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Article in *Physical Education of Students* · August 2022

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Effects of triphasic training model combined with two different cluster sets on vertical jump and reactive strength index

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Authors' Contribution: A – Study design; B – Data collection; C – Statistical analysis; D – Manuscript Preparation; E – Funds Collection

Abstract

Background and Study Aim This study aims to examine the effects of the Triphasic Training Model (TTM) applied with different set designs (15-30 sec intra-set) on reactive strength index (RSI) and vertical jump values.

Material and Methods Sixteen male athletes over 18 with at least three years of strength training experience (2 days a week) actively engaged in sports participated in the study. The study group was divided into two groups by calculating the relative strengths. The 15-second cluster set (C15) group exercises were performed with 15 seconds of rest between repetitions, and the 30-second cluster-set (C30) group practiced the exercises with 30 seconds of rest between repetitions. The triphasic training model was applied to all study groups for six weeks. Countermovement jump (CMJ) and drop jump tests were performed on the athletes before and after the training. Optojump brand photocell system was used for CMJ and RSI tests. For the RSI test, the desk height was determined as 40cm. Kolmogorov-Smirnov values were examined to assess the homogeneity of the data. To compare the means between groups, ANOVA was used for Repeated Measures, and a t-test was used to compare the pretest-posttest mean of the groups. The statistical significance level was determined as $p < 0.05$.

Results After triphasic training, CMJ and RSI values of both C15 and C30 groups increased ($p < 0.05$). When the within-group pretest-posttest values were examined, it was seen that the C30 group showed more improvement than the C15 group.

Conclusions As a result, it was seen that the triphasic training model applied twice a week for six weeks improved the CMJ and RSI values of the athletes, and it was more effective to use C30 instead of C15 in the use of cluster sets.

Keywords: triphasic training, cluster set, reactive strength index, vertical jump, power

Introduction

Resistance training, also known as strength or weight training, has become one of the most popular forms of exercise to increase physical fitness for athletes and sedentary individuals [1]. Thus, strength and power parameters have become essential to improving athletic performance. Different training methods (for example, barbells with body weight, barbell, plyometric, eccentric, ballistic, and kettlebell training) can be applied to improve these parameters [2]. Most traditional training models focus on developing explosive strength by emphasizing the concentric phase of the movement. However, the key to improved strength generation and thus sports performance is not just in the concentric phase. Therefore, to develop explosive power, it is necessary to train the eccentric and isometric phases of dynamic movements at a level equal to that of the concentric phase [3].

Recently, two researchers [3] introduced a popular approach called the “triphasic training model” (TTM), which trains the eccentric, isometric, and concentric phases of the movement separately

with the block training method. This training model aims to train each contraction phase separately and to increase the power output of the movement that ends in the concentric phase at the optimal level. Thus, it aims to increase the athlete's reactive strength and reveal more explosive strength [3].

Reactive strength is defined as the ability to complete the stretch-shortening cycle (SSC) as quickly as possible, that is, to quickly transition from the eccentric phase to the concentric phase [4]. The ability to improve SSC is typically calculated by the reactive strength index (RSI) [5]. RSI provides valuable information on neuromuscular and SSC function by measuring strength and the time taken to produce strength by dividing the jump height by the ground contact time during the drop jump (DJ) [6, 7, 8]. RSI is a reliable scientific measurement [6] and a practical way of evaluating the training quality of athletes [9].

When designing a resistance training program, various factors such as exercise selection, training load, number of repetitions and sets, exercise order, frequency, and rest time should be considered to achieve optimum training results. However, one aspect of developing a resistance training

program that has been largely overlooked and underused is the ability to change the structure of sets [10]. Traditional set structures are performed continuously with no rest between reps, resulting in a decreased power output with each rep in the set [11]. Different set strategies such as cluster set (CS) can be utilized during exercise to maximize power outputs, primarily if a higher volume workout is targeted. CS is a set structure in which a short rest interval (15-45 seconds) is applied between repetitions to provide partial recovery and maximize movement speed and strength [10, 11, 12]. Recently, several studies have shown that instead of rest between sets, rest intervals between repetitions (cluster sets) result in lower speed and strength loss throughout the entire training session, improve mechanical performance [13], and allow larger training volume [11, 13, 14, 15] and can reduce accumulated fatigue seen during the traditional set while maximizing repetition performance [10, 11, 12, 16, 17].

A set structure designed with CS includes a short rest period between reps to partially or fully restore short-term energy systems. Today, CS is used for strength and power training that requires high intensity (>80% 1MR). TTM is a model that uses high intensity. Therefore, the benefits of using CS to TTM are a matter of curiosity. It is thought that using CS during training will allow the athletes to perform more repetitions than they can handle two or more times in a row without losing speed and strength production during intense loading stages over 80% of 1RM, such as TTM.

Purpose of the Study. To our knowledge, there is no study in the literature examining the structure of TTM and CS. Therefore, this study investigates the effects of TTM applied with different CS designs (15-30 seconds intra-set) on the reactive strength index and vertical jump values.

Materials and Methods

Participants

Sixteen male athletes over 18 with at least three

years of strength training experience (2 days a week) actively engaged in sports participated in the study. The G Power [18] program was used to determine the sample group. In addition, before the study, the ability of all participants included in the study to perform back squat and deadlift exercises with an appropriate technique was evaluated by functional movement screen (FMS) [19]. Participants who met the prerequisite of getting 3 points from this test battery were included in the study. Athletes were asked not to participate in daily training programs 24 hours before the test. Tests were completed on two consecutive days in the same laboratory for all participants. The study group reported no chronic illness or a recent injury that could compromise testing procedures. All athletes were briefed on the testing procedures and signed a written informed consent form before starting the study. The study complied with the Declaration of Helsinki and was approved by the Marmara University Non-Interventional Clinical Research Ethics Committee (Protocol No: 09.2020.730). The demographic characteristics of the participants are given in Table 1.

Research Design

This study was evaluated as an intervention training and added to the participants' ongoing training program. Since the study group is selected from the same team, there is no difference between the training programs. At the beginning of the study, the back squat and deadlift one maximum repetitions (1RM) of each participant were taken. The study design is given in Figure 1. Then, the relative strengths of the participants for both strength tests were calculated separately. Next, both groups applied the triphasic training model with two different set-set models: The First Group (n=8) worked by resting for 15 seconds between repetitions (C15), and the Second Group (n=8) completed the training by using a 30-second cluster set (C30) between repetitions. To keep the training coverage equal between the groups, 4 minutes of rest were given in C15 and 3 minutes between sets in C30. The

Table 1. Demographic characteristics of the participants

Characteristics	\bar{X}	Sd	Min	Max	Median	Mod	Range
Age	20.93	5.54	18.00	40.00	19.00	18.00	22.00
Height (cm)	176.50	7.28	163.00	187.00	176.00	176.00	24.00
Body mass (kg)	87.24	18.66	60.00	120.00	83.50	76.00	60.00
BMI (kg/m ²)	27.73	4.11	21.77	37.04	26.89	21.77	4.00
Training experience (years)	5.25	2.79	4.00	15.00	4.00	4.00	11.00

BMI=body mass index; Cm: centimetre; Kg: kilogram; Min: minimum; Max: maximum; Sd: standart deviation

triphasic training model consists of 3 phases. Each of these phases was carried out in the following order according to the protocol determined by Dietz and Peterson [3]: Eccentric (6sec), Isometric (3sec), and Concentric (Explosive) sequences were applied for two weeks each. Eccentric and isometric phases were used two days a week (Monday-Friday), while the concentric phase was applied three days a week (Monday, Wednesday, and Friday). An assistant was kept with the athletes during the application for security purposes. The training program applied to the athletes is given in Figure 2.

Movement Tempo

Each of the four exercise-related numbers in the training program indicates how long, in seconds, the particular “phase” (eccentric, isometric, concentric, and rest time between reps) must be performed. For example, a back squat might be at the following tempo: 6:0:0:0. The first number (6) represents the

duration of the eccentric phase of the movement. The second number (0) represents the isometric phase duration. The third number (0) represents the concentric phase time. Finally, the last number (0) describes how many reps to give a rest (cluster set) [3]. An intermittently beating metronome (Metronomo Batidas, Stonekick) was used to time each stage of the movement.

Measurements

One Maximum Repetitions (1RM) Back Squat-Deadlift Test

The maximum load of the Back squat and Deadlift exercise (1MR) was determined using the procedure outlined by Baechle and Earle [20]. As a warm-up for both exercises before 1MR measurement, athletes worked out with (a) 10 reps at 20 kg, (b) 5 repetitions with an estimated 50% 1MR, (c) 3 reps with an estimated 75% 1MR, (d) 1 rep at an estimated 90% 1MR to achieve maximum effort four sets of back

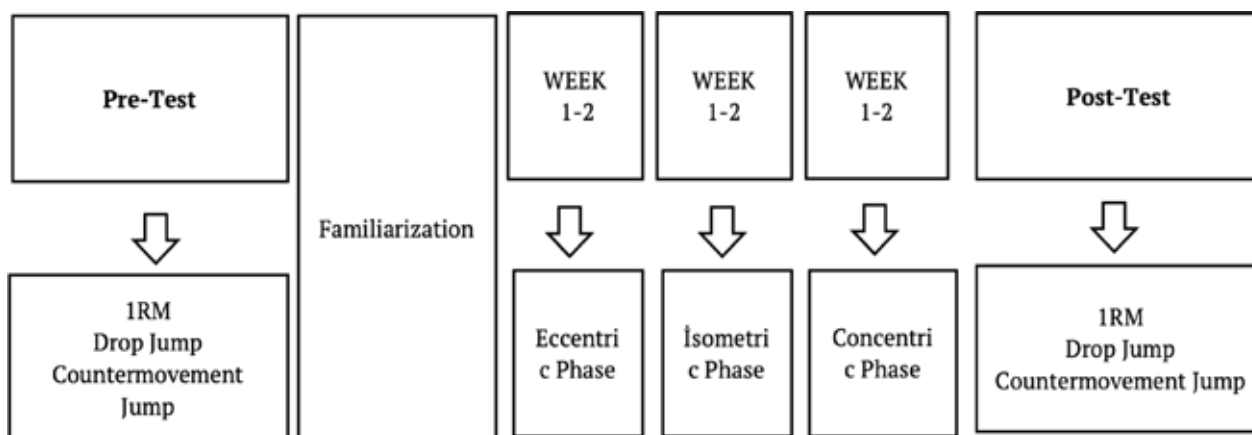


Figure 1. Study Design

EXCENTRIC PHASE (Week 1-2)					ISOMETRIC PHASE (WEEK 3-4)					CONCENTRIC PHASE (WEEK 5-6)				
DAY	LOAD	SEC	REPS	SET	DAY	LOAD	SEC	REPS	SET	DAY	LOAD	SEC	REPS	SET
MON	82-87%	5-6	1-3	3-4	MON	82-87%	2-3	1-3	4-5	MON	82-87%	Explosive	2-3	3-4
FRI	75-80%	6-7	2-4	3-4	FRI	75-80%	3-4	3-4	4-5	WED	90-97%	Explosive	1	1-4
										FRI	75-80%	Explosive	3-4	3-5
LOADING AND REST TIMES FOR THE ECCENTRIC PHASE					LOADING AND REST TIMES FOR THE ISOMETRIC PHASE					LOADING AND REST TIMES FOR THE CONCENTRIC PHASE				
C15			C30		C15		C30			C15		C30		
6.0.0.1			6.0.0.1		0.3.0.1		0.3.0.1			0.0.0.1		0.0.0.1		

Figure 2. 6-Week Triphasic Training Program [3]

squats and deadlift exercise. The estimated 1MR values of the athletes before participating in this study were used to determine the workload. The athletes then attempted an estimated 100% 1MR for both exercises, and the load was increased by 5-10 kg until unsuccessful. 1MR was determined with a maximum of 6 trials. A 5-minute rest was given between trials.

Drop Jump Test

Before starting the measurement, the test protocol was explained to the participants. A 10-minute warm-up program was applied before the measurement. Then, each participant performed three jumps from 40 cm high crates with hands on hips and elbows bent outward (Akimbo pose). A 30-second recovery was given between each trial [21]. Trials in which the technique deteriorated significantly were excluded and repeated. Contact time, air retention time, and jump height were recorded with the Optojump photocell system (Microgate, Bolzano, Italy). Participants were asked to fall with their right foot before the counter to prevent them from jumping off the platform with both feet. Athletes were instructed to “jump as high as possible by minimizing contact time (depreciation + take-off) after ground contact.” RSI was calculated by dividing the jump height (mm) by the contact time (ms) [22].

Countermovement Jump

To familiarize the participants with the CMJ technique, they performed as many trials (ranging from 4 to 7) as necessary in the first test session. Participants stood still with their hands akimbo until the CMJ was given a verbal command. Participants were instructed to minimize the transition between descending and ascending stages and to jump as fast and high as possible. Participants were free to choose the depth of the movement. They were also instructed not to make any movements during the flight. All participants performed three trials. One minute was given between trials [23]. The jump heights of the participants were recorded with the

Optojump photocell system (Microgate, Bolzano, Italy).

Statistical Analysis

The data set collected under the sub-problems of the research was recorded in the electronic environment. In the analysis part of the data obtained, Skewness and Kurtosis values and Kolmogorov-Smirnov values were examined to determine the homogeneity. To compare the means between groups, ANOVA was used for Repeated Measures, and a t-test was used to compare the pre test-post test mean of the groups. The statistical significance level was determined as $p < 0.05$. In addition, ANOVA was used for Repeated Measurements to compare the pre-post test means between the groups, and the Sample t-test was used to compare the intra-group pre-post test means. Statistical analyses were performed using the SPSS 26.0 [24] package program. The effect size of the study was determined as 0.50, power of 0.80 and a margin of error of 0.05.

Results

When Table 2 is examined, it is seen that there is a significant difference between the CMJ ($P < 0,05$) and RSI ($P < 0,05$) pre- and post test values of the athletes participating in 2 different resting protocols. When Table 3 is examined, there is a statistically significant difference between the pre test-post test CMJ results of both groups ($p < 0.05$). When the pre test-post test results of the groups are analyzed as percentage improvement, it is seen that the C30 group showed more improvement (11-8%) than the C15 group. When Table 4 is examined, there is a statistically significant difference between the pre test-post test RSI results of both groups ($p < 0.05$). When the pre test-post test results of the groups were analyzed as percentage improvement, it was seen that the C30 group showed more improvement (11-8%) than the C15 group.

Table 2. ANOVA results for repeat measurements regarding the difference between intergroup CMJ and RSI pre-post test values

Measurement	Group	Pre-test ($\bar{x} \pm Ss$)	Post-test ($\bar{x} \pm Ss$)	F	p	η^2
CMJ (cm)	C15	40.26 \pm 9.76	43.98 \pm 9.43	7.838	.014*	0.35
	C30	39.75 \pm 3.30	45.03 \pm 2.44			
RSI	C15	1.20 \pm .292	1.30 \pm .227	5.832	.030*	0.29
	C30	1.27 \pm .227	1,44 \pm .124			

C15: cluster 15sn. intra-set; C30: cluster 15sn. intra-set; CMJ: countermovement jump; RSI: reactive strength index; Cm: centimetre; *Statistically significant differences ($P < 0.05$).

Table 3. T-test results regarding the difference between within-group pre-post test CMJ values

Group	Measurement	$\bar{x} \pm Ss$	t	Improvement %	p
C15	Pre-test	40.26 ± 9.76	-18.012	%8	.000*
	Post-test	43.98 ± 9.43			
C30	Pre-test	39.75 ± 3.30	-10.200	%11	.000*
	Post-test	45.03 ± 2.44			

C15: cluster 15sn. intra-set; C30: cluster 15sn. intra-set; *Statistically significant differences (P< 0.05).

Table 4. T-test results regarding the difference between within-group pre-post test RSI values

Group	Measurement	$\bar{x} \pm Ss$	t	Improvement %	p
C15	Pre-test	1,20 ± .292	-3.666	%8	.008*
	Post-test	1.30 ± .227			
C30	Pre-test	1.27 ± .144	15.506	%11	.000*
	Post-test	1.44 ± .124			

C15: cluster 15sn. intra-set; C30: cluster 15sn. intra-set; *Statistically significant differences (P< 0.05).

Discussion

This study examines the effects of TTM applied with different CS designs on vertical jump and reactive strength index. In particular, it aims to compare the effects of different rest intervals between repetitions (15sec-30sec) on CMJ and RSI values using the triphasic training model. When the study findings were examined, it was observed that 6-week TTM applied with different rest periods improved both CMJ and RSI values of both groups.

The basis of this development is thought to be the nature of triphasic training, especially the training of the eccentric and isometric phases separately. Because in relation to the eccentric phase, SSC is responsible for the absorption of kinetic energy within the muscle and tendon. Elasticity means that a structure is able to resume its normal shape (length) after being distorted (lengthened). When a muscle and its attached tendon are stretched, elastic energy is stored within these two structures for later use in the concentric phase. An athlete needs a fast-growing, transitional, isometric contraction to maximize this energy transfer channel. Any delay between the eccentric and concentric phases will cause a loss of energy in the ESC as this energy store begins to dissipate as heat as soon as it is absorbed. For this reason, power and strength may increase by transitioning from the isometric phase to the concentric phase without any loss in the amount of energy stored during the eccentric contraction [3]. In one of the rare studies conducted with TTM,

Russell and Brooks [25] studied the effects of TTM and plyometric training on CMJ and 1MR values in their study with seven basketball players. As a result of the study, they reported that six weeks of TTM and plyometric training did not increase the vertical jump values of the athletes. Previously, researchers have reported a reduction in concentric contraction times during strength exercises involving the ESC compared to concentric exercises alone [26, 27, 28]. However, some authors recently reported that additional eccentric training increased the RSI and CMJ values [26, 27]. These results are consistent with the results of our study.

When the within-group pretest-posttest CMJ values were examined, it was observed that the C30 (30sec rest between repetitions) group showed more improvement than the C15 (15sec rest between repetitions) group (11-8%). Similarly, TTM increased the RSI values of both groups. However, when the within-group RSI pretest-posttest values were examined, a higher increase was observed in the C30 group compared to the C15 group (11-8%). The reason why the C30 group increased more than the C15 group for both parameters is that the C30 group had a more extended rest period between repetitions compared to the C15 group.

A common strategy to control acutely developing fatigue is to provide the athlete with rest between repetitions [29]. It has been demonstrated in previous studies that the CS method is an effective method for providing speed and power adaptations

against a specific load [14, 17, 30, 31, 32]. Acutely, such a method allows the athlete to have consistently higher power outputs while subjecting to less metabolic stress and fatigue [29, 33]. Our literature review did not find any studies examining the effect of TTM and intra-set rest intervals. However, the impact of intra-set rest intervals on performance has been investigated in different studies. Wetmore et al. [34] and Tufano et al. [35], in their study comparing TS and CS, reported that CS set structure will produce higher Peak Power, Average Power outputs, and movement speeds compared to TS. Because of its effect on power, CS can be said to be a valuable tool for increasing power, especially in the later stages of a sequential training plan that emphasizes power generation [36, 37]. Again, Hansen et al. [30] compared the effects of TS and three different CS structures on movement speed, strength, and power. As a result of the study, it has been reported that using CS instead of 6 repetitions of TS can reduce power and movement speed decreases throughout the set. In another study [38], the mechanical and metabolic responses between two different TS (TR1: 3x10 repetitions without rest, TR2: 5x6 repetitions without rest) and three different CS (CS5: 5sec between repetitions, CS10: 10sec between repetitions, CS15: 15sec rest between repetitions and 3x10 repetitions) designs in bench press exercise performed with 10MR load were compared. As a result of the study, TR1 and CS5 were reported as the two set designs with the highest speed loss. However, it was observed that there was no significant difference in speed loss in TR2, CS10, and CS15 set designs. When the speed loss between the three CS designs was examined, it was reported that a more significant speed loss occurred for the CS5 compared to the CS10 and CS15. Oliver et al. [39] compared the kinetic and kinematic (Strength, Speed, Power) structures of TS (4x10 reps; rest between sets 120sec) and CS (4 sets of 2x5 reps; 30sec rest between reps, 90sec rest between sets) during back squat exercise in men. The findings showed that using CS positively affected movement speed, power output, and overall volume.

Previous studies have shown that more frequent rest intervals during exercises that begin with eccentric muscle movements, use the lengthening-shortening cycle, and end with concentric muscle movements can preserve power output [11, 15, 39, 40, 41]. For example, Moreno et al. [40] examined

the effects of 3 different cluster-set designs on power output during plyometric squats. Set designs were created as TS (2 sets of 10 reps; 90 seconds rest between sets), CS1 (4 sets of 5 reps; 30sec rest between sets), and CS2 (10 sets of 2 reps; 10sec rest between sets). The results showed that using a set helps maintain power output over a traditional set. Among the set designs, it has been reported that CS2 is the set structure that allows recovery the most. Hardee et al. [11] showed that Peak Power is better preserved when more extended rest periods are used in three different set designs (rest between repetitions: 0-20-40 sec) consisting of 3 sets of 6-rep power clean exercises performed with 80% of 1MR with a load. In this study, the triphasic training model, which considers the phases (eccentric, isometric, concentric) separately, and the cluster set and the traditional set were compared, and it was seen that it was consistent with the previous studies with traditional training models suggesting that using CS can increase power output.

Conclusions

As a result, the use of set sets with a predetermined number of repetitive intra-set rests (e.g., 30-45 s) may provide the most benefit during the strength or power phases of the training [33]. In addition, it can provide movement quality, which can be critical, especially in movements that require skill (for example, weightlifting) with less fatigue that occurs with the use of sets [11]. Thus, CS designs may be a practical resistance training approach that can be considered for use at various stages of periodic programs [33]. In this study, TTM combined with CS structure effectively increased CMJ and RSI values. In addition, it has been shown that applying the rest intervals between repetitions of 30 seconds instead of 15 seconds in the set used in the triphasic training model can provide a more significant stimulus for CMJ and RSI gains. Therefore, according to the outputs of this study, it is recommended that the trainers applying the triphasic training model should use cluster sets and a 30-second rest interval between repetitions in the cluster set. However, due to the insufficient number of studies on TTM, it is recommended to conduct more studies on this subject.

Conflict of interest

The authors declare no conflict of interest.

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Cite this article as:

Kaya S, Pinar S. Effects of triphasic training model combined with two different cluster sets on vertical jump and reactive strength index. *Physical Education of Students*, 2022;26(4):199–206. <https://doi.org/10.15561/20755279.2022.0405>

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Received: 17.07.2022

Accepted: 19.08.2022; **Published:** 30.08.2022