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Acute Investigation of Maximal Strength, Power and Rapid Strength Production on Lower Compartment Circuit Resistance Training of International Female Wrestling Athletes

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Abstract: The circuit resistance training is high intense and high load repetition training method completed on different sport modalities for wrestling women. A total of 10 wrestling women age mean 17 yr, height 1.63 m, body mass 54 kg, training experience 10 yrs participated in this study. Equipment and methods: To circuit resistance training determined on 1RM maximal test, gradually increase rapid strength production and lower leg power to CMJ and SJ actualized on six resistance exercises; a) hip flexion (HP), b) ankle inversion (AI), c) squat (SQ), d) hip extension (HE), e) deadlift (DE), and f) ankle eversion (AE) for wrestling women athletes on team professional sport performance. The lower compartment circuit resistance training was provided on advanced maximal load and power performance by 85% of 1RM (6 rep) high training load and (10 repetition – 20 s interval) intensity. Compared to Pre-test and Post-test that lower compartment resistance training concluded increased maximal strength for acute training load repetition and rapid strength load lifting performance and lower leg power resulted to CMJ decreased for wrestling and SJ increased for wrestling, circuit resistance training promoted high resistance load variability and minimum short time recovery on the one session non-periodic exercises performance with strength and power development. Other, experimental results for different sport modalities may be performing on maximal strength and power performance change in short recovery training phase for minimum effort rapid strength performance.

Keywords: Circuit Resistance Training, Maximal Strength, Lower Leg Power, Rapid Strength Production, Wrestling, Muay Thai Athletes

1. Introduction

A strength performance depending on size and muscle mass amount of regional force produced against a kind of resistance training in the exercise specific task create developing of dynamic muscle strength and power activation. Furthermore traditional muscle strength development executed on low and high loading resistance training performance in ideally continuum of repetition zone (Schoenfeld *et al.,* 2021). The circuit resistance current training both high loading resistance lifting performance and short-term recovery time included in perform to high strength loading range exercise capacity is one of resistance training in sport performance (Alcaraz *et al.,* 2008). To determine circuit resistance training short and long time periodization are evaluated allometric strength as well as high loading maximal strength at 6RM and >8RM with no rest or short-term recovery time loading change between exercise condition (Waller *et al.,* 2011). Is one of circuit resistance training weekly planning positivelly upper and lower compartment regional dynamic muscle strength and power activation to promote rapid strength production with micro periodize non long time recovery of muscle linearly synergies increases (Chtara *et al.,* 2008; Ortego *et al.,* 2009). Accordingly lower compartment regional strength performance outcomes of circuit resistance training short-term recovery phase during micro non-periodize set-ups and exercise variabilities represent to linear strength and power performance (Chtara *et al.,* 2008). For example combine weekly periodization circuit resistance training completed on CMJ height increase (d=0.61), acute maximum strength were increased in the high resistance loading for example >8RM load (Freitas *et al.,* 2016). One study reported that lower compartment circuit resistance non-periodic

setups including ie., weekly changing explosive jumping leg tasks improve combined hip extension strength (Chtara *et al.,* 2008). Conversely, in this case for maximal strength production circuit resistance training provides neuromuscular adaptation similar to long time recovery traditional resistance training (Alcaraz *et al.,* 2008; Alcaraz *et al.,* 2011; Ramos-Campo *et al.,* 2021). Compared to circuit and traditional resistance training its represent the same explosive power and strength however the increase strength production changes only exacuating in circuit resistance training to muscle strength is insufficient and controversial for sport differences (Chtara *et al.,* 2008; Freitas *et al.,* 2016). In one study high loading resistance circuit training consisted of leg extension, bench press and ankle extension conducted on 35 s short time periodization model for each set. Indeed combined circuit exercise tasks increased in average and peak velocity and power (Alcaraz *et al.,* 2008). Other approach, low volume circuit type resistance traditional training associated with 1 or 2 min recovery on single set for muscular strength adaptation observed on 50-65% of 1RM for muscle strength and power progression (Marx *et al.,* 2001). However, circuit training recovery times (30-40 s) may be produce early and late force production periodic gain in the maximum exercise intensity sessions (Ortego *et al.,* 2009; Freitas *et al.,* 2016). To evaluate maximal strength detecting of circuit resistance training commonly for assessing of early and late period rapid force production used for generally 1RM maximal strength test (Waller *et al.,* 2011). One current study Gonçalves *et al.* (2022) noted that evaluation of magnitude forces produced over certain periods of load time is a measure of explosive muscular strength to determine increase rapid strength production.

In order to perform explosive muscle strength and power performance evaluates time-dependent relationship was conducted on certain dynamic muscular activation as muscle ability to exert rapid load time period (Ramos-Campo *et al.,* 2021; Oliveira *et al.,* 2013). Lower limb rapid strength production therefore reflect greater explosive muscle strength in slope of force-time relationship in this reason maximal strength and power changes differ in absolute muscular strength (Oliveira *et al.,* 2013). It is related to lower compartment performance when it is considered that a greater load time change is necessary in the muscular strength was evaluated it was found that high strength and power values associated with load time performance for example highly vertical jump performance (Suchomel *et al.,* 2016; Lawson *et al.,* 2021). Therefore this study aimed to investigate the acute investigate of lower compartment circuit resistance training on muscle performance and increase rapid strength production in different sport modalities.

2. Method

2.1 Participants

The of 10 wrestling women athletes age (17 yr), height (1. 63 m), body mass (54 kg) participated in this study. All maximal strength, lower leg power and rapid strength production performance test sessions and circuit resistance training exacuation were 2 days measurement with 1 week non periodic set-up.

Table 1. Maximal strength characteristics

Exercises	**Wrestling**
Hip flexion ($kg \cdot kg^{-1}$) Allometric hip flexion ($kg.m_b^{-67}$)	1.51 0.98
Ankle inversion ($kg \cdot kg^{-1}$) Allometric ankle inversion ($kg.m_b^{-67}$)	1.06 0.71
Squat ($kg \cdot kg^{-1}$) Allometric squat ($kg.m_b^{-67}$)	0.76 0.51
Hip extension ($kg \cdot kg^{-1}$) Allometric hip extension ($kg.m_b^{-67}$)	2.75 0.70
Ankle eversion ($kg \cdot kg^{-1}$) Allometric ankle eversion ($kg.m_b^{-67}$)	0.87 1.72
Deadlift ($kg \cdot kg^{-1}$) Allometric deadlift ($kg.m_b^{-67}$)	0.76 1.97
1RM= One repetition maximum †.	

2.2 Experimental Approach to the Problem

To determine lower compartment circuit resistance training was planned on training loading by 85% of 1RM high load resistance training lift session. Lower compartment maximal and allometric strength changes to all muscle rapid strength activations composed of incremental loadings such as 80% of 1RM explosive strength range and 90% of 1RM strength/force range and 100% of 1RM maximal strength range as one repetition providing on load time period. The muscle maximal strength actualized force-time change in one session load repetition performance. In this case acute investigate of lower compartment muscle rapid strength activation performed on vary strength load intensities. For linear acute changes 1RM pretest was applied one day before, immediately after 3 days performed circuit resistance training and maximal rapid strength production posttest were taken immediately afterwards. Total experimental performance time for all sport modalities were 2-2.5 hours.

2.3 Strength Production

One repetition maximum (1RM) is muscle strength and allometric strength sessions tested on load increase relationship as well as increase maximal strength production evaluated on lower compartment circuit exercises strength/force potential (Jaric *et al.,* 2002). To circuit resistance exercises conducted composed of circuit running, lunge and stretch dynamic warm-ups before 1RM tests were actualized six resistance exercises; hip flexion, ankle inversion, squat, hip extension, deadlift and ankle eversion. Both 1RM load lifting performance to circuit resistance training was 6RM high load resistance strength used on the NSCA protocol. Strength production completed at 50% of 1RM-loading (5 rep), 80% of 1RM-loading (3 rep), 100% of 1RM-loading (+1 rep) to large muscle group (+16 kg) in lower compartment strength protocol from non-recovery session (Oliveira *et al.,* 2013).

2.4 Circuit Resistance Training

Circuit resistance training performed after one load sessions finished then participants conducted on six resistance exercise by short-term recovery time (Table 1 and Figure 1). Each exercise was created 6RM of 85% of 1RM to all training sessions. Similar to other studies muscle strength exercise performance in high load circuit training was performed for functional strength and power adjustment (Freitas *et al.,* 2016). Resistance training intensity was determined as 4 set and 20 second of rest between repetitions. Resistance exercises were applied on smith machine. It was performed by switching from one set of each exercise to the next and repeating the entire circuit.

Hip flexion was performed with participants hip flexion to strengthening thigh and hip muscles with stand straight to the front a smith machine and cable row on for balance. One knee is slowly was bent towards the chest, they returned to the starting position when the knees reached 90 degrees. Hip extension was performed with standing position at the cable row. They conducted to starting position when the leg reaches extension.

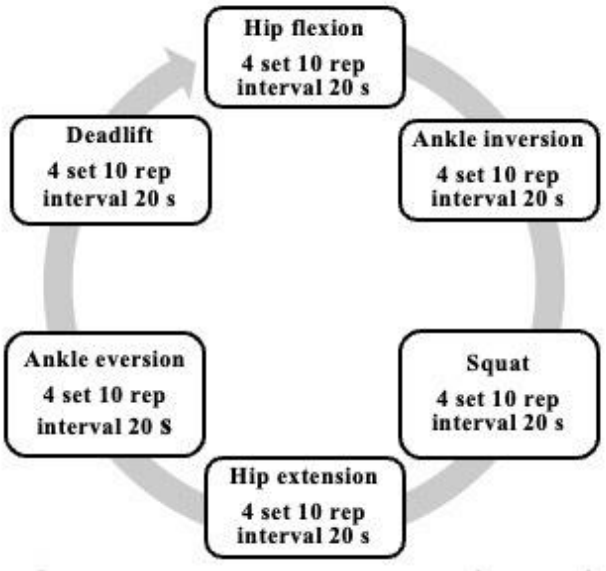

Figure 1. Circuit training periodize model

One leg was slowly lifted backwards without bending and held in this position for 1 second then slowly lowered. The squat was performed by keeping the bar at shoulder level and the knees were returned to the starting point from the position they were lowered to 90 degrees. With the thighs parallel to the floor and the eccentric phase, the concentric resting position is reached. Deadlift was returned to the ankles level after the front lift was done at hip level. A deadlift was considered successful if the hip was locked. Ankle inversion and eversion were performed with a cable attached to the ankle at cable ankle inversion and eversion. Verbal encouragement provided during all session attempts.

2.5 Vertical Jumps

Lower compartment muscle power evaluated on optojump photoelectric cell to estimate vertical jump height. The optojump photoelectric cells included in 2 parallel bars (96 LED lights-resolution of 1.0416 cm) at the floor level allow surface ground reaction interection (Microgate, Bolzano, Italy). The protocol was formed jump modalities, participants performed SJ and CMJ with 1 repetition separated by 10-30 s of rest. To SJ determine started from knee 90° with their hands on their hips. To CMJ determine started from knee 90° with their hands on their waist to provide arm swing (Glatthorn *et al.,* 2011).

2.6 Statistical Analysis

Statistical analysis on muscle strength lower leg power and increase rapid strength production results were resolved SPSS 22. 2.2.1 (UK). Population pre mean, standard deviation and confidence interval (95% CI) were obtained from detect calculation effect size = 0.90, α error probability = 0.5 and power (1-β) error probability = 0.95 transferred by G*Power. Distribution of data were normalized. The effect of the time point (pretest and posttest) was evaluated using a one T-test measurement in (wrestling women athletes). Thus, significant priority alpha level was set at $p < 0.05$. The changes significant descriptors were confidence intervals used to effect size: <0.25 = small, 0.25-0.50 moderate, 0.50-1.00 = large, >1.00 = very large (Hopkins *et al.,* 2009; Rhea, 2004).

3. Results

Increase rapid strength production concluded on maximal strength 1RM load lifting task as the repetitive incremental loading compared to traditional resistance training. Production on maximal strength and lower leg power performance changes promoted on the between pretest and posttest change interaction on different sport modalities.

Current results detected hip flexion of wrestling (p=0.012; t=-3.126; ES=1.39 very large) at 100% of 1RM, (p=0.006; t=-3.560; ES=1.48 very large) at 90% of 1RM and (p=0.004; t=-3.805; ES=1.64 very large) at 80% of 1RM. Ankle inversion of wrestling (p=0.003; t=-3.955; ES=1.43 very large) at 100% of 1RM, (p=0.003; t=-3.980; ES=1.43 very large) at 90% of 1RM and (p=0.003; t=-3.980; ES=1.43 very large) at 80% of 1RM.

Again, squat detected on wrestling (p=0.006; t=-3.540; ES=1.29 very large) at 100% of 1RM, (p=0.007; t=-3.436; ES=1.22 very large) at 90% of 1RM and (p=0.014 t=-3.042; ES=1.11 very large) at 80% of 1RM. Hip extension of wrestling (p=0.015; t=-2.990; ES=0.96 large) at 100% of 1RM, (p=0.013; t=-3.111; ES=1.06 very large) at 90% of 1RM and (p=0.012; t=-3.135; ES=1.07 very large) at 80% of 1RM**.** To ankle eversion determined on wrestling (p=0.010; t=-3.228; ES=0.82 large) at 100% of 1RM, (p=0.009; t=-3.327; ES=1.33 very large) at 90% of 1RM and (p=0.010; t=-3.281; ES=1.33 very large) at 80% of 1RM**.** Again, deadlift determined on wrestling (p=0.041; t=-2.380; ES=0.63 moderate) at 100% of 1RM, (p=0.041; t=-2.384; ES=0.64 moderate) at 90% of 1RM and (p=0.045; t=-2.333; ES=0.53 moderate) at 80% of 1RM.

4. Discussion

The general training popularities were applied progression resistance loads to acute circuit resistance training conducted on studies and maximal performance changes often created intensities during rest periods (Freitas *et al.,* 2016). High loading of circuit resistance training in athletic population was preferred for explosive strength and jump height by conducting of preperation long-term strength training periodization (Chtara *et al.,* 2008). In this case muscular strength of wrestling women athletes in acute effect applied on 1RM strength ranges as repetitions examined on increase strength production at explosive strength and maximal strength session.

One main result noted performance development created strength/force development. Thus, effect on periodic increase of acute circuit resistance training to high strength, power and increase rapid strength production may be effective

method by producing combine weekly strength and power training periodization (Figure 2 ; Table 2 and 3).

Table 2. Increasing of rapid strength production

Exercises	Wrestling					
	80% (Pre – Post)		90% (Pre – Post)		100% (Pre – Post)	
Hip flexion	34.90±6.02	45.90±7.27	32.00±5.94	41.30±6.60	27.90±4.81	35.60±6.14
Ankle inversion	31.30±6.75	40.70±6.39	35.10±7.70	45.50±6.81	39.10±8.49	50.70±7.70
Squat	67.00±12.51	88.00±23.47	57.50±11.84	77.50±19.89	51.00±9.66	70.40±18.78
Hip extension	53.40±8.66	64.80±12.21	48.10±7.75	58.20±10.88	42.20±6.97	51.00±10.79
Ankle eversion	37.40±7.98	49.80±10.93	41.80±8.84	55.80±11.93	46.60±9.84	62.10±13.42
Deadlift	48.50±9.00	54.50±9.90	55.00±11.36	62.50±12.03	64.00±12.64	71.00±13.70

Table 3. Power changes compared to pre test and post test

Power	Wrestling	
	Pre	Post
CMJ	22.98±3.14	21.65±3.00
SJ	22.66±2.29	23.17±3.07

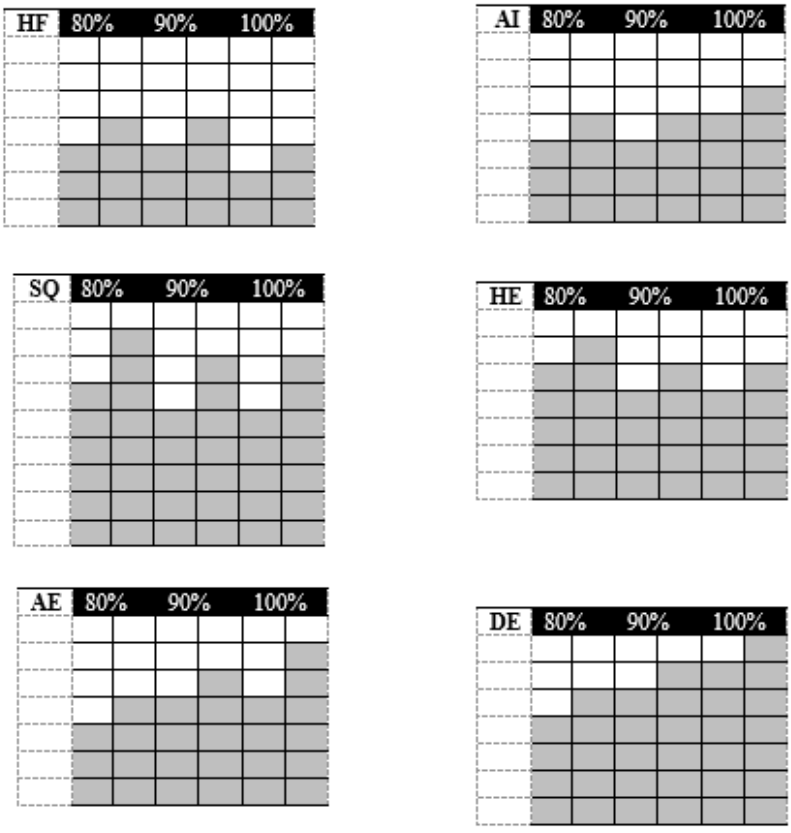

Figure 2. Exercise 1RM rapid strength production development of wrestling.

This weekly training periodization and short-term recovery condition often included in non-periodize power and strength planning on high resistance circuit training was excessive condition (Ortego *et al.,* 2009; Freitas *et al.,* 2016). Specifically, ≥6RM-8RM strength ranges provide on high load resistance training on high resistance training outcomes and adaptation in high threshold intensity loading and increased training volumes. Increased maximal strength on wrestling with no power development (Turner *et al.,* 2020). This study represent dynamic strength prensiple at 1RM loading maximal strength sessions compared to pretest and posttest are highly effective significant results to increase strength production on the 6 resistance exercise.

Similar adaptation, long-term high resistance circuit training periodization to muscular strength was significant increased in 1RM squat performance (Alcaraz *et al.,* 2011). Progressive high strength periodization to develop maximal strength and power performance improved allometric hip extension strength and power in long-term non-periodize combined circuit resistance training (Chtara *et al.,* 2008). Conversely, our study both strength/force developing and allometric force production were conducted on lower compartment in circuit resistance training. Freitas *et al.* (2016) acute circuit resistance training was improved CMJ height, similarly in our study peak height to CMJ and SJ compared pretest and posttest decreased for wrestling increased and decreased. Limited circuit resistance training studies but a popular training method when it provides muscle strength and power similar to traditional high intense training therefore common advanced studies are thought to be needed for lower compartment strength and power development in different sport modalities.

5. Conclusion

Active circuit resistance training non-periodize micro set-up and training session was effective may be advanced strength training periodization. Before circuit resistance training progressive studies were suggested at 6RM or exercise literatures >8RM however, as our study was circuit resistance training must be for macro periodization sessions of different sport modalities. Accordingly high load circuit resistance strength and power training is proper development between 80% of 1RM and 100% of 1RM thresholds athletic performance for other sport population is scarce and unclear in as traditional training-based strength training working.

6. Practical Applications

The circuit high resistance high intense loading strength training is recommended for athletic sport modalities in competitive seasons and training micro periodization. To develop maximal strength, power and increase strength production. Even though progressive strength working to common and current may be effective in peak reach working prensiple. As our must be advanced strength training in sport specific-tasks. The proper periodization strength and power must be repeat performance outcomes in sport modalities.

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The present study permission was obtained from Akdeniz University Clinical Research Ethics Committee on (acceded protocol no: 2023-277).

Author Contribution Statement
Kahraman Y - Conceptualization, Supervision, Validation, Methodology, Data collection, Analysis, Writing—original draft, Varol İ - Writing—review & editing. Both the authors read and approved the final manuscript.

Data availability
The datasets generated and analyzed during the current study are available from the corresponding author upon approval of the request.

Informed Consent
Written consent was obtained from the participants.

Conflict of interest
The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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