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ACUTE EFFECTS OF CLUSTER SET AND TRADITIONAL SET POST-ACTIVATION POTENTIATION PROTOCOLS ON VERTICAL JUMP PERFORMANCE

Abdurrahman Boyaci[1,2i],
Tuba Kizilet[3]
[1]Istanbul Nisantasi University,
School of Physical Education and Sports,
Turkey
[2]Marmara University,
Health Sciences Institute,
Turkey
[3]Marmara University,
Faculty of Sports Sciences,
Turkey

Abstract:
The aim of this study was to investigate the acute effects of different post-activation potential (PAP) protocols on Countermovement Jump (CMJ) performance in female athletes. Twelve elite female taekwondo athletes (age 15.17±.718 years, height 168.66±4.81 cm and body weight 49.25±2.37 kg) participated in the study voluntarily. The resistance training methods of the traditional set (1RM 75% x 3 sets x 12 repetitions and 180 s rest between sets) and cluster set (1RM 75% x 3 sets x 4+4+4 (total 12) repetitions, 30 s rest between sets and 180 s rest between sets) were applied to the research group. CMJ test performances were recorded for 30 s, 4 min and 8 min before and after both PAP protocols. Paired sample t-test was applied for pre-posttest comparison. In the traditional set structure, there was a statistically significant difference between $CMJ_{\text{pre test}}$ and $CMJ_{4\text{ min}}$ test. In the cluster set structure, a statistically significant difference was found between $CMJ_{\text{pre test}}$ and $CMJ_{30\text{ sec}}$, between $CMJ_{\text{pre test}}$ and $CMJ_{4\text{ min}}$ and between $CMJ_{\text{pre test}}$ and $CMJ_{8\text{ min}}$. As a result, the PAP effect is better with the cluster set structure than with the traditional set due to the intermittent rest that will be given with the cluster set structure due to the sudden replenishment of energy stores.

Keywords: PAP, cluster, resistance training, vertical jump

[i] Correspondence: email a.rahmanboyaci@gmail.com

1. Introduction

Taekwondo is a combat sport that requires high-intensity kicking techniques, jumps, and changes of direction to control the distance to the opponent during consecutive strikes (Bridge et al., 2014, 713- 733). During the match, these high-intensity actions are interspersed with low-intensity actions or pauses, resulting in a work-to-rest ratio ranging from 1:2 to 1:8 (da Silva Santos et al., 2016). Regarding physical aspects, scoring actions are mainly based on muscular strength (Bridge et al., 2014)

Athletes are often encouraged to perform concentric muscle movements as explosively as possible, as lifting at the intended maximal speed may provide superior adaptations in strength and power compared to voluntary lifting at submaximal speed (Pareja-Blanco et al., 2014; González- Badillo, et al., 2014). However, regardless of the number of repetitions performed and the loads used, performing multiple repetitions in a sequential manner can (inevitably) result in a decrease in movement speed, neuromuscular fatigue, increased lactate concentration, decreased strength and peak power (Suchomel et al., 2015; Tufano et al., 2016; Jukic & Tufano, 2020; Jukic, et al., 2020). All these events represent negative mechanical, perceptual, and metabolic responses that can subsequently compromise specific training adaptations. Alternative set structures such as cluster set (CS) can be used to combat fatigue and performance decrements associated with traditional set (García-Ramos et al. 2020; Tufano et al., 2016; Jukic & Tufano, 2022).

Post-activation potentiation (PAP) is an acute response in which an improvement in force and power development is observed after performing a conditioning activity with movement similarity (Crewther et al., 2011; Evetovich et al., 2015; Gołaś, Maszczyk et al., 2016). The term PAP can be used to denote short-term gains in muscle force/torque production during an electrically evoked twitch (Blazevich & Babault, 2019), largely attributed to myosin light chain phosphorylation in type II fibers (Tillin & Bishop, 2009). The main physiological rationale explaining the PAP response may be related to the ability of conditioning activity to influence neural activation through an increase in higher threshold motor unit recruitment (Anthi, et al., 2014). It should be noted that although a reinforcement effect is produced, the conditioning activity may simultaneously promote muscle fatigue that may reduce acute performance (Seitz & Haff, 2016; Stone et al., 2008). Seitz and Haff (2016) stated that training status and strength level attenuate the PAP response, as stronger individuals elicit a larger PAP response in a shorter time frame (5-7 min) after the conditioning activity than weaker individuals (≥ 8 min). Therefore, the volume, intensity, rest interval relationship between the conditioning activity and the main activity, and training status should be taken into account when implementing a PAP strategy (Seitz et al., 2016).

The PAP strategy is used in judo (Lum, 2019; Miarka et al., 2011), karate (Margaritopoulos et al., 2015), muay thai (Cimadoro, et al., 2019), and taekwondo (Aandahl, et al., 2018; Castro-Garrido et al., 2020; da Silva Santos et al., 2016). To maximize the PAP response, it is necessary to create strategies that minimize fatigue and

maximize reinforcement. In this sense, a set configuration with a cluster set including inter-repetition rest could be a suitable alternative to promote mechanical tension with less metabolite accumulation (Nicholson, et al., 2016; Oliver, et al., 2015; Tufano et al., 2016). The use of cluster sets can maintain the speed of movement across sets compared to traditional sets without intra-set rest. Boullosa et al. (2020) reported higher peak power output one minute after a 30-second within-set rest protocol conditioning activity, while the traditional set protocol observed improvements after nine minutes. Nickerson et al., (2018) reported an increase in 20-meter sprint times ten minutes after a protocol consisting of three repetitions with 30 seconds of on-set rest.

Therefore, the aim of this study was to compare the effects of traditional set and cluster set configurations on jump performance in young female taekwondo athletes. It was hypothesized that set configurations with cluster set would reduce fatigue and promote PAP within a shorter time after the conditioning activity.

3. Material and Methods

The population of the study is national female taekwondo athletes with at least red black (1st Gip) and a higher belt degree. The sample of the study was formed with the voluntary participation of 12 young elite female taekwondo athletes aged 14-16 years. The age of the athletes was 15,17±,718 years, height 168,67±4,81 cm, weight 49,25±2,37 kg and sports age 5,42±1,240 years.

During the implementation process, the participants' measurements were subjected to a total of 3 experimental conditions on different days. This is a single-group repeated measures study in which athletes were subjected to 1 familiarization and 2 experimental conditions. The athletes visited the laboratory to familiarize themselves with the conditions, tests and all procedures. In the first experimental condition, athletes underwent familiarization drills for the squat exercise and 1 Repetition Maximum (RM) test. In the second experimental condition, they performed the traditional set protocol. A countermovement jump (CMJ) test was taken before the protocol and after 30 s, 4 min and 8 min. In the third experimental condition, they performed the cluster set protocol after taking the CMJ pre-test. CMJ was taken again for 30 s, 4 min and 8 min after the protocol.

Traditional Set (TS): consists of 3 sets with a predetermined 75% RM load. In each set, 12 repetitions were performed consecutively. The rest between sets was 180 seconds. The traditional set protocol was applied as shown in Figure 2 (Figure 1).

Cluster Set (CS): consists of 3 sets with a predetermined 75% RM load. Each set was performed as 4+4+4+4 (total 12 repetitions) repetition sets. After each 4 repetitions, 30 seconds of in-set rest was given. The rest between sets was 180 seconds. The cluster set protocol was applied as shown in Figure 3 (Figure 1).

Warm-up: At the beginning of the whole protocol, the athletes performed a warm-up procedure consisting of running on a treadmill at 9 km/h for 8 min, 2 min rest, static-dynamic stretching and mobility exercises. Afterwards, a squat exercise consisting of 3

repetitions at 20% RM, 3 repetitions at 40% RM, 3 repetitions at 60% RM, 1 repetition at 80% RM and 1 repetition at 90% RM was performed (Figure 1).

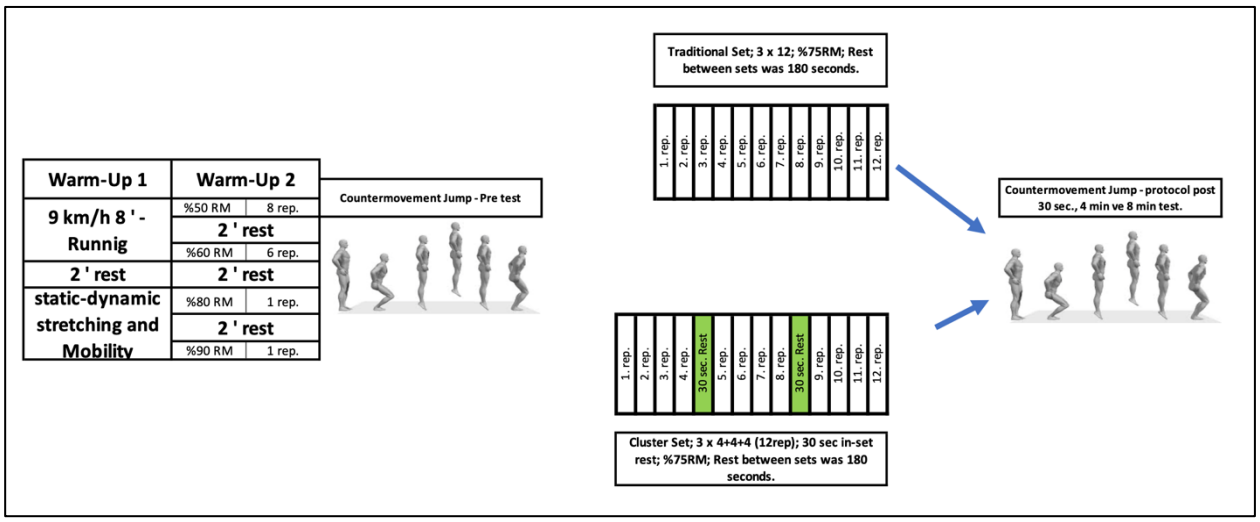

Figure 1: Research procedure

1 Repetition Maximum: For each 1RM assessment, a maximum of five 1RM attempts were allowed, not including a maximum of six warm-up repetitions performed to 90% of 1 RM. In consultation with each athlete, after a successful 1RM attempt, the barbell weight was increased between 0.5 and 2.5 kg until no more weight could be lifted. Rest periods consisted of 2 minutes between warm-up sets and 3 minutes of passive recovery between 1RM trials (Jidovtseff et al., 2011).

Countermovement Jump: OptoJump (MICROGATE, Bolzano / Italy) brand device was used to measure the height reached from the center of gravity, anaerobic power and elastic force affecting explosive power. Participants were asked to stand upright for 2 seconds before jumping. They were asked to squat quickly and jump vertically with the knees fully extended and in an upright position, with natural flexion of the knees.

3.1 Data Analysis

The data obtained as a result of the research were computerized. All statistical analyses were performed using SPSS 26 software package. Descriptive statistical methods (number, percentage, mean, standard deviation) were used to evaluate the data. Mean (X) and standard deviation (SD) values were presented as descriptive data. Shapiro-Wilk test was used in the normality test. As a result of the Shapiro-Wilk test, the data showed normal distribution. T-test (paired-samples) analysis was applied to determine the difference between the pre-test and post-test within the group. Significance was set at $p < 0.05$. To allow for a better qualitative interpretation of the data, effect sizes (ES) of p values were interpreted as small (0.20 to 0.49), medium (0.50 to 0.79) and large (>0.80) (Cohen, 1992).

4. Results

Table 1: Research group descriptive statistical analysis

Variable	**n**	X̄± Ss.	**Min. Max**	**Skewness**	**Kurtosis**
Age (year)	12	14,67±0,78	14.00- 16.00	.719	-.792
Height (cm)	12	168,67±4,81	162.00- 177.00	.140	-.910
Weight (kg)	12	49,25±2,38	47.00- 54.00	.811	-.434

Table 2: Traditional set group CMJ performance values: t test analysis.

Variable	**X̄± Ss.**	**t**	**p**
CMJ $_{\text{pre test}}$	29,88±3,21	-0.562	,585
CMJ $_{\text{30sec}}$	30,00±3,01		
CMJ $_{\text{pre test}}$	29,88±3,21	-3.108	**,010***
CMJ $_{\text{4 min}}$	31,01±2,51		
CMJ $_{\text{pre test}}$	29,88±3,21	-2.118	,058
CMJ $_{\text{8 min}}$	30,49±2,49		

When Table 2 is examined: in the traditional set protocol, there was no statistically significant difference between CMJ pretest-CMJ 30sec and CMJ pretest-CMJ 8min performances. However, there was a statistically significant difference between CMJ pretest-CMJ 4min (ES= 0.39 (small)) performances.

Table 3: Cluster set group CMJ performance values: t test analysis

Variable	n	X̄± Ss.	t	p
CMJ $_{\text{pre test}}$	12	29.21±2.83	-2.543	**,027***
CMJ $_{\text{30sec}}$		30.76±2.82		
CMJ $_{\text{pre test}}$	12	29.21±2.83	-7.065	**,000***
CMJ $_{\text{4 min}}$		32.39±2.90		
CMJ $_{\text{pre test}}$	12	29.21±2.83	-4.626	**,001***
CMJ $_{\text{8 min}}$		30.20±2.84		

When Table 3 is examined: in the cluster set protocol, a statistically significant difference was found between the performances of CMJ pretest- CMJ 30sec (ES= .55 (medium)), CMJ pretest- CMJ 4min (ES= 1.11 (large)) and CMJ pretest- CMJ 8min (ES= 0.35 (small)).

5. Discussion

This study examined the strengthening effects of two PAP protocols on jump performance. Athletes performed squat exercises with 75%RM using a traditional set and a cluster set configuration. Two main findings emerged. First, both protocols led to comparable time course effects on jump performance relative to baseline: 30 s, 4 and 8 min later, there was an increase in CMJ heights measured. Second, in line with our hypothesis, the cluster set configuration resulted in athletes achieving higher jump distances in all post-test measures compared to the traditional cluster configuration. We

hypothesize that this is because intra-set rest intervals may cause less fatigue, thus allowing for a greater extent of strengthening to take effect.

The rest interval between the PAP protocol and the performance test is crucial to obtain the benefits of a PAP effect (Gouvêa et al., 2013). Previous studies have found that the PAP response is highly personalized (Chiu et al., 2003; Duthie et al., 2002; McCann & Flanagan, 2010). The challenge of eliciting the PAP response consistently stems from a careful balance between the athlete's training status, the strength level achieved by the athlete, the intensity of the conditioning activity, and the duration following the strengthening activity. Rest intervals shorter or longer than optimal rest intervals can lead to fatigue or loss of PAP (Villalon-Gasch et al., 2022; Sale, 2002; Seitz et al., 2014; Wilson et al., 2013).

They suggested that stronger individuals may require shorter rest intervals after the conditioning activity for the PAP effect and have a greater PAP effect than individuals who have received recreational training (Chiu et al., 2003). A recent study with 27 taekwondo athletes (14 men and 13 women) investigated the effects of different set structures on PAP. According to the results of the study, the rest given within the set increases the PAP effect (Ouergui et al., 2022). However, the study did not examine the effect between female athletes and male athletes. The PAP effect between female athletes, who are more resistant to fatigue (Fulco et al., 1999), and male athletes (Arabatzi et al., 2014; Hatzikotoulas et al., 2009; Zafeiridis et al., 2005). In addition, the PAP effect can be achieved at rest intervals of 4 minutes or less in individuals with faster recovery, such as women and children (Arabatzi et al., 2014).

Cimadoro et al., (2019) had combat athletes perform 20 strokes (as hard as possible) every 3 seconds. They reported a significant increase in CMJ height (3.3±3.0%) after 5 minutes of rest from the applied technical stroke. Margaritopoulos et al. (2015) showed that a 5-minute jump intervention (3 x 5 jumps) in elite karate athletes resulted in a significant 3.5% improvement in CMJ height compared to the control group. da Silva Santos et al., (2015) investigated the difference between resistance training (1 x 3 sets, 95% RT), plyometric training (10x3 sets, 40 cm height) and complex training (resistance training + plyometric) methods in elite taekwondo athletes. They reported positive effects on CMJ performance compared to the control group after different rest periods (5 min, 10 min and self-selected rest interval). According to the findings from the meta-analysis of Wilson et al. (2013), recovery times between training volume and post-activation performance are considered to be determinants of performance success. Therefore, the acute increase in neuromuscular performance is associated with a higher sensitivity of actin and myosin molecules to Ca2+ availability (Esformes & Bampouras, 2013), increased excitability of œ-motor neurons, increased synchronization of motor unit firing, and reduced peripheral inhibition from Golgi tendon organs (Baker, 2001; Baker, 2003 Ebben, et al., 2000; Wilson et al, 2013). As a result of our study, it was determined that CMJ values were better in the CS protocol compared to TS, i.e. a similar effect was found.

A comparative or descriptive analysis of the study based on results, on previous studies, etc. The results should be presented in a logical sequence, giving the most

important findings first and addressing the stated objectives. The number of tables and figures should be limited to those absolutely needed to confirm or contest the premise of the study. The authors should deal only with new or important aspects of the results obtained. Material from the Results section should not be repeated, nor new material be introduced. The relevance of the findings in the context of existing literature or contemporary practice should be addressed.

5. Recommendations

It is important to conduct new studies on different PAP effects on female athletes. It is recommended to investigate the effects of different conditioning activities on metabolic stress and perceived exertion levels. In addition, more research should be conducted on female athletes in different teams and individual sports to better understand the effects of PAP.

6. Conclusion

Different resistance training set structures have different effects on PAP. Although there was no acute increase in performance 30 s after the end of the TS protocol with high-intensity load and multiple high repetition sets, an increase was observed in the CS protocol. This increase is thought to be due to the sudden replenishment of energy stores by the intermittent rests given within the set. In the study, the highest jump height was reached 4 min after both TS and CS protocols. In addition, there was a decrease in the jump height values 8 min after the TS protocol and it was observed that it approached the pre- protocol value. However, although there was a decrease in the jump height values 8 min after the CS protocol, it was found to be at a higher level than the pre-protocol value. In conclusion, when CS is used in the resistance training period, exercises following heavy loads are thought to be more effective in maintaining neuromuscular performance and PAP effects of female taekwondo athletes than TS.

About the Author(s)
Abdurrahman Boyaci, Marmara University, Institute of Health Sciences, Department of Physical Education and Sports, PhD student in movement and training sciences.
Istanbul Nişantaşı University, School of Physical Education and Sports, Coaching Education Department, Lecturer.
Email: a.rahmanboyaci@gmail.com
ORCID: https://orcid.org/0000-0002-3398-1189
ResearchGate: https://www.researchgate.net/profile/Abdurrahman-Boyaci
Google Scholar: https://scholar.google.com/citations?user=R4NhfowAAAAJ&hl=tr
Tuba Kizilet, Faculty of Sport Sciences, Department of Coaching Education, Department of Movement and Training Sciences.
Email: tuba.kizilet@marmara.edu.tr

ORCID: https://orcid.org/ 0000-0002-4460-2551
ResearchGate: https://www.researchgate.net/profile/Tuba-Kizilet-Bozdogan
Google Scholar:
https://scholar.google.com/citations?user=YWinp04AAAAJ&hl=tr&oi=ao

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