aforementioned plyometric exercises. However, changes must reach a certain threshold considering the exercises intensity and volume in order to lead to a beneficial outcome even to preadolescent gymnasts. The findings of this study have important implications when considering implementation of plyometric exercises to take advantage of the PAP phenomenon. The results support that the utilization of a general (DTJ) or a specific (Rondat) plyometric exercise produces an acute enhancement of DJ height. Therefore, for gymnasts compete in floor exercises or in vaulting horse event incorporating a plyometric warm-up motor task similar to that of the current study is likely to lead to a potentiating effect on performance with minimal fatigue. Condition stimuli exercises may be applied in preadolescent gymnasts taking into consideration that the intensity of these exercises should fluctuate depending on the level of their muscular strength.

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