EFFECTS OF INTER-SET RECOVERY OF PLYOMETRIC TRAINING ON ANAEROBIC POWER AND EXPLOSIVE POWER PERFORMANCE OF BOYS

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Abstract

Objectives: to find out the effects of inter-set recovery of plyometric training on the anaerobic power and explosive power performance of boys.

Design: The students were divided randomly into 3 groups' plyometric training group (PG; n = 20), Plyometric and recovery training group (PRG; n = 20) and control group (CG; n = 20).

Setting: The three groups did not significantly ($p > 0.05$) after randomisation in the dependent variable. The data obtained from the subjects are analysed statistically by applying analysis covariance (ANACOVA) at a 0.05 level of significance.

Participants: 60 physically active boy students were recruited from the age group of 14 to 17 years. The selected students were randomly divided into three equal groups. Control Group (CG – 20 No, Age 15.4 ± 1.71, Height 170.3 ± 6.81, Body mass 69.4 ± 5.34 and BMI 24.3 ± 1.91), Plyometric Group (PG - 20 No, Age 15.2 ± 1.89, Height 169.7 ± 8.44, Body mass 70.5 ± 5.91 and BMI 24.5 ± 1.62) and Plyometric and Recovery Group (PRG- 20 No, Age 15.5 ± 1.74, Height 172.5 ± 6.92, Body mass 69.2 ± 7.51 and BMI 23.1 ± 1.21).

Main Outcome Measures: Explosive performance was assessed using a jump and reach method and anaerobic power was assessed by using the Margaria Kalamon stair climb power test.

Results and conclusion: The study's findings indicated that 12 weeks of plyometric and recovery training increased explosive performance and anaerobic capacity.

Keywords: Recovery, Margaria Stair Climb, Depth Jump, Intensity, Explosive Power.

INTRODUCTION

Children not practicing physical exercise will never fully develop their genetic potential in terms of motor skills. If they are doing regular physical activity, leads to better blood circulation and oxygen supply to the brain, an increase in bone and muscle density, and higher tolerance to stress (Branet et al., 2020; Tabacchi et al., 2019). Plyometric training is composed of extremely fast, powerful, short-duration movements designed to increase the speed and the force of the muscle contractions. Therefore plyometrics is used predominantly to improve explosive, forceful sporting activities, such as running speed in a 100-meter sprint, jump height in a high jump, distance in a javelin throw or the power of a boxer's punch (Sproule, 2012). Plyometric training is a category of explosive bodyweight resistance exercise which focuses on exploiting the additional force output of the stretch reflex of a muscle to increase speed and power (Booth & Orr, 2016).

The plyometric exercise involves stretching the muscles immediately before making a rapid concentric contraction. The combined action is commonly called a stretch-shortening cycle (SSC) (Abka& Hephard, 2010). Traditional plyometric exercise includes variations of bounding, hopping and jumping drills. However, true plyometric training requires the rapid pre-stretch of the muscle and maximal effort of the athletes during the concentric muscle action. This type of plyometric training can be found in various forms of depth jump and box jump (LaChance, 1995; Luebbers et al., 2003).

Plyometric exercises help to develop the whole neuromuscular. This exercise has two stages of muscle contraction, eccentric contractions in the first stage and the second stage involves the contraction of the introspective eccentric contraction which occurs immediately after (Hemmati Sarapardech et al., 2014). Plyometric movements, in which a muscle is loaded and then contracted in rapid sequence, use the strength and innervations of muscle and surrounding tissue to jump higher and run faster, depending on the desired training goal (Ameer, 2020). Plyometric exercise as a result of tension is built on the reflex contraction of the muscle fibres due to the sudden pressure on these fibres (Hemmati Sarapardech et al., 2014; Myer et al., 2006). Plyometric exercise evokes the elastic properties of the muscle fibres and connective tissues in a way that allows the muscles to store energy during the deceleration phase and release that energy during the acceleration period (THAKUR et al., 2016).

In terms of training volume, weight training with lower volume and higher explosive velocity induce similar strength gains and greater improvement in jump and sprint performance compared with high load weight (Arris et al., 2008; Guan et al., 2021; McBride et al., 2002; Rodríguez-Rosell et al., 2017). Recovery is a process which is directly related to the applied training load. The proper recovery will help to restore lost energy. The impact resulting from proper recovery after exercise will increase physical quality and performance (Kurniawan et al., 2021) and help to return the physical condition to its original state. However, few types of research have been conducted concerning the effect of inter-set recovery time on athletes' performance during plyometric training. The inter-set recovery time is most important to avoid physical fatigue. Muscle fatigue is not beneficial for sports performance; it is harmful and causes serious injury when the fatigue level is high.

Plyometrics have been used for many decades in the Russian and eastern European training of track and field (Fischetti et al., 2018). The minimum duration of plyometric training must be at least 6 weeks to bring significant benefits and increased performance to young athletes. (Faigenbaum et al., 2007; Fischetti et al., 2018). Plyometric training can elicit varied training effects depending on the nature of the training program. This is usually determined by the desired spot-specific performance (Booth & Orr, 2016). The main findings were that plyometric training is, likely to provide greater benefits to vertical jump than sprint speed (Fischetti et al., 2018). Plyometric training is explosive; therefore accurate measurement of performance is vital to detect significant worthwhile changes (Booth & Orr, 2016). It is measured in several ways. Most commonly, the force plate measures contact time ground reaction forces, take-off velocity (Donoghue et al., 2011; Etushek, 2011) and electromyography to evaluate muscle activation patterns are used to assess performance with plyometric exercise (Benelli& Massimiliano Ditroilo, 2004; Booth & Orr, 2016).

In sports such as soccer, basketball etc in which numerous bursts of explosive activity are required, explosive strength determines high-level performance (Ampo et al., 2009; Manolopoulos et al., 2006). Research has demonstrated that plyometric training has a positive impact on maximal strength and power (Booth & Orr, 2016). Explosive strength is the property of producing powerful momentum in the shortest time possible. It defines the speed of producing power from the beginning of the movement up to reaching the maximum level of expression (Branet et al., 2020). A specific type of explosive strength training may lead to specific neural adaptation, such as an increased rate of activation of motor units, whereas muscle hypertrophy remains much smaller than during typical heavy resistance strength training (Paavolainen et al., 1999).

Currently, available findings regarding jump height and sprint performance are contradictory. In one study, 6 weeks of depth jump or CMJ training improved the vertical jump height ($p < 0.05$) of youth soccer players but their sprint performance remains unchanged (Abka& Hephard, 2010; Homas & Rench, 2009). Likewise, another study found that 10 weeks of plyometric training increased squat jump (SJ) and CMJ height and power but 20 m sprint time remained unchanged (Abka& Hephard, 2010; Markovic et al., 2007). In contrast, other studies found that 8 weeks of plyometric training improved 0-10 m and 0 to 40 m sprint time (Rimmer& Sleivert, 2000). Devillavrcal (Sáez-Sáez de Villarreal et al., 2008) recently noted significant decreases in 20 m sprint time and jump height (CMJ and drop jump) if a 7-week plyometric training program was followed by 7 weeks of detraining.

METHODOLOGY

The current study was conducted to compare the effects of the same type of plyometric training with equal volume and intensity with different rest duration of anaerobic power and vertical jump performance. For the completion of this study, 60 physically active boys students were recruited from an Indian school in Qatar with the age group of 14 to 17 years. The selected students were randomly divided into three equal groups. Control Group (CG – 20 No, Age 15.4 ± 1.71, Height 170.3 ± 6.81, Body mass 69.4 ± 5.34 and BMI 24.3 ± 1.91), Plyometric Group (PG - 20 No, Age 15.2 ± 1.89, Height 169.7 ± 8.44, Body mass 70.5 ± 5.91 and BMI 24.5 ± 1.62) and Plyometric and Recovery Group (PRG- 20 No, Age 15.5 ± 1.74, Height 172.5 ± 6.92, Body mass 69.2 ± 7.51 and BMI 23.1 ± 1.21). Each subject was informed about the benefits and risks of plyometric training. Parental concern was also obtained for the subject.

All the initial data were collected two days before training started. Using the jump and reach method the vertical height was measured. All participants completed an aerobic warm-up followed by stretching and perform a 3 to 4 practice jump at the sub-maximal effort. Three test jumps were allowed to the participants with 4 min recovery between the jumps. Out of the three jumps, the best performance was used to determine vertical jump peak power using the formula of Harmon (Engel, 2014; Luebbers et al., 2003). The Margaria Kalamon stair climb power test was conducted using two switch mats on the third and ninth steps. Each participant completed a standardized aerobic warm-up followed by stretching and performed three practice stair run with sub-maximal effort. The participants started 6 metres from the base of the stair. The participants then sprinted 2-3 steps at a time. The time is automatically recorded between the third and ninth steps. The power output was calculated by (Stair et al., 2014)

$$P = \frac{\mathrm{W} * \mathrm{D}}{\mathrm{t}}$$

Where P = Power in Watts

W = Body weight in Kilogram

D = Vertical height between the stair (1.05 m)

T = Time in seconds.

The same type of Plyometric training schedule was given to both the experimental group. The plyometric training period lasted for 45 to 90 minutes and consisted of various sprints (5-10 m, 10-20 m) and jumping exercises (Hurdle jump, Vertical jump, Drop jump – 20 cm, drop to hurdle jump- 20 cm to 50 cm, standing triple jump, squat jump, Hopping- 10 m and Bounding – 20 m). The training session was conducted in both experimental groups three days a week for 12 weeks. After completing the training section, the students rested for two days, and then the subjects performed the final test. The test was conducted under the same experimental condition by the same researcher. Only verbal encouragements were provided throughout the test to make the sure maximal effort. The mean and the standard deviation were calculated from the collected data using the standard statistical method. Training related measured by one-way analysis of variance (ANOVA). If a significant F value was observed, Scheffe's post hoc procedure was applied to identify pairwise differences. Plyometric Training schedule for 12 weeks

Table 1, Training schedule for 1-12 weeks

Weeks	Exercises	Set/Repetition	Plyometric Group (Rest)	Plyometric and Recovery Group (Rest)
1 – 4	1. Vertical jump	2 x 10	1Min / 3 Min	2Min / 6 Min
	2. Standing triple jump	2 x 6	1Min / 3 Min	2Min / 6 Min
	3. Sprint 5-10 m	2 x 5	1Min / 3 Min	2Min / 6 Min
	4. 20 m bounding	2 x 5	1Min / 3 Min	2Min / 6 Min
5 – 8	1. Hurdle jump 50 cm	2 x 10	1Min / 3 Min	2Min / 6 Min
	2. Drop jump 20 cm	3 x 6	1Min / 3 Min	2Min / 6 Min
	3. Squat jump	3 x 8	1Min / 3 Min	2Min / 6 Min
	4. Sprint 10 – 20 m	2 x 5	1Min / 3 Min	2Min / 6 Min
9 – 12	1. Drop to hurdle jump (20 cm to 50 cm)	3 x 6	1Min / 3 Min	2Min / 6 Min
	2. Hopping 10 m	3 x 5	1Min / 3 Min	2Min / 6 Min
	3. Standing triple jump	3 x 6	1Min / 3 Min	2Min / 6 Min
	4. Squat jump	3 x 8	1Min / 3 Min	2Min / 6 Min

Table-2, Anthropometric profiles of the subjects.

Groups	Age (years)	Height (cm)	Body weight (kg)	BMI
Control Group	15.4 ± 1.71	170.3 ± 6.81	69.4 ± 5.34	24.3 ± 1.91
Plyometric Group	15.2 ± 1.89	169.7 ± 8.44	70.5 ± 5.91	24.5 ± 1.62
Plyometric and Recovery Group	15.5 ±1.74	172.5 ± 6.92	69.2 ± 7.51	23.1 ± 1.21

RESULTS AND DISCUSSION

The 12 weeks of plyometric training revealed significant performance among both PTG and PRG in anaerobic power and vertical jump performance.

Result of Anaerobic Power

The anaerobic results are given in Tables 3-5. The applied plyometric and plyometric recovery training program resulted in significant changes in the anaerobic power of the Margaria Kalamon stair climb power test. The pre and post-test mean and SD of CG were 77.51 ± 8.81 and 77.88 ± 8.99, in PTG was 76.47 ± 8.75 and 83.01 ± 9.15by improved the performance by 9.07% and in PRG was 78.21 ± 8.85 and 87.28 ± 9.35 was the pre and post-test result by improved the performance of 11.5 % respectively. The F value of the post-test score of the anaerobic power shows 4.11 was significant at a 0.05 level of confidence. Scheefs post-hoc analysis showed that the anaerobic performance was different in PTG, PRG and CG. The mean difference between PRG and CG was 9.4, between PRG and PTG was 4.27 and between PTG and CG was 5.13. The above data shows that PRG had a better performance in anaerobic power compared to PTG and CG.

Table-3, Mean and SD for Pre and Post-test scores of Anaerobic Power

scores	Pre-test	Post-test
	Mean ± SD	Mean ± SD
Control	77.51 ± 8.81	77.88 ± 8.99
Plyometric	76.47 ± 8.75	83.01 ± 9.15
Plyometric and Recovery	78.21 ± 8.85	87.28 ± 9.35

Table-4, Result of one-way ANOVA between Control, plyometric and Plyometric & Recovery with respect to the Anaerobic Power

Source at Variance	dt	Ssx	SSy	MSX (Vx)	MSY (Vy)
Between groups	2	30.9	1046.77	15.5	523.29
Within groups	57	685.29	7247.32	12.03	127.15
Total	59	116.11	8294.09	F= 1.28	F= 4.11

Table value of 5% level -3.18, 1% level – 5.06

F value of pre-test score = 1.28 (insignificant)

F value of post-test score = 4.11 (significant)

Table-5, Scheefs post hoc test for difference between groups for anaerobic power

Mean values			Mean difference	L.S
Plyometric and Recovery	Plyometrics	Control		
87.28		77.88	9.4	0.01
87.28	83.01		4.27	0.01
	83.01	77.88	5.13	0.01

C.I value at 0.05% - 6.42, 1% - 8.112

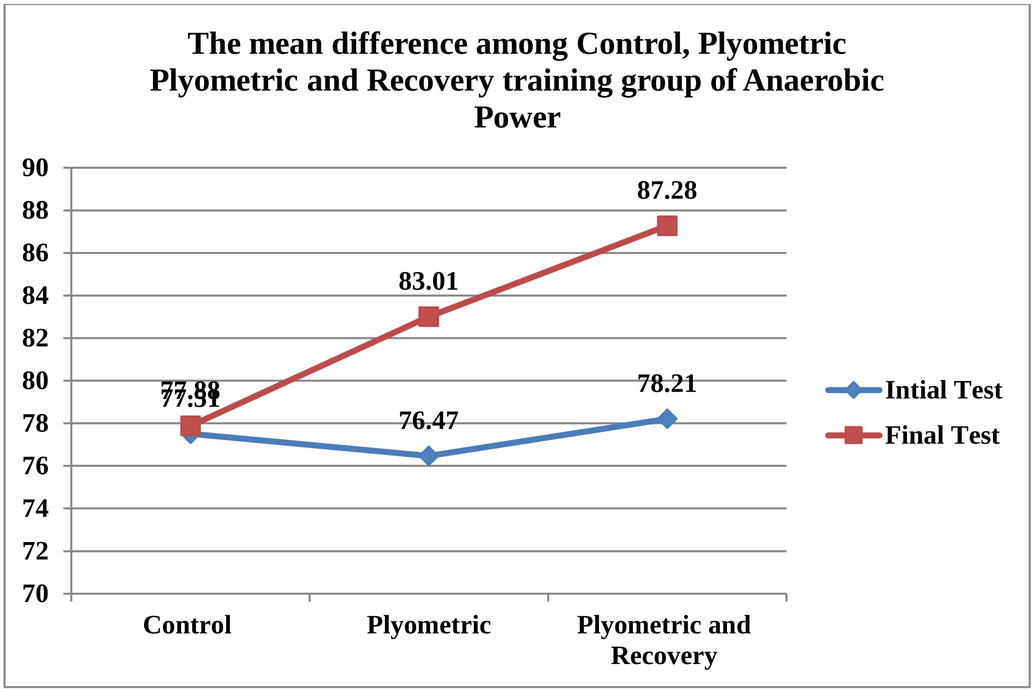

Figure-1

Result of Vertical Jump

The vertical jump performance results are given in Tables 6-8. The applied plyometric and plyometric recovery training program resulted in significant changes in the vertical jump test. The pre and post-test mean and SD of CG were 54.76 ± 7.40 and 54.71 ± 7.40, in PTG was 54.16 ± 7.36 and 60.21 ± 7.76 by improved the performance by 11.17% and in PRG was 53.81 ± 7.34 and 63.76 ± 97.99 was the pre and post-test result by improved the performance of 18.49 % respectively. The F value of the post-test score of the anaerobic power shows 12.77 was significant at a 0.01 level of confidence. The Scheefs post-hoc analysis showed that the vertical jump performance was different in PTG, PRG and CG. The mean difference between PRG and CG was 9.05, between PRG and PTG was 3.55 and between PTG and CG was 5.5. The above data shows that PRG had a better performance in vertical jump height performance compared to PTG and CG.

Table-6, Mean and SD for Pre and Post-test scores of Vertical Jump

Groups	Pre-test	Post-test
	Mean ± SD	Mean ± SD
Control	54.76 ± 7.40	54.71 ± 7.40
Plyometric	54.16 ± 7.36	60.21 ± 7.76
Plyometric and Recovery	53.81 ± 7.34	63.76 ± 7.99

Table-7, Result of on- way ANOVA between Control, Plyometric and Plyometric & Recovery concerning the vertical jump

Source at Variance	dt	Ssx	SSy	MSX (Vx)	MSY (Vy)
Between groups	2	9.24	831.71	4.616	415.86
Within groups	57	3013.51	1855.16	52.87	32.55
Total	59	3022.75	2686.87	F= 0.087	F= 12.77

Table value of 5% level -3.18, 1% level – 5.06

F value of pre-test score = 0.087 (insignificant)

F value of post-test score = 12.77 (significant at 1%)

Table-8, Scheefs post-hoc test for difference between groups for vertical jump

Mean values			Mean difference	L.S
Plyometric and Recovery	Plyometrics	Control		
63.76		54.71	9.05	0.01
63.76	60.21		3.55	N S
	60.21	54.71	5.5	N S

C.I value at 0.05%-16.38, 1 % -20.695

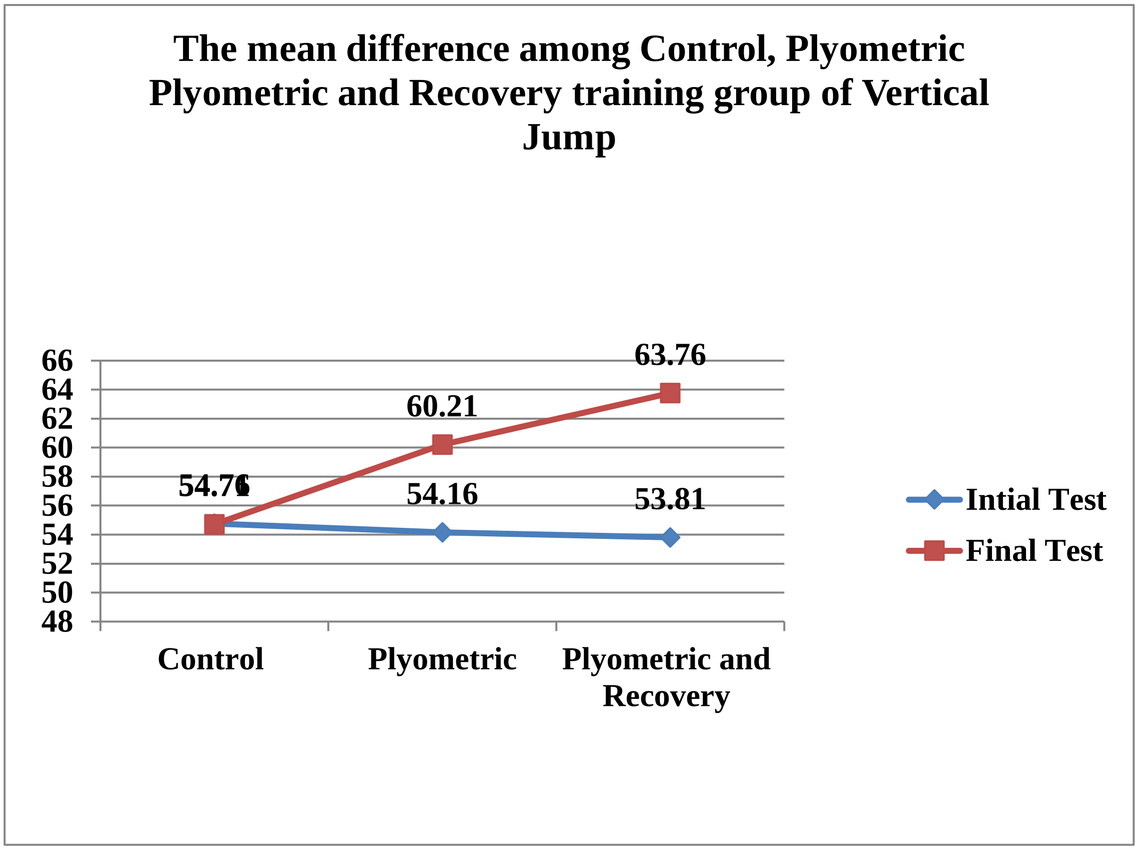

Figure-2

DISCUSSION

This research study, through a randomised controlled study design with experimenter blinding, proved the hypothesis that three sessions per week of plyometric and plyometric recovery training, performed for 12 weeks had a significant improvement in Margaria Kalamon stair climb anaerobic power test and vertical jump performance in the experimental groups and there is no significant difference in the control group in the pre and post-test results. The most improvement was observed between the pre-test and post-test performance of the plyometric and recovery group about Margaria Kalamon stair climb anaerobic power test and vertical jump performance.

Research has suggested that inter-set recovery time during plyometric training should be two to four minutes to avoid muscle fatigue that may lead to unnecessary risk of injury, incorrect technique, overtraining, over-reaching and poor performance (Guan et al., 2021; Markovic, 2007; Willardson, 2006, n.d.) The ability to maintain a high intensity throughout multiple exercise sets depends on the recovery from one exercise set to the next. Because oxygen plays a vital role in the physiological system during exercise and recovery and also affected the performance of the athlete if the supply of oxygen is limited (Buchheit et al., 2012; Guan et al., 2021). This research study did not examine the exact amount of recovery rest time needed. However, a proper rest period should be included in the plyometric training and also the volume and intensity of the plyometric training determines the rest recovery period. It was observed that subjects who added plyometrics with recovery achieved greater improvement in anaerobic power and vertical jump height.

The most commonly used plyometric exercise revolves around the vertical jump and the variation of explosive jumping. Therefore plyometrics is the most common tool for both training measurement of performance enhancement (Booth & Orr, 2016). It is important to understand the necessary recovery duration to employ to incur optimal results and avoid overtraining (Luebbers et al., 2003). In this study, the total training load and intensity of both the experimental group were given the same and the only difference in the recovery duration between the repetition and set. This recovery difference shows the significant changes in the post-test of anaerobic power and vertical jump performance of the plyometric and recovery groups. Limited studies have examined the influence of recovery time before competitions following this type of programme (Luebbers et al., 2003). Improvement of vertical jump always depends upon various neuromuscular adaptations, such as the increased neural drive to the agonist's muscles changes in muscle-tendon, mechanical stiffness characterization alterations in muscle size or architecture and changes in single fibre mechanics (Slimani et al., 2016; Thomas 2009).

The performance of plyometric training always depends upon different factors such as training level, gender, age, sports activity and years of training experience also some other important factors depend upon the plyometric training performance like the type of training, training load and intensity, duration of the training, and also rest between the repetition and the set. The findings of this study agree with Francesco et.al (2018) that proved plyometric training is likely to provide greater benefits to vertical jump and sprint speed. Alirezaetal (2014) proved improved in anaerobic and explosive power ages (Stair et al., 2014). These data also exposed that although 12 weeks of plyometric training was sufficient time to produce significant improvements in anaerobic power and explosive vertical jump (Adigüzel& Günay, 2016; Ampo et al., 2009; Booth & Orr, 2016; Pramod R., n.d.; THAKUR et al., 2016). If there is no muscle fatigue, peak explosive power recovers after the inter-set recovery period. Explosive power loss especially after eccentric exercise is one of the most valid and reliable indirect measures of muscle fatigue in humans (Guan et al., 2021)

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ETHICAL DECLARATIONS

Ethics approval and Consent Participation

The project entitled "Effects of inter-set recovery of plyometric training on anaerobic power and explosive power performance of boys " was approved on 15 December 2018 by the Alagappa University College of Physical Education, Alagappa University, Karaikudi, Tamil Nadu, India. Therefore, this manuscript was created, and all participants gave their written consent to participate in the experiments according to the principles outlined in the Declaration of WMA Declaration of Helsinki -Ethical Principles for Medical Research Involving Human Subjects. Furthermore, all methods were performed according to relevant guidelines and regulations.

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