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The Effects of Plyometric Conditioning on Post-Activation Bench Press Performance

by
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The present study aimed to determine the effects of plyometric push-ups as a conditioning activity (CA) on high-loaded bench press performance. Two groups of resistance-trained males age (24.5 ± 2.6 years, body mass 84.8 ± 8 kg) performed one of two CA protocols: 3 sets of 5 repetitions of plyometric push-ups with a 1 min rest interval between sets (PAPE; n=12) or equal time aerobic warm-up (CONT; n=12). Four minutes after completion of the CA protocols the participants performed 3 sets of 3 repetitions of the bench press exercise at 70%1RM and 4 min rest interval between sets to assess post-activation differences in peak power output (PP), mean power output (MP), peak bar velocity (PV), and mean bar velocity (MV) between conditions. The two-way ANOVA revealed significant condition × set interaction effect for PP (p<0.01), MP (p<0.05), PV (p<0.01), and MV (p=0.02). The post hoc for condition × set interaction showed that PAPE caused a significant decrease in PP and PV for P-Set2 and P-Set3 when compared to baseline (BA). The MP and MV for the PAPE condition decreased significantly during the P-Set3 compared to BA and to P-Set1. The t-test comparisons for delta values showed significant differences between PAPE and CONT in PP for P-Set1 – BA (p<0.01), in MP for P-Set2 – P-Set1 (p<0.03) and for P-Set3 – P-Set1 (p=0.04). Furthermore, there were significant differences in PV for P-Set3 – BA; P-Set2 – P-Set1; P-Set3 – P-Set1 (p<0.01; p<0.01; p<0.02 respectively). Finally, there were significant differences in MV for P-Set1 – BA; P-Set2 – P-Set1 and P-Set3 – P-Set1 (p<0.01; p<0.01; p<0.02 respectively). This study demonstrated that plyometric push-ups lead to performance enhancement of the bench press exercise at 70%1RM. The increases in performance were observed only in the first set following the CA, while a significant decrease of these variables was registered in P-Set2 and P-Set3.

***Key words**: push-up, PAPE, complex training, sport performance, resistance training.*

Introduction

Post-activation performance enhancement (PAPE) is a unique possibility to achieve short-term improvement of voluntary force and power output production due to a prior muscle stimulation (Cuenca-Fernández et al., 2017). This phenomenon became the subject of research interest and paid attention to strength and conditioning coaches, as an attractive strategy used during training sessions and immediately before competitions to enhance athletic performance. In training practice, PAPE is induced by a resistance exercise conditioning activity (CA) followed by an explosive activity with a similar movement structure (Golas et al., 2016, 2018). The efficiency of PAPE depends above all on an optimal relationship of the CA induced potentiation and the level of fatigue. Factors, such as type of exercise, volume, tempo of movement and load used during the CA, as well as level of strength of the subject can affect the magnitude of PAPE (Tillin and Bishop, 2009; Seitz and Haff, 2016).

Taking into consideration the load used during the CA, studies demonstrated that high- or even supramaximal loads effectively induce potentiation of subsequent ballistic or plyometric sports tasks, such as the bench press throws (Ulrich and Parstorfer, 2017; Krzysztofik et al., 2020), sprints (Crewther et al., 2011; Miller et al.,

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2019) or squat jumps (Golas et al., 2017; Chen et al., 2018). However, the reverse order of conventional PAPE protocols i.e. ballistic or plyometric exercises performed as the CA before explosive, high-load resistance exercises has not been widely studied. The study by Sharma et al. (2018) found that plyometric CA was effective in acute improvements of the countermovement jump and 20m sprint performance in comparison to high-loaded resistance exercise CA. Moreover, Ulrich and Parstorfer (2017) indicated that a single set of 10 plyometric push-ups led to a significant increase of power output during a subsequent bench press throw at 30% of one-repetition maximum (1RM). Further, the results of Ulrich and Parstorfer (2017) showed that a plyometric CA was capable of inducing an increase in potentiation comparable to those achieved through high-loaded resistance exercises (3 repetitions of the bench press at 80%1RM) (Ulrich and Parstorfer, 2017). However, to the best of the author's knowledge only two previous studies (Masamoto et al., 2003; Wilcox et al., 2006) investigated the impact of plyometric CA on post-activation high-loaded exercise performance. Wilcox et al. (2006) found that 2 repetitions of plyometric push-ups, as well as medicine-ball chest passes (3 to 5 kg) increased 1RM in the bench press exercise. Masamoto et al. (2003) on the other hand showed that 2 repetitions of depth jumps significantly increased 1RM in the squat exercise. However, currently there are no studies which have assessed the effects of plyometric CA on power output in high loaded resistance exercises.

Previous studies demonstrated that the ratio of exercise volume and intensity to rest duration is a significant factor for optimal development of PAPE (Seitz and Haff, 2016; Wilk et al., 2020a). Considering, that for optimal development of PAPE the rest interval should ensure a proper balance between fatigue and potentiation, an additional advantage of plyometric CA can include a relatively lower level of fatigue compared to high-loaded resistance exercises (Seitz and Haff, 2016). Thus, plyometric CA may be an attractive solution to induce PAPE due to easy practical application, without the need for specific equipment. Since, previous research has shown that the use of plyometric exercise as a CA induce PAPE in similar explosive tasks, it can be postulated that, such CA may also effectively enhance power output in high-load resistance exercises. Therefore, the purpose of the present study was to determine whether a plyometric CA performed before a high-loaded resistance exercise can enhance explosive performance. We hypothesized that plyometric push-ups significantly increase power output and bar velocity in the post-activation bench press exercise at 70%1RM.

Methods

Participants

Twenty-four healthy males, experienced in resistance training volunteered for the study. Detailed characteristics of the participants are presented in Table 1. The participants were randomly assigned to the experimental group (PAPE; n = 12) or to the control group (CONT; n = 12). The inclusion criteria included a bench press personal record of at least 120% body mass and several years of experience in resistance exercise (Wilk et al., 2019). The participants were instructed to maintain their normal dietary habits over the course of the study and to abstain from the use of any supplements or stimulants for the duration of the experiment. All participants were required to refrain from resistance training 72 hours prior to each experimental session, were familiarized with the exercise protocol, and were informed about the benefits and potential risks of the study, before providing their written informed consent for participation. The study protocol was approved by the Bioethics Committee for Scientific Research, at the Academy of Physical Education in Katowice, Poland (2/2019) and performed according to the ethical standards of the latest version of the Declaration of Helsinki, 2013.

Familiarization session and one repetition maximum test

The week before the main experiment, the participants performed the 1RM bench press test and familiarization training session. They arrived at the laboratory at the same time of day as in the upcoming experimental sessions. Upon arrival, a standardized warm-up protocol was used for each session, including a general warm-up of approximately 5 minutes using a cycling ergometer with upper-body component (Keiser M3i Total Body Trainer, Keiser Corporation, Fresno, CA) at a resistance of 100 W and cadence within 70–80 rpm, followed by a general upper-body warm-up consisting 2 circuits of 10 bodyweight squats, 10 trunk rotations and trunk side-bends on each side, 10 internal and external rotary movements of the shoulders and 10 push-ups. Next, the athletes performed 15, 10, and 5 bench press repetitions using 20, 40, and 60% of their estimated 1RM, respectively. The loading started at 80% estimated 1RM and was increased by 2.5 to 10 kg for each subsequent attempt, and the process was repeated until failure. During the 1RM test, the participants executed single repetitions with constants tempo of movement (2-s duration of eccentric phase, maximal speed in the concentric phase) (Wilk et al., 2020bc) and with 5 min rest interval between successful trials. The 1RM was determined within 5 trials. Hand placement on the barbell was set at 150% individual bi-acromial distance. All repetitions were performed without bouncing the bar off the chest, without intentionally pausing at the transition between the eccentric and concentric phases, and without raising the hips off the bench. After the complete 1RM test, the participants performed the familiarization session. During the familiarization session the participants performed 3 sets of 3 repetitions of the bench press at 70%1RM at the maximal tempo of movement with a 4 min rest interval between sets.

Experimental sessions

The participants arrived at the laboratory at the same time of day and were randomly assigned to PAPE or the CONT group. After a standardized warm-up all study participants performed 3 repetitions of the bench press exercises at 70%1RM with concentric and eccentric contractions at a maximal tempo of movement to assess baseline (BA) values of power output and bar velocity. The repetitions were performed without intentionally pausing at the transition between the eccentric and concentric phases. Next, the participants assigned to the PAPE group performed 3 sets of 5 repetitions of plyometric push-ups with 1 min rest intervals between sets. The participants assigned to the CONT group cycled approximately 4 min on a cycle ergometer with upper-body component (Keiser M3i Total Body Trainer, Keiser Corporation, Fresno, CA), at a resistance of 100 W and cadence within 70–80 rpm. Four minutes after completion of the CA routine the participants (from both groups) performed 3 sets of 3 repetitions of the bench press exercises at 70%1RM and 4 min rest interval between sets to assess post-activation values of power output and bar velocity. A linear position transducer system (Tendo Sport Machines, Trencin, Slovakia) was used for the evaluation of bar velocity. The Tendo Power Analyzer is a reliable system for measuring movement velocity and power output (Goldsmith et al., 2019). The measurement was made independently for each repetition and automatically converted into values of peak power output (PP), mean power output (MP), peak velocity (PV), and mean velocity (MV). The mean power output and bar velocity were obtained as the mean of the three repetitions. Peak power output and peak bar velocity were obtained from the best repetition.

Statistical Analysis

All statistical analyses were performed using Statistica 9.1 and were presented as means with standard deviations. The Shapiro–Wilk and Mauchly's tests were used in order to verify the normality/homogeneity and sphericity of the sample data variances, respectively. Verification of differences between CONT and PAPE conditions in PP, MP, PV, and MV was performed using a two-way 2 × 4 (condition × set) analysis of variance (ANOVA) with repeated measures. Statistical significance was set at $p < 0.05$. In the event of a significant main effect, comparisons were conducted using Tukey's post hoc test. Furthermore, t-test comparisons between conditions were made for delta values in P-Set1 – BA; P-Set2 – BA; P-Set3 – BA; P-Set2 - P-Set1; P-Set3 - P-Set1 and P-Set3 - P-Set2 for all variables. Additionally, independent sample t-tests were used to verify the differences between successive sets independently for PAPE and CONT conditions. Percent changes and 95% confidence intervals were also calculated. Effect sizes (Cohen's d) were reported where appropriate and interpreted as large ($d \geq 0.80$); moderate (d between 0.79 and 0.50); small (d between 0.49 and 0.20) and trivial ($d < 0.20$) (Cohen 2013).

Results

The two-way repeated measures ANOVA revealed significant condition × set interaction effect for PP ($p < 0.01$; F = 5.039), MP ($p < 0.05$;

F = 2.922), PV ($p < 0.01$; F = 5.38), and MV ($p = 0.02$; F = 3.75). The post hoc for condition × set interaction showed that PAPE caused significant decrease in PP and PV for P-Set2 and P-Set3 when compared to BA. The MP and MV for PAPE condition were significantly decreased in P-Set3 compared to BA, and significant decreased in P-Set3 compared to P-Set1 (Table 2).

The t-tests comparisons for delta values showed significant differences between PAPE and CONT condition in PP for P-Set1 – BA ($p < 0.01$), in MP for P-Set2 – P-Set1 ($p < 0.03$) and for P-Set3 – P-Set1 ($p = 0.04$) (Table 2). Furthermore, there were significant differences between PAPE and CONT condition in PV for P-Set3 – BA; P-Set2 – P-Set1; P-Set3 – P-Set1 ($p < 0.01$; $p < 0.01$; $p < 0.02$ respectively). Finally, there were significant differences between PAPE and CONT conditions in MV for P-Set1 – BA; P-Set2 – P-Set1 and P-Set3 – P-Set1 ($p < 0.01$; $p < 0.01$; $p < 0.02$ respectively).

The results of the t-tests used to compare differences between successive sets of the bench press exercise for the CONT and PAPE conditions are presented in Table 3.

Table 1

Descriptive characteristics of the study participants.

	All	PAPE	CONT
Age [years]	24.5 ± 2.6	24.7 ± 3.1	24.4 ± 2
Body Mass [kg]	84.8 ± 8	85 ± 7.6	84.7 ± 8.7
Bench Press 1RM [kg]	105.8 ± 9.9	105.6 ± 9.6	106 ± 10.5
Experience in RT [years]	6.3 ± 2.5	6.6 ± 2.8	6 ± 2.2

Mean ± standard deviation (SD); RT – resistance training; 1RM – one-repetition maximum

Table 2

Power output and bar velocity in successive sets of the bench press exercise under CONT and PAPE conditions.

	BA	P-Set1	P-Set2	P-Set3
		Peak Power Output (W)		
CONT	636 ± 57	622 ± 39	626 ± 65	634 ± 51
(95% CI)	(600 to 672)	(597 to 647)	(585 to 668)	(601 to 666)
PAPE	605 ± 148	649 ± 152	590 ± 139	583 ± 135
(95% CI)	(511 to 699)	(552 to 745)	(501 to 678)	(497 to 668)
		Mean Power Output (W)		
CONT	421 ± 36	415 ± 26	420 ± 22	413 ± 26
(95% CI)	(398 to 444)	(399 to 431)	(406 to 434)	(397 to 430)
PAPE	379 ± 87	389 ± 68	376 ± 78	348 ± 96
(95% CI)	(324 to 434)	(346 to 432)	(326 to 426)	(286 to 409)
		Peak Bar Velocity (m/s)		
CONT	0.97 ± 0.14	0.97 ± 0.14	0.99 ± 0.16	0.97 ± 0.14
(95% CI)	(0.88 to 1.06)	(0.88 to 1.06)	(0.88 to 1.09)	(0.88 to 1.07)
PAPE	0.99 ± 0.12	1.04 ± 0.12	0.97 ± 0.1	0.94 ± 0.13
(95% CI)	(0.91 to 1.06)	(0.96 to 1.11)	(0.9 to 1.03)	(0.86 to 1.02)
		Mean Bar Velocity (m/s)		
CONT	0.73 ± 0.09	0.72 ± 0.11	0.73 ± 0.11	0.72 ± 0.1
(95% CI)	(0.67 to 0.78)	(0.65 to 0.78)	(0.66 to 0.8)	(0.66 to 0.78)
PAPE	0.68 ± 0.08	0.71 ± 0.07	0.68 ± 0.08	0.65 ± 0.12
(95% CI)	(0.63 to 0.74)	(0.67 to 0.75)	(0.63 to 0.73)	(0.57 to 0.72)

CONT—control condition; PAPE—post activation performance enhancement;
Mean ± standard deviation (SD)

Table 3

A comparison of particular sets of the bench press exercise between PAPE and CONT conditions.

Bench Press	CONT	PAPE	Mean Difference	95% CI For Difference	*p*	ES
Differences between sets			**Peak Power Output**			
P-Set1 – BA	-14.2 ± 27.7	44.2 ± 40.2	58.3	27.1 to 89.6	0.01*	1.69
P-Set2– BA	-9.9 ± 38.7	-15.2 ± 57.2	-5.3	-56.1 to 45.6	0.82	0.11
P-Set3 – BA	-2.8 ± 30.4	-22.2 ± 21.8	-19.4	-50.1 to 12	0.20	0.73
P-Set2– P-Set1	4.3 ± 41	-59.3 ± 90.1	-63.6	-131.2 to 4.04	0.06	0.91
P-Set3 – P-Set1	11.4 ± 34.8	-66.3 ± 54.9	-77.8	-129.2 to -26.3	0.07	1.69
P-Set3 – P-Set2	7.2 ± 30.8	-7 ± 39.4	-14.2	−40.7 to 12.4	0.27	0.4
Differences between sets			**Mean Power Output**			
P-Set1 – BA	-6.1 ± 27.2	9.8 ± 25.4	15.9	-5.9 to 37.7	0.14	0.6
P-Set2– BA	-1 ± 27.6	-3.1 ± 22.8	-2.1	-30.6 to 26.3	0.88	0.08
P-Set3 – BA	-7.6 ± 20.5	-31.6 ± 42.6	-24.0	-57.6 to 9.6	0.15	0.72
P-Set2– P-Set1	5.1 ± 15	-12.9 ± 22.1	-18.0	-33.4 to -2.6	0.03*	0.95
P-Set3 – P-Set1	-1.5 ± 21.3	-41.4 ± 53	-39.9	-78.4 to -1.4	0.04*	0.99
P-Set3 – P-Set2	-6.6 ± 17.2	-28.5 ± 47	-21.9	-56.9 to 13.1	0.2	0.62
Differences between sets			**Peak Bar Velocity**			
P-Set1 – BA	-0.006 ± 0.064	0.048 ± 0.069	0.054	-0.023 to 0.131	0.15	0,81
P-Set2– BA	0.013 ± 0.081	-0.022 ± 0.068	-0.035	-0.104 to 0.034	0.29	0.47
P-Set3 – BA	0.002 ± 0.043	-0.049 ± 0.039	-0.051	-0.086 to -0.015	0.01*	1.24
P-Set2– P-Set1	0.019 ± 0.045	-0.07 ± 0.096	-0.089	-0.143 to -0.035	0.01*	1.19
P-Set3 – P-Set1	0.008 ± 0.077	-0.098 ± 0.07	-0.105	-0.182 to -0.028	0.02*	1.44
P-Set3 - P-Set2	-0.012 ± 0.081	-0.028 ± 0.063	-0.016	-0.068 to 0.036	0.52	0.22
Differences between sets			**Mean Bar Velocity**			
P-Set1 – BA	-0.01 ± 0.049	0.024 ± 0.051	0.034	-0.007 to 0.076	0.01*	0.57
P-Set2 – BA	0.001 ± 0.038	0 ± 0.046	-0.001	-0.048 to 0.047	0.97	0.02
P-Set3 – BA	-0.008 ± 0.029	-0.039 ± 0.054	-0.032	-0.074 to 0.011	0.13	1.19
P-Set2 – P-Set1	0.011 ± 0.03	-0.024 ± 0.041	-0.035	-0.059 to -0.011	0.01*	1.14
P-Set3 – P-Set1	0.003 ± 0.038	-0.063 ± 0.073	-0.066	-0.117 to -0.149	0.02*	1.79
P-Set3 – P-Set2	-0.008 ± 0.024	-0.039 ± 0.064	-0.031	-0.0.78 to 0.016	0.18	0.42

*Mean ± standard deviation (SD); * statistically significant difference p < 0.05; CONT—control condition; PAPE—post activation performance enhancement.*

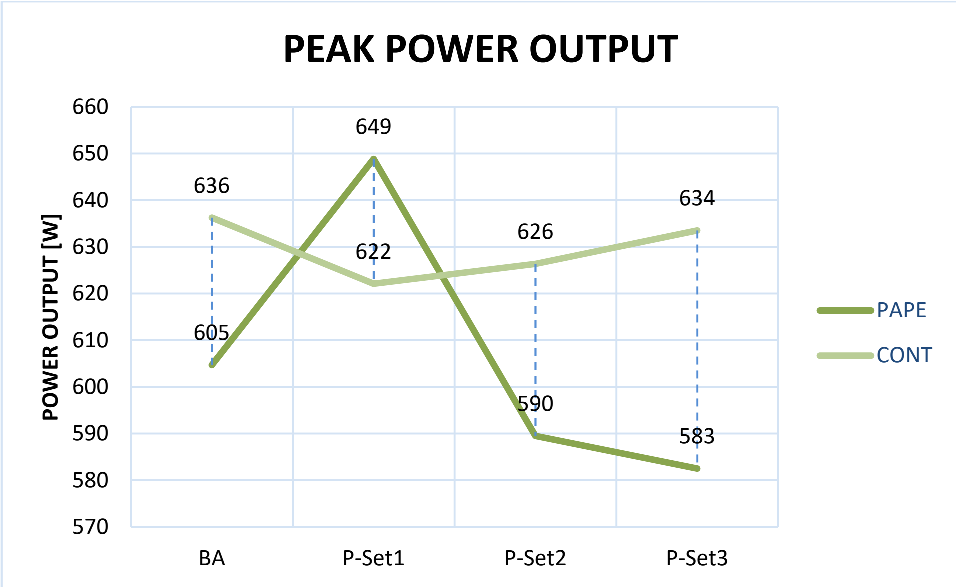

Figure 1

Peak power output for the PAPE and CONT conditions at baseline and during three successive sets of the bench press exercise after the conditioning activity.

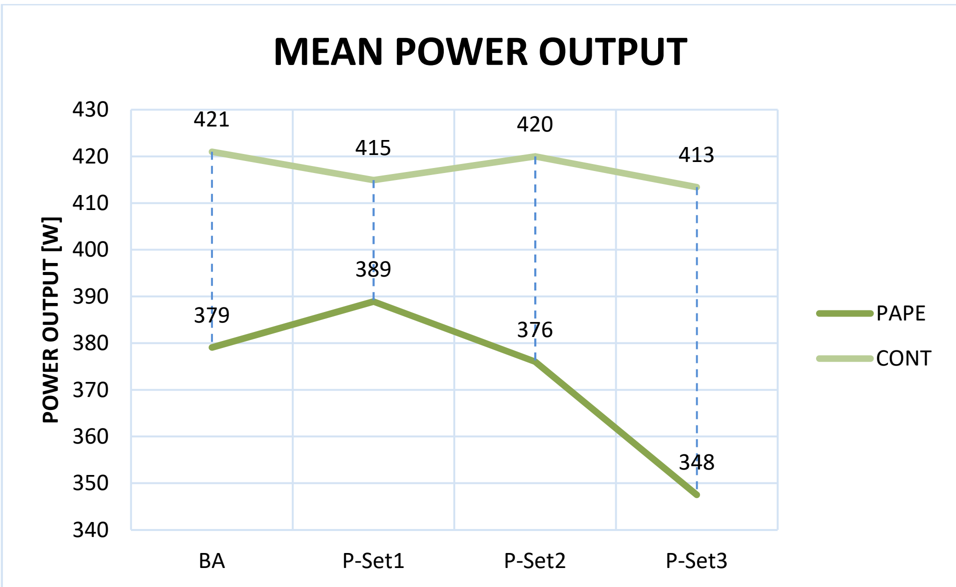

Figure 2

Mean power output for the PAPE and CONT conditions at baseline and during three successive sets of the bench press exercise after conditioning activity.

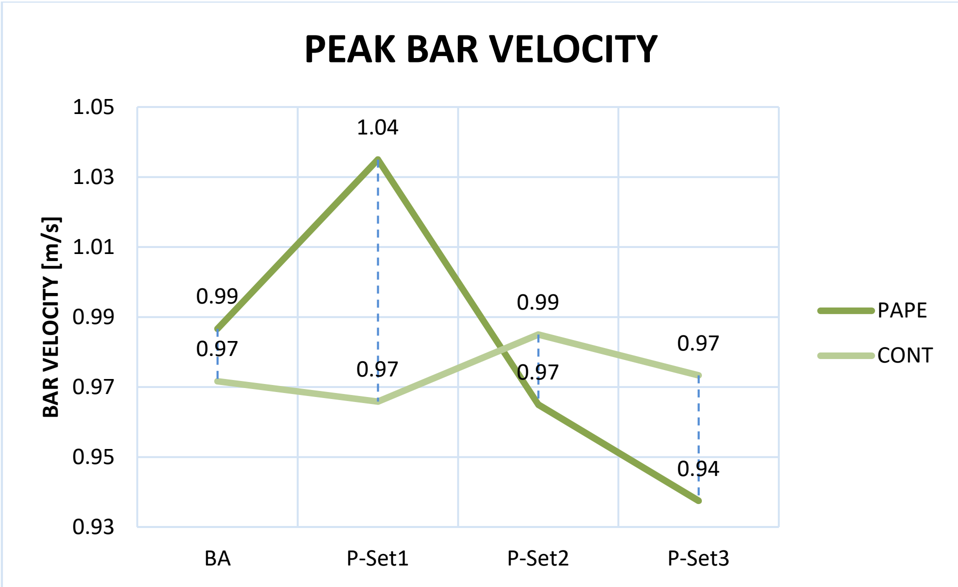

Figure 3

Peak bar velocity for the PAPE and CONT conditions at baseline and during three successive sets of the bench press exercise after the conditioning activity

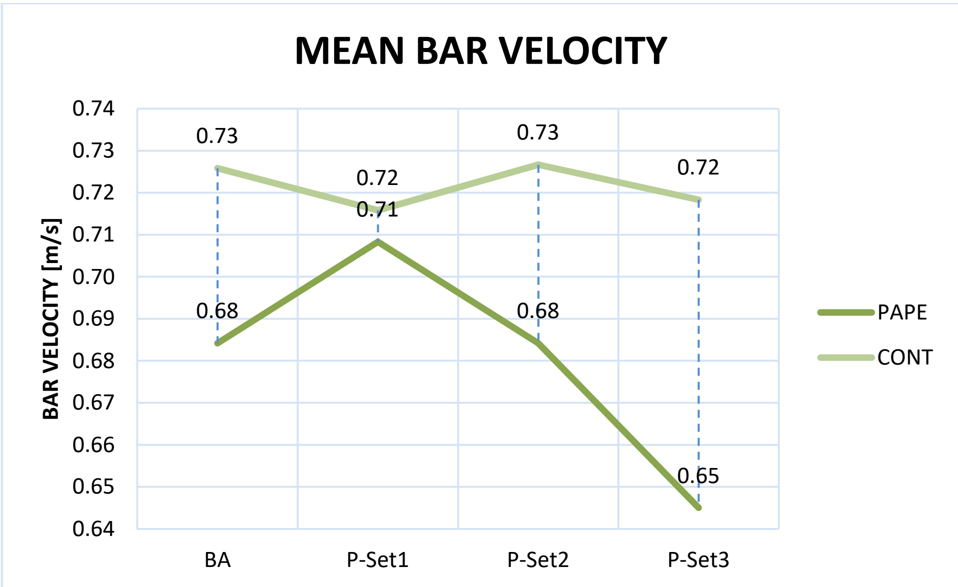

Figure 4

Mean bar velocity for the PAPE and CONT conditions at baseline and during three successive sets of the bench press exercise after the conditioning activity.

Discussion

The main finding of the study was that the plyometric push-ups performed as a CA significantly increase power output and bar velocity during the bench press exercise. This study showed that PP and PV significantly increased in the P-Set1 compared to baseline for the PAPE condition while such changes were not observed under CONT conditions. Furthermore, the PP, MP, PV, and MV significantly decreased in P-Set3 compared to BA, as well as in the P-Set3 compared to P-Set1 for PAPE condition, however, such a decrease was not recorded in the CONT condition. Therefore, the results of the presented study indicate that the use of plyometric exercises as a CA changes the kinetics of power output and bar velocity during post-activation sets of the bench press exercise.

The presented results are consistent with previous studies that examined the effectiveness of plyometric CA or directly compared them with high-loaded resistance exercise CA on the PAPE effect (Saez Saez de Villarreal, 2007; Tobin and Delahunt, 2014; Ulrich and Parstorfer, 2017). The only study by Ulrich and Parstorfer (2017) considered strength changes in the upper limbs, however the evaluation of PAPE effects concerned only one post-activation set, which is not the habitual practice during sports training, where several sets of each exercise are used in order to obtain significant adaptive changes (Wilk et al., 2020d). Furthermore, to date, only two studies examined the reverse order of commonly practiced potentiation protocols i.e. high-load resistance exercise performed after ballistic or plyometric CA (Masamoto et al., 2003; Wilcox et al., 2006). Masamoto et al. (2003) and Wilcox et al. (2006) showed that a plyometric CA performed before 1RM testing enhances bench press and squat performance among trained athletes. Meanwhile, to the best of our knowledge, there are no available data regarding the acute power output and bar velocity changes during high-loaded upper body resistance exercise performed after a plyometric CA which limits the possibility of comparing our results with other studies. Nevertheless, significant knowledge and training clues can be derived from the current data.

Despite the fact that the results of the current study showed that a plyometric CA improves power output and bar velocity during post-activation high-load resistance exercises, different kinematic changes were observed in successive sets, compared to CONT conditions. A detailed analysis of the differences between successive sets indicated that PP and PV values significantly increase in the P-Set1 when compared to baseline for the PAPE condition. However, power output and bar velocity in P-Set2 and in P-Set3 for the PAPE condition decreased in comparison to baseline values as well as in comparison to P-Set1. However, such a decrease in successive sets was not observed in the CONT condition. It is possible that benefits from the PAPE effect in P-Set1 could be counterbalanced by more pronounced muscle exhaustion in P-Set2 and P-Set3, what was also observed in a previous study by Wilk et al. (2020e). The plyometric CA increased power output during the first set of the post-activation bench press exercise, however, such an increase of performance may induce greater fatigue which, as a consequence, may cause a decrease in power and related variables in subsequent sets of the exercise, as observed in the present study. Therefore, it can also be assumed that decreased performance in P-Set2 and P-Set3, may be associated with an insufficient rest interval and accumulated fatigue. Those results indicate that a 4 min rest interval between the plyometric CA and post-activation exercises can be sufficient to induce the PAPE effect, and there is a need for a longer rest interval between successive sets when high-loaded exercises are used.

The results of the presented study may be of particular importance for strength and conditioning coaches and athletes which often encounter specific movements in their sport events (Mayhew et al., 1997). The reverse order of conventional PAPE protocols implemented as a complex training set (i.e. plyometric CA prior to high external resistance tasks or high-loaded resistance exercise) can be similar to the specifics of a particular sport. Furthermore, plyometric CA seem to be highly practical due to the requirement of no or little equipment. Different warm-up routines are carried by athletes prior to competition with the expectation that it will enhance subsequent performance. Since access to equipment is often limited during competition, the application of resistance exercise with high-loads as a CA is not possible. Thus, it may be concluded that the use of plyometric exercises as part of the warm-up routine is a simple solution to improve athletic performance.

The present study has some limitations which have to be addressed. Although the results showed that the PAPE effect occurred during the high-loaded bench press exercise after plyometric push-ups, the direct causes of these changes cannot be determined and explained due to the lack of physiological analysis. Further, the results of our study refer only to PAPE effects of the upper-body during the bench press exercise, and cannot be translated into other exercises, volumes, or intensities. Thus, future studies are required, especially in assessing the acute impact of different plyometric CA exercises with different variations in volumes and rest intervals on the PAPE effect.

Practical Implications

The plyometric push-ups significantly increase power output and bar velocity during the high-loaded bench press exercise. Due to the lack of equipment requirements, the employment of plyometric exercises as part of a warm-up routine may be an attractive and easy solution to induce PAPE before the competition. Moreover, the implementation of plyometric CA before high-loaded resistance exercises can improve the ability to develop power against a specific external load that athletes often encounter during competition. However, the acute improvement in power performance following plyometric CA will not necessarily be maintained for multi-sets exercise. When several sets of a high-loaded exercise are performed following CA, it seems that a longer rest interval is needed in comparison to that used in the present study. Furthermore, the increase in acute power performance should be controlled by measuring devices in order to individually adjust the optimal number of sets and the time interval to induce PAPE.

Conclusion

This study demonstrated that the plyometric push-ups (3 sets of 5 repetitions) lead to performance enhancement of the bench press exercise at 70%1RM. The increases in performance were obtained only in the first set following the CA, and during the next sets we observed a significant decrease in P-Set2, and P-Set3. Furthermore, the results of the study showed different kinetics of power output and bar velocity during successive sets of the bench press exercise between PAPE and CONT conditions. The application of the reverse PAPE protocol can introduce, a new, training approach to the development of power output, which opens opportunities for modification of strength training programs, particularly in elite athletes.

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