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Research article

THE EFFECT OF ISOMETRIC CONTRACTION POTENTIATION ENHANCEMENT ON ANAEROBIC POWER

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Onur Çoban[1], Berkant Erman[1], Gençer Yarkın[2], Mehmet Zeki Ozkol[3]

[1] Department of Sport Health Sciences, Institute of Health Sciences, Ege University, Bornova, Izmir, Turkey
[2] Department of Exercise and Training Science, Institute of Health Sciences, Marmara University, Beykoz, Istanbul, Turkey
[3]Coaching Education Department, Faculty of Sport Sciences, Ege University, Bornova, Izmir, Turkey

Abstract. *The aim of this study was to examine the effect of isometric contraction potentiation enhancement (ISO-PAPE) on anaerobic power. Twelve professional female volleyball players participated in this study. The participants came to the laboratory on two sessions 72 hours apart. The participants were randomly assigned to either the control (n = 6) or experimental (n = 6) group. In the first session, the Bosco repeated jump test (BRJT) was applied to both the control and experimental group. In the second session, the experimental group also applied the isometric mid-thigh pull exercise for 3 seconds with 3 sets and 2 minutes of recovery between repetitions. After the applied ISO-PAPE protocol, the BRJT was performed. The control group performed only the BJRT after the standard warm-up protocol. The anaerobic power measurements of both the control and experimental group were performed. According to the findings of the study, there were no significant differences between the groups before the ISO-PAPE application (p>0.05). After the ISO-PAPE application on the experimental group, there were only significant differences in flight time (p=0.025). This difference in the experimental group was found to be significantly lower than in the control group (p≤0.005). In conclusion, it was thought that the ISO-PAPE protocol did not have a positive effect on anaerobic power.*

Key words: *post activation potentiation, isometric strength, anaerobic performance.*

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Corresponding author: Mehmet Zeki Özkol
Coaching Education Department, Faculty of Sport Sciences, Ege University, Bornova, Izmir, Turkey
E-mail: zeki.ozkol@gmail.com

INTRODUCTION

Strength is a crucial component for elite athletic performance (Canavan and Vescovi, 2004; Kraemer et al., 2001). Strength assessment is also used to change the performance and assess the success of the appropriate training program in the latter phase (Kraemer et al., 2003). The phenomenon of acutely elevated qualities of muscular function after a specific contraction is known as post-activation potentiation (PAP) (Tillin and Bishop, 2009). In order to increase performance before a competition or training session, this phenomenon is exploited as a warm-up (Feros et al., 2012). There are various practices that aim to achieve acute performance improvements on athletic performance. One of these short-term methods to improve performance is the PAP, while another is post activation performance enhancement (PAPE). Although PAP and PAPE are related, they are different in that the mechanisms that produce PAP are different from those for PAPE (Villalon-Gasch et al., 2022). After a warm-up based on high-intensity exercise, the PAPE phenomenon is observed, especially when a long rest period is applied to increase the subsequent voluntary force production instead of electrical stimulation (Cuenca-Fernández et al., 2017). PAPE is a phenomenon that suggests that a muscle can be acutely optimised by past experience of contraction, which can then influence the outcome of the task performed (Brink, Constantinou, and Torres, 2022).

Regulatory light chain (RLC) phosphorylation is assumed to be the primary mechanism behind PAP. Myosin light chain kinase (MLCK) improves the actin-myosin connection, increasing its sensitivity to Ca^{+2} produced from the sarcoplasmic reticulum (Hodgson, Docherty, and Robbins, 2005). This transient molecular modification enhances Ca^{+2} sensitivity and concentration in striated muscle, and this enhances force production (MacIntosh, 2010). The actin-myosin complex is made more sensitive to myoplasmic Ca^{+2} by MLCK phosphorylation of RLC, which leads to increased myosin cross-bridge activity and high contraction force or torque production (Sale, 2002; Tillin and Bishop, 2009). Furthermore, PAPE has an effect that can occur in different intensities and durations depending on changes in muscle temperature, the water level in muscle fibres and the number of motor units activated (Blazevich and Babault, 2019; Zimmermann, MacIntosh, and Dal Pupo, 2020).

Since the effect of PAPE varies depending on the levels of fatigue and potentiation (Sale, 2002), the magnitude of activation will depend on this relationship and hence performance will be enhanced if the potentiation effect is greater than that of fatigue (Tillin and Bishop, 2009). In training practice, a wide range of external loads can be used to achieve PAPE, ranging from 70% of one repetition maximum to 110-130% (Krzysztofik et al., 2020). It is understood that high intensity exercise should be applied to achieve further performance enhancement (Wilson et al., 2013). This interaction is influenced by many variables such as subjective physiological characteristics of the participants, training history, age, muscle fibre type and maximal strength (Xenofondos et al., 2010). A different recovery time may be required for each participant; however, it is thought that participants may be optimised for maximum performance by performing a conditioning activity of similar quality and intensity (Brink et al., 2022).

Isometric contraction protocols can be a practical method to initiate PAPE-related enhanced neural activity in athletes. Before a competition or training session, simple isometric exercises can be conducted without any extra equipment. An athlete can participate in this kind of workout to help initiating the PAPE become ready for the activity. Therefore, this study aims to investigate the effects of isometric contraction potentiation (ISO-PAPE) with female volleyball players on anaerobic power.

The literature on isometric contraction strengthening primarily focuses on its effects on muscular strength and power, but its specific application to volleyball is still under-researched. This research aims to fill this gap and provide information on how isometric contraction strengthening can be used to improve the performance of volleyball players.

METHODS

Participants and Anthropometric Variables

The sample size was calculated using GPower 3.1.9.7 [power size (1-β) = 0.80, the effect size (f) = 0.78, type-1 error (α) = 0.05, number of groups = 2, number of measurements = 2, cor. among rep. measure = 0.5]. According to the results of this analysis, sample size was 12.

Twelve professional female volleyball players participated in this study. The participants were divided into a control group (n=6) (Age: 19.33±0.75 years, Height: 182.0±6.45 cm, Weight: 70±5.26 kg) and experimental group (n=6) (Age: 19.33±0.75 years, Height: 185.5±5.22 cm, Weight: 69.16±4.48 kg).

Height was measured with the aid of a wall-mounted floating caliper (Holtain Ltd., UK) with an accuracy of ±0.1 cm while the participant assumed the anatomical posture, following inspiration. Body weight was measured with a measurement accuracy of ±0.1 kg, wearing sports clothes and without shoes on a scale (Seca, Germany).

The Bosco Repeated Jump Test

The maximum repeated vertical jumps performed for 15 seconds was measured using the Bosco repeated jump test (BRJT). The participants were instructed to keep their hands in the akimbo position during the measurement to minimise the effect of upper limb strength on performance. The participant's knee was positioned at a 90° flexion using a handheld goniometer to ensure they understood the required depth of knee flexion during the transition from landing to the subsequent maximum vertical jump. During the measurement, if the athlete failed to achieve or exceeded the 90° criterion, verbal feedback was provided. This feedback was given for all jumps in which knee flexion was not performed at the specified angle (Sands et al., 2012). Verbal encouragement was also given to the participants throughout the test to help them maintain their knee angle and their best performance until the end of the performance. The participants performed the exercises with the Chronojump system (BoscoSystem, Spain). The formula used in the system for anaerobic power at the end of the repeated jumps is shown below (Bosco, Luhtanen, and Komi 1983): $W = (9.81^2 * TF * TT) / [4n * (TT-TF)]$ (TF) is the flight time, (TT) is the duration of the test, and (n) is the number of jumps performed during the test.

Procedures

The participants were randomly assigned to either the control (n = 6) or experimental (n = 6) group with an allocation ratio of one-to-one. In this study, blinding was not possible due to the nature of the intervention. The data were collected during the preparation period of the season. Measurements were performed at the same time of the day (02:00 p.m.). The experimental procedures are in agreement with the principles of the Declaration of Helsinki. All tests were performed on two different days with at least 72 hours between tests. For both groups, a standardized warm-up was conducted for each session, including 10 min of cycling at constant power (1 Watt per kg of the participant’s body mass) on an ergometer (Monark 818 E, Sweden) before each test. Adjustments of the seated position were performed to make sure the participants were in the best riding position. Following the cycling warm-up, a 3-minute mobility session was conducted that included dynamic movements that mimicked the workout (such as a half squat) as well as dynamic hip, knee, and ankle movements (Beato et al., 2019). After the standardized warm up, the participants performed the BRJT with the Chronojump system (BoscoSystem, Spain) in the designated area. The reasons for using the Chronojump system (BoscoSystem, Spain) are that it is a practical, accurate, and affordable test tool (Pueo, Penichet-Tomas, and Jimenez-Olmedo 2020). Prior to the main BRJT test, the participants performed a 15-seconds warm-up consisting of vertical jumps at submaximal effort on the Chronojump system platform. In the test, both groups performed a 15-second BRJT by paying attention to the 90° knee flexion as mentioned above. The participants were briefed on the study procedures and informed consent was obtained before they took part in the study.

In the second session, the experimental group performed an isometric mid-thigh pull exercise for 3 seconds with 3 sets and 2 minutes between sets, unlike the control group (Lim and Kong, 2013). The isometric mid-thigh pull is a multi-joint exercise test to assess whole-body strength and force production capabilities (Martin and Beckham, 2020). The mid-thigh pull exercise includes producing the most isometric force possible while gripping a barbell and strength in the exercise is regarded as safe and closely related to dynamic workout performance (Grgic et al., 2022). The isometric mid-thigh pull exercise's position is the strongest and most powerful position during weightlifting movements and has been shown to generate the highest forces and velocities of any part of the lifts (Brady, Harrison, and Comyns, 2020). After 15 seconds of recovery came the ISO-PAPE protocol, where the experimental group performed the BRJT. During the BRJT, anaerobic power (W/kg), total counts of jumps, flight time (ms), ground contact time (ms) were evaluated for both groups.

Statistical Analysis

To assess differences between the 2 before-after measurements (peak power Bosco, flight time, ground contact time, total number of jumps) of the groups, the independent t-test was performed. In addition to this, for the before-after differences of the individual groups, the paired t-test was performed. The statistical significance level was set at $p \leq 0.05$.

RESULTS

In this study, the ISO-PAPE performance effect was studied on two different groups. The groups' descriptive features are shown in Table 1.

Table 1 Descriptive Features of the Groups

	Control Group (M±SD)	PAPE Group (M±SD)
Age (years)	19.33 ± 0.75	19.33 ± 0.75
Height (cm)	182.00 ± 6.45	185.50 ± 5.22
Weight (kg)	70.00 ± 5.26	69.17 ± 4.18

M±SD: Mean ± Standard Deviation.

Group differences before application of the PAPE are shown in Table 2.

Table 2 Independent t-test Results Before Application

Measurements	Before PAPE (M±SD)			
	Control	PAPE	t	p
Bosco Index (W/kg)	25.66 ± 4.14	30.14 ± 8.72	-1.136	0.282
Flight Time (ms)	0.41 ± 0.02	0.44 ± 0.04	-1.597	0.141
Total Counts of Jumps	22.17 ± 1.47	19.50 ± 4.63	1.343	0.209
Ground Contact Time (ms)	0.28 ± 0.04	0.30 ± 0.11	-0.387	0.707

M±SD: Mean±Standard Deviation, PAPE: before Activation Potentiation Enhancement

Group differences after application of the PAPE are shown in Table 3.

Table 3 Independent t-test Results After Application

Measurements	After PAPE (M±SD)			
	Control	PAPE	t	p
Bosco Index (W/kg)	23.84 ± 2.5	25.71 ± 4.83	-0.845	0.418
Flight Time (ms)	0.38 ± 0.02	0.42 ± 0.02	-2.640	0.025*
Total Counts of Jumps	22.83 ± 2.04	20.33 ± 3.32	1.569	0.148
Ground Contact Time (ms)	0.26 ± 0.01	0.32 ± 0.14	-1.067	0.311

M±SD: Mean±Standard Deviation, PAPE: Post Activation Potentiation Enhancement

The control group paired-t test results are shown in Table 4.

Table 4 Control Group Paired T-test Results.

Measurements	Before PAPE (M±SD) Control Group	After PAPE (M±SD) Control Group	t	*p*
Bosco Index (W/kg)	25.66 ± 4.14	23.84 ± 2.5	1.257	0.264
Flight Time (ms)	0.41 ± 0.02	0.38 ± 0.02	2.043	0.097
Total Counts of Jumps	22.17 ± 1.47	22.83 ± 2.04	-0.510	0.632
Ground Contact Time (ms)	0.28 ± 0.04	0.26 ± 0.01	1.112	0.313

M±SD: Mean±Standard Deviation, PAPE: Post Activation Potentiation Enhancement.

The experimental group paired-t test results are shown in Table 5.

Table 5 Experimental Group Paired T-test Results

Measurement	Before PAPE (M±SD) Experimental Group	After PAPE (M±SD) Experimental Group	t	*p*
Bosco Index (W/kg)	25.71 ± 4.83	30.14 ± 8.72	2.177	0.081
Flight Time (ms)	0.42 ± 0.02	0.44 ± 0.04	1.436	0.211
Jumps	20.33 ± 3.32	19.50 ± 4.63	-0.353	0.738
Ground Contact Time (ms)	0.3 ± 0.11	0.32 ± 0.14	-1.197	0.113

$^{*}p<0.05$, M±SD: Mean±Standard Deviation, PAPE: Post Activation Potentiation Enhancement.

DISCUSSION

This study was conducted to evaluate whether there is any PAPE effect on anaerobic power performance of isometric contraction, and it was hypothesized that BRJT performance of the experimental group would improve after the ISO-PAPE protocol, as compared to the control group. However, there were no differences between the control and experimental group after the application of ISO-PAPE protocol (Table 2). Small sample sizes in studies significantly affect the validity and reliability of study findings. In our study, there were a total of 12 participants (control group (n=6) and experimental group (n=6)). In order to minimise the effect of the number of participants on the validity and reliability of the study, the participants were randomly assigned.

The main conclusion of this study was that an isometric training program consisting of 3 reps of 3-seconds isometric mid-thigh pulls did not cause an increase in the anaerobic power parameter values measured with the BRJT. When compared with the control group, we observed a significantly lower flight time after the BRJT, despite the absence of significant effects in the anaerobic power. The ISO-PAPE protocol was not suitable for maximizing the PAPE effect in comparison to the control group. Such findings were not consistent with previous studies, as they reported that greater PAPE with maximum voluntary contractions compared to maximal and near-maximal concentric contractions (French, Kraemer, and Cooke, 2003; Güllich and Schmidtbleicher, 1996). There is a limit to the stimulation frequency at which potentiation can have an enhancing effect on the rate of force development, even if it is higher than the stimulation frequency produced by the ISO-PAPE protocol (Sale, 2002). For this reason, it is important to determine the stimulation frequency to be applied according to individual differences.

In the literature, a number of techniques have been used to identify PAPE. This emphasizes how difficult it is to determine the best way to execute PAPE (McBride, Nimphius, and Erickson, 2005). Depending on the type of applied contraction, its strength, volume, individual traits, and muscle length effect on the potentiation (Prieske et al. 2020). Response to PAPE is also influenced by several factors, such as training age, training status, chronological age, genetics (muscle fiber type), gender, and strength levels. Individual variations for reaction to PAPE are also revealed by these variables (Robbins, 2005). Ebben (2002) stated that there was a connection between strength and PAPE.

Maximum voluntary contraction performed for short periods of time (<10 seconds) results in evoked contraction force. The condition that elicits potentiation is more effective than the condition that elicits fatigue (Çoban, Ünver, and Cinemre, 2022). Impaired performance involving both motor and sensory systems are criteria of fatigue (Enoka, 1988). Fatigue causes a reduction in the mechanical reaction to contraction of the muscle. The main cause of this condition is the build-up of H^+ and inorganic phosphate, which is known to restrict Ca^{+2} release, lessen myofibrillar Ca^{+2} sensitivity, and decrease the quantity of strong binding cross-bridges (Allen, Lannergren, and Westerblad, 1995; Metzger and Moss, 1990). Exercise characteristics, such as contraction type, intensity, duration, and recovery times, have a significant impact on whether PAPE or fatigue predominates (Skurvydas et al., 2016).

Lum et al. (2021) found that three seconds of isometric contractions increased muscular strength more than one second of isometric contraction. Similar to this, French et al. (2003) also found that an isometric knee extension workout conducted with 3 seconds, 3 sets, and 3 minutes of recovery time between repetitions revealed a PAPE effect. Rixon, Lamont, and Bemben (2007) suggest that the optimal isometric loading to elicit the PAPE effect is 3 sets for 3 seconds and 2 minutes of isometric practice between sets. Because of this, 3 sets 3 seconds protocols may have been enough to enhance the excitability of the fast twitch motor units to create a PAPE effect. These studies support the protocol used in this study. Additionally, compared to a maximal dynamic contraction of same time, an isometric contraction had a lower metabolic cost, which may lead to less fatigue (Rixon et al., 2007). This may lead to the theory that performing maximal isometric contractions during the warm-up phase may reduce the detrimental effects of accumulated fatigue and improve subsequent explosive performance (Baudry and Duchateau, 2007). PAPE is influenced by activation intensity, volume, and the protocol applied as well as the jump intensity applied after potentiation (Suchomel, Lamont, and Moir, 2016). There is an interaction between fatigue and recovery. Optimal recovery is an important component for the effect of PAPE on subsequent performance (Tillin and Bishop, 2009). Although 2 minutes were given as recovery time between sets in the protocol applied in this study, the measurement was performed 15 seconds after the last repetition, which may have affected the result.

Tsolakis et al. (2011) did not found a potentiation effect with a protocol which was 3 sets of 3 seconds and 15 seconds rest between sets. For some participants it was sufficient to reveal and prevent the potentiation effect from occurring. In the present study, this supports the results of Tsolakis et al. (2011) as the ISO-PAPE protocol had a negative effect on flight time in the BRJT. The training level of the experimental group should be considered in order to ascertain the intensity and volume of PAPE application and to reveal the ideal PAPE response (Çoban et al., 2022). It is likely that the neuromuscular fatigue caused by the applied strengthening protocol caused a reduction in flight time due to the masking of the PAPE effect, while the individual strength level of the participants plays an important role in the balance between PAPE and fatigue. The PAPE response appears to be triggered by the time between contractions. The rest period between contractions appears to be important for triggering the PAPE response.

One of the main reasons underlying the decrease in flight time performance is the participant's poor strength development rate ability after the ISO-PAP protocol. However, fatigue also plays an important role. The BRJT appears to be a testing method that requires high performance and accumulates fatigue load. The physical fatigue that occurs after the BRJT has negatively affected the reaction times in the body, resulting in difficulty in maintaining the required speed during the BRJT. With the combination of these factors, a significant decrease in hover time performance was observed. The possibility that fatigue may have contributed to changes in the participants' performance should be taken into account when evaluating the results of this study. This may lead to limitations in the generalisability of the results.

In the present study, the fact that the hands were kept in the akimbo position in the measurements performed on professional volleyball players may have limited the sport-specificity of the results obtained. The results obtained may not fully reflect the natural state of the volleyball and may increase the possibility of incompatibility with the actual in-game performance. In this context, when generalising the results of the study, it should be taken into consideration that the measurement of the hands in the akimbo position may limit the sport-specificity.

This study examined the PAPE effect of maximal isometric contractions. There was no noticeable difference in anaerobic power output after the ISO-PAPE protocol, but flight time may have been adversely affected, possibly as a result of fatigue from the high intensity repeated contractions during the BRJT.

CONCLUSION

In this study, in which the effects of ISO-PAPE on anaerobic power were examined, no significant difference was found. Only a difference in flight time was observed. The reduction in flight time was not advantageous. This study shows that the ISO-PAPE protocol consisting of 3 sets and 3 seconds of isometric contractions does not have a positive effect on anaerobic power. However, further studies are needed to determine the ideal conditioning activity protocol for performance. In addition, the measurement method to be applied is also important in determining the appropriate protocol. Optimal recovery should be ensured without applying high-intensity measurement methods.

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POTENCIJACIJSKI EFEKAT IZOMETRIJSKIH KONTRAKCIJA NA ANAEROBNU SNAGU

Cilj ovog istraživanja bio je da se ispita efekat pojačanja izometrijske kontrakcije (ISO-PAPE) na anaerobnu snagu. U ovom istraživanju učestvovalo je 12 profesionalnih odbojkašica. Učesnici su dolazili u laboratoriju na dve sesije u razmaku od 72 sata. Nasumično su raspoređeni u kontrolnu (n = 6) ili eksperimentalnu (n = 6) grupu. U prvoj sesiji, Bosco ponovljeni test skoka (BRJT) je primenjen i na kontrolnu i na eksperimentalnu grupu. U drugoj sesiji, eksperimentalna grupa je takođe primenila izometrijsku vežbu povlačenja sredine butina u trajanju od 3 sekunde sa 3 serije i 2 minuta oporavka između ponavljanja. Nakon primenjenog ISO-PAPE protokola, urađen je BRJT. Kontrolna grupa je izvela samo BJRT nakon standardnog protokola zagrevanja. Izvršena su merenja indeksa anaerobne snage i kontrolne i eksperimentalne grupe. Prema rezultatima, nije bilo značajnih razlika između grupa pre primene ISO-PAPE (p>0,05). Nakon primene ISO-PAPE na eksperimentalnoj grupi, značajne razlike uočene su samo u vremenu leta (p=0,025). Utvrđeno je da je ova razlika u eksperimentalnoj grupi značajno manja nego u kontrolnoj grupi (p≤0,005). U zaključku, smatralo se da ISO-PAPE protokol nije imao pozitivan efekat na anaerobne parametre snage.

Ključne reči: *potencijacija nakon aktivacije, izometrijska snaga, anaerobni učinak.*