Effects of Plyometric and Cluster Resistance Training on Explosive Power and Maximum Strength in Karate Players

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ABSTRACT: The purpose of this study was to investigate the effects of plyometric and cluster resistance training on explosive power and maximum strength in karate players. Eighteen women, karate players (age mean ± SD 18.22 ± 3.02 years, mean height 163 ± 0.63cm, and mean body mass 53.25 ± 7.34 kg) were selected as volunteer samples. They were divided into two groups with respect to their recorded one repetition maximum squat exercise: [1] plyometric training (PT=9) and [2] Cluster training (CT=9) groups and performed a 9-week resistance training protocol that included three stages; [1] General fitness (2 weeks), [2] Strength (4 weeks) and [3] Power (3 weeks). Each group performed strength and power trainings for 7 weeks in stage two and three with owned protocol. The subjects were evaluated three times before stage one and after two and three stages for maximum strength and power. Data was analyzed using two way Repeated Measures (ANOVA) at a significance level of (P≤0.05). The statistical analysis showed that training stages on all research variables had a significant impact. The maximum strength of the pre-test, post-test strength and post-test power were in cluster group: 29.05 ± 1.54; 32.89 ± 2.80 and 48.74 ± 4.33w and in plyometric group were 26.98 ± 1.54; 38.48 ± 2.80 and 49.82 ± 4.33w respectively. The explosive power of the pre-test, post-test strength and post-test power in cluster group were 359.32±36.20; 427.91±34.56 and 460.55±36.80w and in plyometric group were 333.90±36.20; 400.33±34.56 and 465.20±36.80w respectively. However, there were not statistically significant differences in research variables between resistance cluster and plyometric training groups after 7 weeks. The results indicated both cluster and plyometric training program seems to improve physical fitness elements at the same levels.

KEY WORDS: Cluster training, plyometric training, Explosive power, maximum strength
INTRODUCTION

Muscular strength and power are considered as critical elements for a successful athletic performance, as well as for carrying out daily activities and occupational tasks [13, 6]. Also in sports that require jumping and sprinting, throwing, kicking, or hitting for speed or distance demand high-speed movement as well as force there is a need for muscular strength and power [22]. Although various training methods, including weight-training, explosive and ballistic type resistance training methods, electro stimulation training and vibration training have been effectively used for the enhancement of strength performance [7].

Benefits from the Plyometric Training (PT) include improved measures of muscular strength and power explosive. PT refers to performance of stretch-shortening cycle (SSC) movements that involve a high intensity eccentric contraction immediately after a rapid and powerful concentric contraction [2, 18, 24]. PT is explosive movements which generate large amount of force quickly [15]. The aim of these exercises is to increase concentric power output by lengthens the muscle prior to the contraction. This produces the greater force through the storage of elastic energy. PT also may enhance strength because muscles are trained under tensions greater than normal maximum tension due to the SSC [9].

Rahimi and Behpoor evaluated the effects of plyometric, weight and plyometric-weight combination training on anaerobic power and muscular strength. Based on their training, forty-eight male college students were divided into 4 groups: PT group (n=13), a weight training group (n=11), a plyometric plus weight training group (n=14), and a control group (n=10). In this research, the experimental subjects trained six-week for 2 days per week. This study was suggested that maximal strength as measured by the IRM squat was improved more by weight training than by plyometric training and there was no significant difference between weight training and plyometric - weight training and that short term plyometric training is capable of improving the vertical jumping ability, muscular strength and anaerobic power but its combination with weight training is even more beneficial [21].

The development of strength and power is an important component of training programs for the preparation and development of elite athletes. The complex nature of resistance training prescription for collision sports, training interventions require careful consideration to ensure that training outcomes are achieved.

Cluster Trainings (CT), sometimes termed inter repetition rest training, describes a training system whereby the rest periods are manipulated, breaking sets into small clusters of repetitions. [15, 8]. The concept of an inter repetition rest interval, or CT, was suggested as a method for allowing each repetition of the set to be performed with the highest quality. It was hypothesized that the cluster set configuration with 15–30 seconds of recovery period between repetitions may result in some Phosphocreatine (PCr) replenishment and therefore would allow the individual to experience partial recovery period and perform each repetition with a higher power output [8]. The cluster set was used maximum velocity and power in training. It has been postulated that breaking sets into small “clusters” of repetitions may improve the kinematic and kinetic (force, power, velocity) profile of a training set. This in turn may lead to improved training outcomes, particularly in the ballistic
performance training [8]. However, there is very little research tracking training outcomes after the implementation of cluster loading programs. Only one study to date has reported greater strength gains with the use of cluster. Reported cluster resulted in greater strength gains in the parallel back squat exercise (cluster, 52.4% ± 3.4%; Traditional, 41.8% ± 3.4%) following a 12-week per iodized program design.

These greater gains in strength occurred, despite no significant differences in hypertrophy or fiber type changes between traditional and cluster trainings. This is suggesting a possible neuromuscular adaptation [19].

The lower body strength and power adaptation in the squat (strength) and jump squat (power) movements compared between a cluster intervention and traditional resistance training resulted that strength significantly increased in both groups. There was also a significant increase in the power of the cluster group which was greater than the traditional group [25].

Since PT improved power and strength by coaches and athletes well known and no research has so far studied long-term effects of CT on the development of lower body power in karate players. Also, there are few studies on strength and power among young women. Therefore, the main purpose of this study is to compare power and strength between the CT and PT.

METHODS

This study used a quasi-experimental research with repeated measures to compare the effects of cluster and plyometric training on exclusive power and strength. The participants consisted of 18 female karate player age: 18.22±3.02 years; height: 163 ± 0.63 cm; body mass: 53.25 ± 7.34 kg who had no history of main injuries. This study was performed in nine weeks, which consisted of three stages: (1) General fitness (2 weeks), (2) strength (4 weeks), and (3) Power (3 weeks). General fitness training involved two types of movements that were performed 3 times in a week and for 2 weeks. In general fitness stage, two types of the movements (A and B) were used in order to involve both the lower and upper extremities muscles. Muscles specially involved in karate were mainly trained in the strength and power stages. Type (A) movement included: squat, leg extension, leg curl, heel raise, French curl, and barbell curl. Type (B) movement included: Bench press, incline bench press, lat pull-down, behind the neck press with barbell, and overhead press with barbell. The movements were performed in 3 sets of 60-80% of one Repetition Maximum (1RM), each set containing 9 repetitions with 60-90 seconds of rest between each two sets. The participants’ strength and power levels were measured for three times before general fitness stage and after strength and power stages. The effect of menstrual period on dependent variable monitored by questionnaire and in time data collection almost most of the subjects were not in menstrual cycle.

The maximum strength was evaluated by 1RM of squat movement. The subjects performed each repetition with knee flexion at 90°. One repetition maximum was calculated by the following formula. Results from this calculation method has been shown to have a very high correlation (r = 0.97) with actual 1RM in the squat movement [16].

\[
1RM = 100 \times \frac{W}{[102.78 - (2.78 \times R)]}
\]

RM: repetition maximum, W: weight, R: Repetition

After a standardized warm-up, each subject performed 6 jumps up squat movements at
20% of 1RM applying the technique described by Hori et al. The power test (jump up technique) (Figure 1) involved the subjects standing at a self-selected foot width with an Olympic bar placed on their upper trapezius immediately below C7 [10]. The subjects performed a countermovement to a self-selected depth and immediately preformed a maximal jump up. The subjects were instructed to keep the depth of countermovement consistent between the jumps for maximum height on each repetition. All the subjects were familiar with the jump up squat movement. The six motion analyzer cameras (Raptor-H Digital Real Time System) were utilized to record the participant movements. The software (Cortex Version 2.5.0.1160-64 Bit) was measured subject speed by 200 frames per second. Since the cameras only markers know, Markers were connected on the parts of body participants. These three markers installed on anterior-superior iliac spines, big toe and barbell on the right view of body subject. Then, the squat jumps techniques were filmed and the displacement was measured as following: \( m \) = mass; body + mass barbell (kg); \( g \) = gravitational acceleration (9.81 ms\(^{-2}\)); \( h \) (the jump height) ; \( h_s \) (the height of hip marker in the starting position); \( h_{po} \) (vertical push-off distance).

The mean power of the lower limbs developed as following formula (Pierre, 2008):

\[
P = mg \left(1 + h_{po}\frac{h}{h_s}\right) \sqrt{gh_s^2} \]


The maximum strength and power were evaluated after 2 weeks of general fitness as described previously. Subsequently, the subjects were grouped according to their 1RM calculation. The means of 1RM in squat movement was approximately equal between two groups. Then the subjects were divided into 2 groups: (1) plyometric group (n=9), (2) cluster group (n=9), and performed strength and power trainings for 7 weeks. The strength phase included Squat, lunge, leg curl, French curl, and Bench press; which the volume and intensities of training protocol were presented in Table1. Each training session consisted of three steps: (1) Warm up (2) Basic training and (3) Cool-down. Both groups performed the first and the third stage in 10 minutes. The movements of cluster group in Power phase include: Squat, jump squat.
and bench press and the plyometric group include: jump squat, bench press, box jump, jump deep (Table 2).

Table 1
The training protocol of strength stage in cluster and plyometric groups

| Groups  | Period (week) | Sessions (Week) | Sets | repetition | Inter set rest (second) | Inter repetition rest (second) | (% 1RM) | Intensity |
|---------|---------------|-----------------|------|------------|------------------------|-----------------------------|---------|
| Cluster | 4             | 3               | 3    | 5          | 120                    | 10-30                       | 85%     |
| plyometric | 4             | 3               | 5    | 5          | 120                    | 0                           | 85%     |

Table 2
The training protocol of power stage in cluster and plyometric group

| Groups     | Period*Sessions (week) | Set* Repetition | Inter set rest (S) | Inter repetition rest (S) | Intensity (% 1RM) |
|------------|------------------------|-----------------|--------------------|--------------------------|-------------------|
| Cluster    | 3*3                    | 3*5             | 120                | 10-30                    | squat 80% Jump squat 20% Bench press 45% |
| plyometric | 3*3                    | 3*12            | 180                | 0                        | Box Jump (30cm) deep push Jump (50cm) squat Bench press 20% 45% |

Statistical analysis
Two-way repeated measure (ANOVA) and Bonferroni post hoc tests were used for comparing data between plyometric and cluster groups in the pre-test and two post-test stages (strength and power) (P\(\leq 0.05\)). All the statistical analyzes were performed by SPSS software (version 16, SPSS, Inc., Chicago, IL).

**STATISTICAL RESULTS**
The p value (0.001) and the F ratio (40.89) calculation indicated that the training stages had a significant impact on the maximum strength among the subjects (p\(\leq 0.05\)).

The mean differences of the maximum strength between three training stages were identified by Bonferroni test. Table 3 and Figure 1 indicated that significant differences were between pretest and post-test strength stages (7.67; p=0.001); pretest and post-test power stages 21.26; p=0.000); and post-test strength and post-test power stages (13.59; p=0.001). There was no significant difference (F=0.19; p=0.66) on maximum strength between plyometric and cluster training group.

Table 3
Bonferroni post hoc test (comparison between the two levels of training)

|                           | Mean differences ± SD | P Value |
|---------------------------|------------------------|---------|
| Pre-test                  |                        |         |
| post strength             | 7.67±1.57              | 0.001   |
| post power                | 21.26±2.57             | 0.001   |
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|                  | Post-test strength | Post-test power |
|------------------|--------------------|-----------------|
| Pre test         | -7.67±1.57         | -21.26±2.57     |
| Post power       | 13.59±2.81         | -13.59±2.81     |

The p value (0.001) and the F ratio (65.57) calculation indicate the training stages had a significant impact on the explosive power among the subjects (p≤0.05). The mean differences of the explosive power between three training stages were identified by Bonferroni test. Table 4 and Figure 2 indicates that significant differences were between pretest and post-test strength stages (62.50; p=0.00); pre-test and post-test power stages (-111.26; p=0.00) and post-test strength and post-test power stages (48.75; p=0.00). There was no significant difference (F=1; p=0.79) on explosive power between plyometric and cluster training group.

![Graph showing maximum strength changes](graph.png)

**Figure 1:** The maximum strength changes in various stage of cluster and plyometric group

|                  | Post-test Power | Post-test Strength | Pre-test |
|------------------|-----------------|--------------------|----------|
| Cluster          | 48.74           | 32.89              | 29.05    |
| Plyometric       | 49.82           | 38.48              | 26.98    |

**Table 4**
Bonferroni post hoc test (comparison between the two levels of training)

|                | Mean differences ± SD | P Value |
|----------------|------------------------|---------|
| Pre-test       |                        |         |
| post strength  | 62.50±8.50             | 0.001   |
| post power     | 111.26±11.94           | 0.001   |
| Post-test strength |                  |         |
| pre test       | -62.50±8.50            | 0.001   |
| post power     | 48.75±8.34             | 0.001   |
| Post-test power |                      |         |
| pre test       | -111.26±11.94          | 0.001   |
| Post strength  | -48.75±8.34            | 0.001   |
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Explosive Power

| Watt |
|------|
| 500  |
| 450  |
| 400  |
| 350  |
| 300  |
| 250  |
| 200  |
| 150  |
| 100  |
| 50   |
| 0    |

Posttest Power

Posttest Strength

Pretest

Cluster

460.2

427.91

359.32

Plyometric

465.2

400.33

333.9

Figure 2: The explosive power changes in various stage of cluster and plyometric

DISCUSSION

The hypotheses testing indicate the strength and power stages had significant influence on maximum strength (p=0.0001) of karate players. Mean differences of strength and power training stages were 13.59 ± 2.81kg (p =0.001) and 7.76 ± 1.57 kg (p =0.001) respectively.

The maximum strength of the pre-test, post-test strength and post-test power were in cluster group: 29.05 ± 1.54; 32.89 ± 2.80 and 48.74 ± 4.33W and plyometric group were 26.98 ± 1.54; 38.48 ± 2.80 and 49.82 ± 4.33W respectively.

The cluster recovery time was 15 seconds which result in increasing maximum force generation capacity and it is approximately 79.7% of its initial capacity [21]. The conceptual model of employing a cluster set configuration appears to be a sound model for developing maximal strength, enhancing power generating capacity, or stimulating greater hypertrophy [8].

Collectively, it appears that, from a theoretical standpoint, the inclusion of cluster set configurations has the potential to alter the training stimulus and ultimately magnify the adaptive response. By altering the set configuration, the strength and conditioning professional may have the ability to develop specific adaptive responses that may favor maximal strength, explosive strength and power, or muscular growth [15].

Research indicates plyometric training improves strength, power output, coordination, and athletic performance [1, 10]. Numerous studies on plyometric training have demonstrated improvements in maximal strength, ranging from11 kg to 60 kg (performing exercises such as drop jumps, countermovement jumps, and squat jumps or combined weights and plyometric training) that could be attributed to the enhanced coordination and the individual’s ability to rapidly increase muscle tension resulting in greater maximal rate of force development [13, 5].

The improvements in ballistic type strength training is probably due to adaptation of the neural system during the initial weeks, such as increased motor unit firing frequency, motor unite synchronization, motor unite excitability and efferent motor drive. Also, the part of these
may be due to a reduction in antagonist activation muscle and increasing activation of the synergist muscles [7].

The findings showed that the exercise of strength and power stages have significant effect on the explosive power (p=0.00) karate players. The mean difference explosive power of strength and power stages respectively were 48.75 ± 8.34 w (p=0.00) and 62.50 ± 8.50 W (p =0.00) respectively.

The explosive power of the cluster group in the pre-test, post-test (strength stage) and post-test (power stage) were 359.32 ± 36.20, 427.91 ± 34.56W and 460.55 ± 36.80W respectively; also plyometric group were to 333.90 ± 36.20, 400.33 ± 34.56W and 465.20 ± 36.80W respectively.

Loading cluster, 15-30 seconds of rest between the repetitions helps re-synthesizing some of the depleted phosphocreatine (PCr) in the muscle cell, and thus reduces fatigue [8]. Bogdanis et al. (1995) demonstrated that PCr re-synthesis is important in the recovery of power during repeated bouts of sprint exercise. Significant correlations were found between the re-synthesis of PCr and the percentage of mean power restoration during the initial 6 seconds of exercise and after 1.5 and 3 minutes of recovery [3]. Furthermore, studies demonstrated PCr synthesis half-time to be 21-22 seconds, and that occlusion of the blood circulation to a fatigued skeletal muscle inhibits PCr re-synthesis. Therefore, it is speculated that an inter-repetition rest of at least 20 seconds may allow for partial PCr resynthesize and maintenance of power, force, and velocity [20, 9]. This notion is supported by Pereira et al. who demonstrated that rest interval lengths of 14 to 17 seconds were sufficient to maintain jumping performance during 30 maximal volleyball spikes. Whereas, a rest interval length of 8 seconds resulted in increased blood lactate concentrations and decreased countermovement jump performance [20].

Plyometric exercises increase the speed contraction of eccentric to concentric contraction phase and the concentric activity recruiting more motor units and producing more force. The plyometric training nature is interaction between speed and strength and improving explosive power muscle. These exercises improve muscle-skeletal system, involve muscle spindles and effect on viscoelastic properties of the muscles and consequently produce more maximum power [12].

Explosive power is forming a tensional-shortened contraction which extensor muscles demonstrate more stiffness and increases tension in the tendons. This increased tension results in eccentric phase to be more effective and efficient. In addition, the functional nerve reflexes are more affected during plyometric stretches compared to voluntary contraction. These reflexes correspondingly increase tension in the tendons along with neurological outcome in phase concentric makes one produce a stronger pressure to leave the land [4].

There were no significant differences between seven weeks plyometric and cluster training on strength and explosive power in karate players and the impacts of two type training on strength and explosive power were similar statistically.

Wilson et al. investigated the effects of plyometric and weight training on eccentric and concentric forces. Forty-one trained males randomly grouped in control, plyometric, and weight training and the training protocol performed among the experimental group for 8 weeks. The Peak force of counter movement jump increased in plyometric and weight training groups but there was no significant difference between the groups.
There was no significant difference in rate of force development (RFD) between the three groups and there was no significant difference in peak force concentric contraction among three groups. The RFD of plyometric group increases significantly [24]. In addition, the effects of plyometric depend on training level, gender, age, sport activity and plyometric training backgrounds [7].

Holcomb et al. (1996) compared the effects of resistance training and plyometric-style training involving various types of depth jump and they found no significant differences between groups in jump height or power. They concluded that power in plyometric training had no more effective than traditional resistance training [10].

Duration and training volume in experimental groups and exercise protocol probably due to lack of difference between training methods. Based on the results, these training methods had equally effect on explosive power and strength. It seems a longitudinal study need to compare the effects of these trainings methods.

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REFERENCES

1. Adams, K., O'Shea, J. P., O'Shea, K. L., and Climstein, M. The Effect of Six Weeks of Squat, Plyometric and Squat-Plyometric Training on Power Production. The Journal of Strength & Conditioning Research, (1992). 6(1), 36-41.

2. Bobbert, M. F. (1990). Drop jumping as a training method for jumping ability. Sports medicine, 9(1), 7-22.

3. Bogdanis, G. C., Nevill, M. E., Boobis, L. H., Lakomy, H. K., and Nevill, A. M. Recovery of power output and muscle metabolites following 30 s of maximal sprint cycling in man. The Journal of physiology, (1995). 482(Pt 2), 467.

4. Bompa Tudor O. Power Training for Sport: Plyometric for Maximum Power Development Paperback – January 1, (2010).

5. Clutch, D., Wilton, M., McGown, C., and Bryce, G. R. The effect of depth jumps and weight training on leg strength and vertical jump. Research Quarterly for Exercise and Sport, (1983). 54(1), 5-10.

6. De Villarreal, E. S. S., Kellis, E., Kraemer, W. J., and Izquierdo, M. Determining variables of plyometric training for improving vertical jump height performance: a meta-analysis. The Journal of Strength & Conditioning Research, (2009). 23(2), 495-506.

7. De Villarreal, E. S. S., Requena, B., and Newton, R. U. Does plyometric training improve strength performance? A meta-analysis. Journal of Science and Medicine in Sport, (2010). 13(5), 513-522.

8. Haff, G. G., Hobbs, R. T., Haff, E. E., Sands, W. A., Pierce, K. C., and Stone, M. H. Cluster training: a novel method for introducing training program variation. Strength & Conditioning Journal, (2008). 30(1), 67-76.

9. Hori, N., Newton, R. U., Andrews, W. A., Kawamori, N., McGuigan, M. R., and Nosaka, K. Comparison of four different methods to measure power output during the hang power clean and the weighted jump squat. The Journal of Strength & Conditioning Research, (2007). 21(2), 314-320.

10. Komi, P. V. Stretch-shortening cycle: a powerful model to study normal and fatigued muscle. Journal of biomechanics, (2000). 33(10), 1197-1206.

11. Kraemer, W. J., Mazzetti, S. A., Nindl, B. C., Gotshalk, L. A., Volek, J. S., Bush, J. A., ... and Hakkinen, K. Effect of resistance training on women's strength/power and occupational performances. Medicine and Science in Sports and Exercise, (2001). 33(6), 1011-1025.

12. Kramer, J. F., Morrow, A., and Leger, A. N. D. A. Changes in rowing ergometer, weight lifting, vertical jump and isokinetic performance in response to standard and standard plus plyometric training programs. International journal of sports medicine, (1993). 14(8), 449-454.

13. Lawton, T. W., Cronin, J. B., and Lindsell, R. P. Effect of interrepetition rest intervals on weight training repetition power output. The Journal of Strength & Conditioning Research, (2006). 20(1), 172-176.

14. LeSuer, D. A., McCormick, J. H., Mayhew, J. L., Wasserstein, R. L., and Arnold, M. D. The Accuracy of Prediction Equations for Estimating I-RM Performance in the Bench Press, Squat, and Deadlift. The Journal of Strength & Conditioning Research, (1997). 11(4), 211-213.

15. Malisoux L, Francaux M, and Nielsens H. Stretch-shortening cycle exercises: An effective training paradigm to enhance power output of human single muscle fibers. Journal of Applied Physiology: (2006). 100,771–9
18. Matavulj, D., Kukolj, M., Ugarkovic, D., Tihanyi, J., and Jaric, S. *Effects of plyometric training on jumping performance in junior basketball players*. Journal of sports medicine and physical fitness, (2001). 41(2), 159.

19. Oliver, J. M., Jagim, A. R., Sanchez, A. C., Mardock, M. A., Kelly, K. A., Meredith, H. J., and Kreider, R. B. *Greater gains in strength and power with intraset rest intervals in hypertrophic training*. The Journal of Strength & Conditioning Research, (2013). 27(11), 3116-3131.

20. Pereira, G., Almeida, A. G., Rodacki, A. L., Ugrinowitsch, C., Fowler, N. E., and Kokubun, E. *The influence of resting period length on jumping performance*. The Journal of Strength & Conditioning Research, (2008). 22(4), 1259-1264.

21. Rahimi, R., and Behpur, N. *The effects of plyometric, weight and plyometric-weight training on anaerobic power and muscular strength*. Physical Education and Sport, (2005). 3(1), 81-91.

22. Sahlin, K., and Ren, J. M. *Relationship of contraction capacity to metabolic changes during recovery from a fatiguing contraction*. Journal of Applied Physiology, (1989). 67(2), 648-654.

23. Wilson, G. J., Newton, R. U., Murphy, A. J., and Humphries, B. J. *The optimal training load for the development of dynamic athletic performance*. Medicine and science in sports and exercise, (1993). 25(11), 1279-1286.

24. Young, W. B., and Bilby, G. E. *The Effect of Voluntary Effort to Influence Speed of Contraction on Strength, Muscular Power, and Hypertrophy Development*. The Journal of Strength & Conditioning Research, (1993). 7(3), 172-178.

25. Zarezadeh-Mehrizi, A., Aminai, M., & Amiri-khorasani, M. *Effects of Traditional and Cluster Resistance Training on Explosive Power in Soccer Players*. Iranian Journal of Health and Physical activity, (2013). 4(1).