JOURNAL OF PHYSICAL EDUCATION RESEARCH

Journal of Physical Education Research, Volume 8, Issue II, June 2021, pp.22-33
ISSN: Print-2394 4048, Online-2394 4056

ACCOMMODATING RESISTANCE TRAINING: SCOPUS REVIEW

FANFAN CHARLES, MARK DEBELISO*
Department of Kinesiology and Outdoor Recreation, Southern Utah University, UNITED STATES.
***Email:** markdebeliso@suu.edu*

How to cite this article: Charles, F., & DeBeliso, M. (June 2021). Accommodating resistance training: Scopus review. Journal of Physical Education Research, Volume 8, Issue II, 22-33.

Received: May 04, 2021 **Accepted:** June 12, 2021

ABSTRACT

There are a variety of resistance training (RT) modalities that coaches, trainers, and physical therapists use to help their clients and patients improve their muscular strengths and power. Dynamic constant external (DCE) RT using free weights is commonly selected as the modality of choice for fitness enthusiasts and athletes. Accommodating resistance training (ART), where the resistance is being manipulated within a repetition using resistance bands or chains is gaining in popularity. However, it is unclear what evidence exists that supports the use of ART for improving muscular strength and power. The purpose of this review is to examine the available scientific literatures regarding ART with respect to improving muscular strength and power among athletes and individuals of ages 13 to 65 years old. Using a 3-step approach searches were conducted across 4 electronic databases: MEDLINE, CINAHL, SPORTDiscus, and APA PsycInfo. After the removal of duplicates and irrelevant articles, the reference lists of all identified reports and articles were searched for additional studies. After searching the electronic databases, a total of 1247 articles were retrieved. Following the removal of duplicates 1187 articles were left to be screened for relevance based on their titles and abstracts. The included articles were scrutinized to extract information about ART, training protocols, outcomes and results. A total of 9 randomized controlled studies that met the inclusion criteria were retained for this scoping review to assess the effects of 4 weeks or longer ART intervention on muscular strength and power among males and females ages 13-65 years old. Within the parameters of this scoping review it is concluded that there are limited number of studies that have investigated ART. The ART modalities investigated included either bands or chains added to DCE RT modalities. It appears that ART is effective at improving muscular strength and power among individuals ranging in age from 17-44 years. However, there is not enough evidence to determine if ART is superior to DCE RT with respect to improving muscular strength and/or power. Additional investigations utilizing ART with a broader participant pool and extended duration RT protocols are warranted for the purpose of determining if ART is superior to DCE RT for improving muscular strength and power.

Keywords: *Resistance training, muscular strengths and power.*

1. INTRODUCTION

Resistance, strength training or weight training are forms of physical training exercise methods designed to improve muscular fitness by allowing the muscles to push against opposing forces (Fleck & Kraemer, 2014; Kumar et al., 2020; Kumaravelu & Govindasamy, 2018). These types of training exercises benefit individuals of all ages and are especially essential for athletes in sports that require speed, power, and strength (Aradi & Azadi. 2011; Hermassi et al., 2020; Vivekanth & Vallimurugan, 2018; Wisloff, 2004). Resistance training (RT) has been around for centuries and it is becoming prevalent among all age groups, including the elderly and children (Barbieri & Zaccagni, 2013; Faigebaum et al., 2003; Hunter

Correspondence: Mark DeBeliso (Ph.D.), Professor, Department of Kinesiology and Outdoor Recreation, Southern Utah University, Cedar City, USA, Email: markdebeliso@suu.edu

et al., 2004; Mayer et al, 2011). The back squat (BS), deadlift (DL), and bench press (BP) exercises have been commonly used as the top choices of RT modalities to improve lower and upper body strength and power (Baker, 2000; Del Vecchio, 2013). These RT modalities along with the Olympic lifts and their derivatives are known as multi-joint exercises and are more popular in the athletic strength and conditioning environment due to their specificity to sport applications (Suchomel et al., 2017). The BP, BS and DL have ascending strength curves, which allows the lifter to exert more force at the later range of motion during the ascending phase of the lift (Fleck & Kraemer, 2014; Galpin et al. 2015). The aforementioned free weight modalities are referred to as dynamic constant external RT modalities (DCE) as the resistive load remains constant throughout the range of a repetition (Fleck & Kraemer, 2014).

The human strength curves consist of three major types: ascending, descending, and bell shaped (Fleck & Kraemer, 2014). According to Fleck and Kraemer (2014), ascending strength curve modalities, such as the BS and the BP, allows the lifter to lift more weight when performing the last half or quarter of the concentric action in a repetition. As such, DCE RT modalities, which have ascending strength curves, do not optimally challenge the musculature during the later ranges of motion during the ascending phase of the lift. Conversely, descending strength curve modalities, such as the upright row, allows more weight to be lifted when performing the first half or quarter of the concentric action in a repetition (Fleck & Kraemer, 2014). Finally, bell-shaped curve modalities, such as bicep curls, and several other single-joint exercises allow greater resistance to be lifted in the middle portion of the range of motion (Fleck & Kraemer, 2014). In order to optimally meet the demands of each strength curve, specific variable resistance (VR) maybe applied throughout the full range of motion (eccentric and concentric muscle actions) while executing a single repetition of an exercise (Kramer et al., 2001).

Variable RT is manipulating the external resistance throughout the range of motion during the exercise and is often referred to as accommodating resistance training (ART) (Berning & Adams, 2004). There are several ways of modifying and adjusting the external resistance of an exercise: a) VR between repetitions-when altering the resistance in between repetitions of a given set, b) VR between sets-modifying the resistance between each set of a given exercise, c) Intra-VR-when altering the resistance within a series of exercises, d) Intra-repetition VR-when resistance is modified within a given repetition (Chirosa et al., 2014). For the purpose of this study, when the term ART is used, it is referring to modifying an external resistance of an exercise within a given repetition. This form of ART requires the use of specialized machines, resistance bands, and weight chains (see Figure 1).

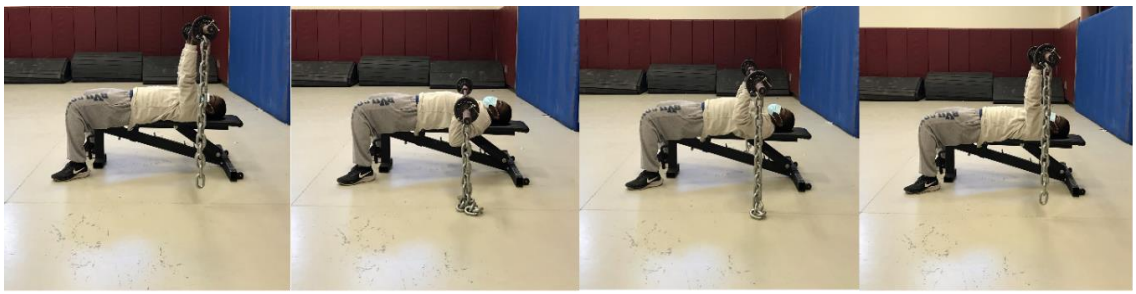

Figure 1: Bench press with chains added to allow for accommodating resistance

Specialized machines the utilizing levers and/or cams as the ART modality involves altering the external resistance through the full range of motion of an exercise in attempt to match the muscle's capacity for generating force (Chirosa et al., 2014). Levers and/or cams ART modalities are considered safer than free weight RT modalities and would be better suited for novice lifters because it is easier to control the load of an exercise compared to free weight RT (Chirosa et al., 2014). However, lever and/or cam ART has several disadvantages. One

of the biggest disadvantages of lever and/or cam ART equipment is that they are typically tailored to the size of an average person. As such, this type of equipment is ill suited for very tall or short individuals given their anthropometrics (McMaster et al., 2009). Likewise, these machines are not effective in matching the biomechanical strength curves in all individuals. With that said, the use of elastic bands and/or chain resistance have emerged as common ART training modalities (Ataee et al., 2014).

Chains and bands are added to a DCE free weight exercise (ex. BP or BS) in addition to the plates or maybe be used alone on the barbell as the mechanism of resistance. The elastics band resistance and/or weighted chains added to the barbell are considered to alter a DCE modality into an intra-repetition ART modality (Ataee et al., 2014). Rubber band resistance has an elastic characteristic that creates an increase and/or decrease in tension, which affects the amount of resistance being applied to the barbell with in a given repetition (McMaster et al., 2009). Similarly, chain external resistance demonstrates a linear function by continuously adding or reducing resistance while raising or lowering the barbell (Neelly et at., 2010). Given the aforementioned, rubber band and chain resistance added to a DCE modality appear to provide ART within a single repetition of an exercise. Despite the increasing popularity of using ART, there is a lack of research regarding ART's effectiveness for enhancing muscular strength and power (Berning et al., 2004).

1.1 Objectives

The purpose of this review is to examine the available scientific literature regarding ART with respect to improving muscular strength and power among athletes and individuals of ages 13 to 65 years old. In addition, we attempt to summarize the studies completed to date and identify any knowledge gaps to inform future research on the effectiveness of using ART. These following questions were considered to help guide the research: What are the different forms and methods of ART? What are the characteristics and results of the existing research conducted on the effectiveness of ART for improving muscular strength and power among individuals ranging from 13-65 years old?

2. METHODS AND MATERIALS

2.1 Protocol

The protocol for this scoping review was established by using the Preferred Reporting Items for Systematic Reviews and Meta-analysis (PRISMA) Extension for Scoping Reviews: Checklist and Explanation (Tricco et al. 2018).

2.2 Eligibility Criteria

The Population-Concept-Context framework, recommended by the Joanna Briggs Institute (JBI) Reviewer's Manual, was used to establish the eligibility criteria of this scoping review (Peters et al. 2020).

2.3 Population

Male and female ages 13-65 years and who were capable of participating in a RT program were suitable for inclusion.

2.4 Concept

The concept of this scoping review was to identify the different forms and methods of ART. In addition, this scoping review sought to identify the characteristics and results of the existing research conducted on the effectiveness of ART on improving muscular strength and power among individuals ranging from 13-65 years old. This review did not include studies that employed RT machines that featured Cams as the ART modality.

2.5 Context

This scoping review did not exclude any study designs. Study designs such as published articles and reviews, conference proceedings, and chapters in the text, with the exceptions of gray literature, were considered and included if they met eligibility criteria. Following the

PRISMA-ScR Checklist, we conducted a search of 4 electronic databases from inception to 20 November 2020. There were no exclusions in searching for publications. A single reviewer screened the literature and abstracted data from relevant publications.

2.6 Information Sources

A 3-step approach was used to identify potential relevant literature. The first step that was used was an initial limited search of two online databases relevant to the topic: MEDLINE and CINAHL. This initial search was then followed by an analysis of the text words contained in the title and abstract of retrieved papers, and of the index terms used to describe them. A second search using all identified keywords and index was then conducted across these electronic databases: MEDLINE, CINAHL, SPORTDiscus, and APA PsycInfo. Thirdly, after the removal of duplicates and irrelevant articles, the reference list of all identified reports and articles were searched for additional studies.

2.7 Search

The final search strategy for all databases used can be found in Appendix 1.

2.8 Selection of Sources of Evidence

A priori eligibility criteria were adopted to develop a standardized questionnaire for study selection to screen titles, abstracts, and full text. Following the removal of duplicates, the lead investigator screened papers based on titles and abstracts. Any papers that that failed to meet the criteria for eligibility were not included. Following the removal of ineligible articles, the full texts of the remaining articles were screened in detailed for the final stage of the eligibility process. A flow diagram with an outline of the study selection process was develop using the PRISMA guidelines. After searching the electronic databases, a total of 1247 articles were retrieved. Following the removal of duplicates 1187 articles were left to be screened for relevance based on their titles and abstracts. Studies were included if: 1) at least one form of ART is used as the experimental group, 2) physiological outcome variables were measured; muscular strength and power, 3) participants were between 13 years to 65 years old, 4) articles are published in the English language, 5) at least 4 weeks or longer of training intervention duration.

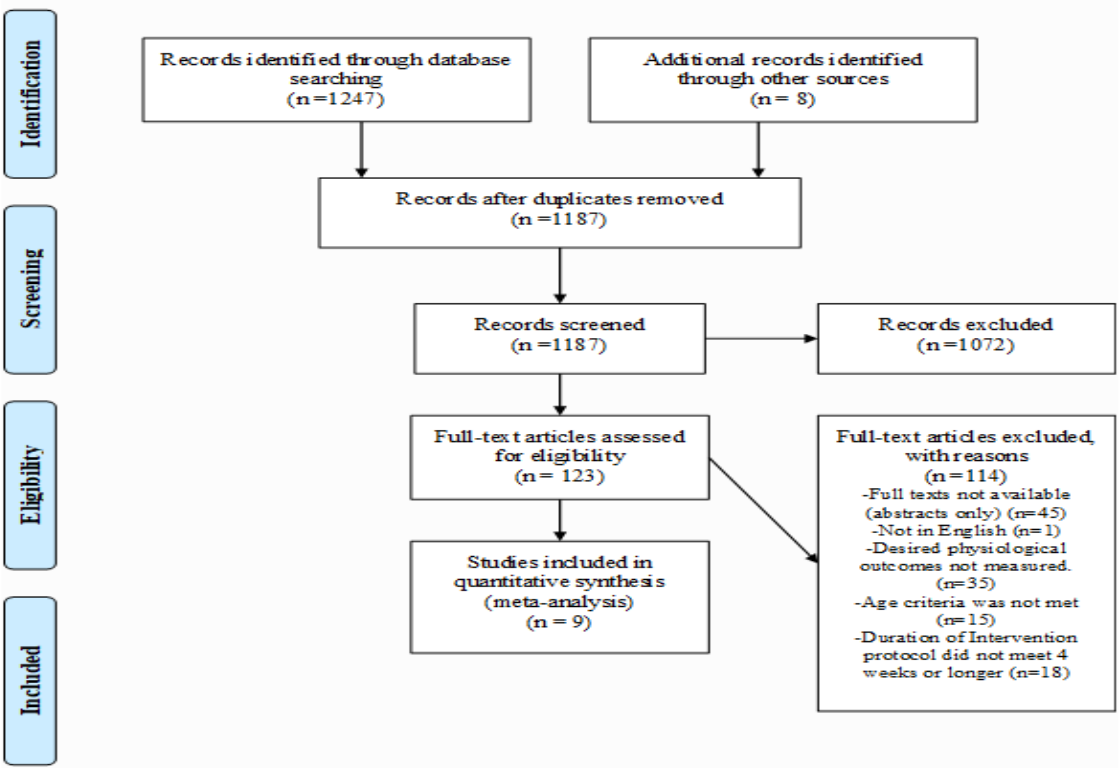

Figure 2: From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

2.9 Data Charting and Data Items

The recommended JBI Methodology Guidance for conducting Scoping Reviews were used at the protocol stage to create a data-charting form (Peters et al. 2020). The key areas of focus that were identified were study citation details (author, year of publication, reference type, country of origin, and study design), study sample characteristics (sample population, size), and key study characteristics (study aims, methodology adopted, outcomes measured, key findings and area of application). Additional fields such as, type of ART used, gender/age of participants, and duration of study intervention, were included after updating the data extraction fields. The lead investigator extracted important information from each form upon completing the refining process of the data-charting form. The final extraction data-chart form included study citation details (author, year of publication, reference type, country of origin, and study design), study participant characteristics (sample population, size, gender and mean age), and key study characteristics (study aims, total duration of study intervention, methodology adopted, type of ART used, outcome variable measured, key findings and area of application).

2.10 Synthesis of Results

The findings of the studies were categorized according to study characteristics such as participant characteristics, types of physiological outcome variables measured, the ART exercises modalities used, and the results of the study intervention with regards to muscular strengths and power measured (see Tables 1-4).

3. RESULTS

A total of 9 randomized controlled studies that met the inclusion criteria were retained for this scoping review to assess the effects of 4 weeks or longer ART intervention on muscular strength and power among males and females ages 13-65 years old. The subsequent subsections provide a synopsis of the study characteristics and outcomes.

Resistance Training Characteristics

Table 1: Details of characteristics of included studies (n=9)

	Subject Characteristics				
Author(s), year,	**n & Gender**	**Age**	**Weight**	**Height**	**Type of participants**
Aloui et al, (2019)	30 Men	18.7 ± 0.8	81.1 ± 15.4 kg	1.82 ± 0.06 m	Trained national junior handball players
Aloui et al, (2019)	30 Men	18.7 ± 0.8	81.1 ± 15.4 kg	1.82 ± 0.06 m	Trained national junior handball players
Andersen et al, (2015)	32 Women	24 ± 5	67 ± 8.5 kg	169 ± 6.5 cm	Healthy scarce trained in free weight lifting
Anderson et al, (2008)	44 Mixed	20 ± 1	⸸	⸸	Collegiate basketball, wrestling & hockey players
Ataee et al, (2014)	40 Men	20.5 ± 2.00	70.22 ± 10.5 kg	173.34± 6.53 cm	Trained Kun-Fu athletes & wrestlers
Ghigiarelli, (2009)	36 Men	19.96±1.03	96.3 ± 15 kg	180.83±6.24 cm	NCAA Division 1 American football players
Izadi et al, (2020)	24 Men	17.25 ± 0.9	66.7±7 kg	174.65±5.5 cm	Junior competitive soccer players
Rhea et al, (2009)	48 Men	21.4 ± 2.1	⸸	⸸	Trained NCAA Division 1 athletes
Shoepe et al, (2011)	12 Mixed	19.76 ± 1.33	66.8 ± 11.1 kg	168.77±10.3 cm	Scarce trained college students

Training Characteristics							
					Intensity (%)		
Reference	ART	Duration	Frequency	Sets & Repetitions	PAR	PCR	PMR
Aloui et al, (2019)	Elastic Bands	8 weeks	2 days/week	3-4 x 6-10	∔	∔	∔
Aloui et al, (2019)	Elastic Bands	8 weeks	2 days/week	3 x 12-15	∔	40-60	∔
Andersen et al, (2015)	Elastic Bands	10 weeks	2 days/week	3-6 x 2-10	58-27	50-70	of 6RM
Anderson et al, (2008)	Elastic Bands	7 weeks	3 days/week	3-6 x 2-10	15	85	85
Ataee et al, (2014)	Chains	4 weeks	3 days/week	3 x 5	20	85	85-100
Ghigiarelli, (2009)	Band/ Chain	7 weeks	4-5 days/week	5-6 x4-6	∔	∔	∔
Izadi et al, (2020)	Chains	8 weeks	2 days/week	3-5 x 6-10	10-15	60-85	60-85
Rhea et al, (2009)	Elastic Bands	12 weeks	2-3days/week	4 x10	∔	∔	75-85
Shoepe et al, (2011)	Elastic Bands	24 weeks	3 days/week	3-6 x 6-10	20-35	80-60	65-95

**ART=accommodating resistance training; PAR=percentage accommodating resistance; PCR=percentage constant resistance; PMR=percentage maximal resistant; NCAA=National Collegiate Athletic Association; ∔=not define*

Figure 1 shows the PRISMA flow chart diagram from the scoping review search; 9 studies that met inclusion criteria to be analyzed. The articles were published from 2008-2020. Table 1 displays an overview of the characteristics of the included studies of this scoping review. Six of the studies used elastic bands training exclusively as the type of the ART for the experimental training groups (Aloui et al., 2019; Aloui et al., 2019; Andersen et al., 2015; Anderson et al., 2008; Rhea et al., 2009; Shoepe et al., 2011) whereas two studies used chains as the ART (Ataee et al., 2014; Izadi et al, 2020). In the study by Ghigiarelli et al. (2009) two experimental groups were used with one control group. Elastic bands were used by one of the experimental groups training and chains were used by the other. The duration of the training protocols ranged from 4 to 24 weeks with 7-8 weeks being used most often. The frequency of the training ranged from 2 to 5 days a week with 2-3 days a week being most frequently used. Finally, sets and repetitions were between 3-6 and 2-15 respectively with 3 sets and 4-10 repetitions being commonly employed.

Table 2: Outcomes measured (muscular strength and power) and exercises of included studies (n=9)

Type of physiological outcome(s) measured and exercises		
Reference	Muscular strength	Muscular power
Aloui et al, (2019)	Bench press 1RM & Pull over 1RM	Overhead Throw and Force-Velocity test
Aloui et al, (2019)	Back half squat 1RM	Squat Jump, CMJ and Force-Velocity test
Andersen et al, (2015)	Back Squat (6RM)	CMJ (jump height at 60°, 90°, 120°)
Anderson et al, (2008)	Bench Press & Back Squat 1RM	CVJ (Countermovement Vertical Jump)
Ataee et al, (2014)	Bench Press & Back Squat 1RM	Medicine ball throw test & Vertical jump test
Ghigiarelli, (2009)	Bench press 1RM predicted	Speed bench press 5RM
Izadi et al, (2020)	Back squat 1RM	Vertical jump test
Rhea et al, (2009	Back squat 1RM	Countermovement Jump test
Shoepe et al, (2001)	Squat and Bench press 1RM	Isokinetic test velocity of quadriceps

Participant characteristics

A total of 296 subjects (mostly men) were examined from the included studies ranging from 17-44 years of age. Six of the included studies contained men participants only (Aloui et al., 2019; Aloui et al., 2019; Ataee et al., 2014; Ghigiarelliat al., 2009; Izadi et al., 2020; & Rhea et al., 2009) while one study included only women participants (Andersen et al., 2015). The remaining two studies had a mix of both men and women (Anderson et al., 2008; Shoepe et al., 2011). Most of the participants were well-trained collegiate athletes of various sports; 128 participants were NCAA Division 1 athletes (North American football, basketball, wrestling, and hockey). The other participants were trained national junior handball players (60 total), trained national junior soccer players (24 total), trained Kun-Fu athletes and wrestlers (40 total), healthy limited RT college students (12 total), and 32 limited RT females ranging from 20-40 years old.

Strength effects of ART of included studies (n=9)

Table 3: Results of included studies n=9

		Strength Results 1RM									
		Control Groups					Experimental Groups				
Reference	Exercise	Pretest (kg)	SD (kg)	Posttest (kg)	SD (kg)	ES	Pretest (kg)	SD (kg)	Posttest (kg)	SD (kg)	ES
Aloui et al,	BP	66.6	10.3	67.7	11.3	0.1	66.4	10.3	83.1	11.9	1.51
Aloui et al,	HBSQ	124	14	125	15	0.07	123	10	138	11	1.42
Andersen et al,	BSQ	60	7.2	73.9	8.6		58.2	8	72.7	9.3	
Anderson et al,	BP	81.07	32.82	84.41	33.37	0.43	80.69	35.34	87.37	35.52	0.66
	BSQ	108.19	35.61	115.28	33.7	0.86	105.8	33.7	121.75	35.7	1.58
Ataee et al,	BP	76.5	15.14	87.87	16.68		80	10.84	92.5	14.41	
	BSQ	116.75	24.02	142.25	20.04		117.62	11.99	163.12	18.82	
Ghigiarelli,	BP	141.8	23	149.5	23	1.44	127.7	25	137.7	25	1.4
	BP						129.5	15	138.6	14	2.13
Izadi et al,	BSQ	120		125		0.5	1130		1651		1.1
Rhea et al,	BSQ	115.94	36.07	119.18	35.56	0.38	116	31.43	125.81	30.69	1.1
	BSQ	122.31	39.04	131.94	36.43	1.08					
Shoepe et al,	SQ	66.9	16.5	88.9	23.2	2.72	69.3	27	91.4	31.9	2.27

*BP=Bench press, HBSQ=Half back squat, BSQ=Back squat, SQ=Squat

** Effective size

Table 3 provides a summary of the strength results measured for the included studies. When measuring muscular strength, the 1RM back squat (BS) and bench press (BP) were used by the majority of the included studies. However, Andersen et al. (2015) used the 6RM BS and Ghigiarelli et al. (2009) used the 1-RM predicted BP.

In the study conducted by Ataee et al. (2014) chains were used to induce ART and were used by the experimental group (ART) while the comparison group used DCE RT. The ART group demonstrated a significantly greater increase in lower body strength then the DCE group. However, there was no significant differences in upper strength between the ART and DCE RT groups as the result of the study intervention.

The study by Ghigiarelli et al. (2009) utilized three study groups of NCAA North American football players using different BP modalities: chains, bands or DCE RT. All of the study groups demonstrated a significant improvement in the 1-RM BP as a result of the study protocols, however there was no difference between any of the groups.

The remainder of the included studies used bands to induce ART as the modality for the experimental groups, DCE RT was used as the modality for the comparison groups, and no RT was employed for control groups. The studies by Aloui et al., (2019 a,b) demonstrated superior increases in upper and lower body strength by the ART group compared to the control groups.

In the study by Andersen et el. (2015) the ART experimental and DCE RT groups demonstrated similar significant improvements in lower body strength as a result of the study intervention. Likewise, a study by Anderson et al. (2008) demonstrated significant improvements in upper and lower body strength for both the ART experimental group and DCE RT comparison group, however the ART group demonstrated a significantly greater increase in lower and upper body strength compared to the DCE RT group.

Studies by Izadi et al., (2020), Rhea et al., (2009) and Shoepe et al. (2001) yielded comparative results. Rhea et al., (2009) demonstrated that ART and DCE RT interventions yield similar significant increase in lower body strength. Research by Shoepe et al., (2001) suggested that ART and DCE RT interventions yield similar significant increase in lower and upper body strength. Finally, Izadi et al., (2020) demonstrated significant increases in lower body strength measures as the result of ART when compared to a control group.

Power effects of ART of included studies (n=9)

Table 4: Results of Power outcomes of included studies n=9

		Power Results									
		Control Group					Experimental Group				
		Pretest	SD	Posttest	SD		Pretest	SD	Posttest	SD	
Reference	Exercise					ES					ES
Aloui et al,(2019)	FVT (W)	417	76	456	99.6		427	87.6	632	144	
Aloui et al,(2019)	FVT Wpeak	675	133	701	127	0.2	646	141	867	155	1.49
	CMJ (W)	1852	323	1867	264	0.12	1864	340	2104	355	0.69
	SJ (W)	1510	300	1570	284	0.2	1475	190	1677	206	1.01
Andersen et al,	CMJ 60° (CM)	21.1	4	23.7	3.2		22.1	5.2	25.1	5.9	
-2015	CMJ 90° (CM)	21.1	2.6	24	3.1		22	4.4	23.9	4.1	
	CMJ 120°(CM)	20.3	2.1	22.7	3.41		20.9	4.5	22.4	3.7	
Anderson et al,	CVJ	1434.03	438.15	1499.85	471.06		1500.02	500.82	1523.68	497.27	
-2008											
Ataee et al,	MBT (M)	4.56	0.43	4.56	0.43		4.73	0.41	5.06	0.45	
2014	VJ (W)	3644.29	394.02	3814.46	486		4055.87	791.19	4324.3	746.32	
Ghigiarelli,	SB (W)	877	142	858	153		(C)823	153	823	134	
2009	SB (W)			885	157				815	101	
	SB (W)						(B)812	171	812	174	
									835	181	
Izadi et al,(2020)	CMJ (CM)	41		44		0.04	38		45		1.5
Rhea et al,(2009)	CMJ F (W)	1124.75	174.25	1264.25	192.37	0.8	1146.38	226.41	1387.19	221.65	1.06
	CMJ S (W)	1151.56	205.6	0.028							
Shoepe et al,	Iso (90)	124	43.3	115	38.6		143.1	38.6	144.5		
2011											

*FVT=free velocity test; CMJ=countermevement jump; CVJ=countermovement vertical jump; SB=speeed bench;

Table 4 lists a summary of the muscular power results measured for the included studies. The study by Ataee et al. (2014) found no significant differences in upper or lower body power measures between the ART and DCE RT group as the result of the study intervention. Counterintuitively, the authors did not state if power measures increased within the study groups.

The study by Ghigiarelli et al. (2009) utilized three study groups of NCAA North American football players using different BP modalities: chains, bands or DCE RT. None of the study groups improved upper body power.

Similarly, Rhea et al. (2009) found that ART at fast speed promotes significantly greater lower body power output than slow speed DCE RT but not high speed DCE RT.

In the study by Andersen et el. (2015) the ART and DCE RT groups demonstrated similar significant improvements in lower body power output as a result of the study intervention. Likewise, a study by Anderson et al. (2008) demonstrated significant improvements in lower body power measures (peak and average power output) for both the ART experimental group and DCE RT comparison group, however the ART group demonstrated a significantly greater increase average power output compared to the DCE RT group.

The studies by Aloui et al. (2019 a,b) demonstrated superior increases in upper and lower body power output by the ART compared to the control groups. Likewise, research by Shoepe et al. (2001) demonstrated significant increases in lower body power output as the result of ART when compared to a control group. However, Shoepe et al. (2001) did not state if ART led to significantly greater increases in lower body output when compared to DCE RT. Izadi et al. (2020) demonstrated significant increases in lower body power output as the result of ART when compared to a control group.

4. DISCUSSION

In this scoping review we summarized the findings of selected studies that met the inclusionary criteria as well as the outcomes of the search strategy. The questions that we attempted to answer focused on the results of existing literature regarding ART modalities employed, as well as the impact of ART with regards to improving muscular strength and power.

The majority of the participants were either trained collegiate athletes or trained junior national athletes. The remainder of the participants were either scarcely trained college students or minimally trained healthy individuals ranging from 17-44 years of age. Only three of the studies included females. Future research should be more inclusionary regarding female participants. Likewise, investigations should look to include youths as well as mature adults as the benefits of RT are enjoyed by both of these populations (Baechle et al., 2000).

The duration of training interventions ranged between 4-24 weeks. However, 7-8 weeks of training seemed to be widely used in the included studies. Future research could look to include ART as a modality within a multi-year periodized RT program which is now common place for collegiate athletes (Baechle et al., 2000). The ART modalities used in the studies were a combination of either elastic bands and/or chains coupled to the DCE RT modalities of the BP or BS. Future research should look to use other DCE RT modalities to modify with bands and/or chains to function as ART modalities. For example, one could include bands and or chains to isolated joint RT modalities such as the biceps curl. Further one could imagine incorporating bands and/or chains with certain Olympic lifting derivatives (e. mid-thigh pull) as well as hip thrusts. Mechanisms for use of bands to induce ART could include suspension where by the bands are mounted to a power rack and used to unload an Olympic bar as it is lowered during the BS, BP, or deadlift.

The inclusionary criteria for the current study focused on the dependent variables of muscular strength and power. Future research could include the impact of ART on muscle mass as theoretically ART challenges the musculature to a greater extent throughout the range of motion of a repetition. Likewise, future investigations might examine if ART could serve beneficial with respect to developing running speed and acceleration. Finally, studies examining the effectiveness of ART among older adults could include functional outcome variables such as a stair limb or a seated get up and go test.

5. LIMITATIONS

Our scoping review has some limitations. First, this review excluded all publications that were not written in English. Second, this review focused only on maximal muscular strength and power benefits as the physiological outcome variables measured, which excluded articles measuring other physical fitness components such as aerobic and/or anaerobic capacity. Third, this scoping review excluded articles containing studies with training intervention lasting less than 4 weeks. Fourth, this review excluded participants less than 13 years old and older than 65 years old. Finally, the various analysis of existing research (i.e. screening, inclusion/exclusion, and data charting) was conducted by the principle investigator which may had led to a degree of reviewer bias.

6. CONCLUSION

Within the parameters of this scoping review it is concluded that: there are limited number of studies that have investigated ART, the ART modalities investigated included either bands or chains added to DCE RT modalities, it appears that ART is effective at improving muscular strength and power among individuals ranging in age of 17-44 years, there is not enough evidence to determine if ART as a modality is superior to DCE RT modalities with respect to improving muscular strength and/or power. Additional investigations utilizing ART with a broader participant pool and extended duration RT protocols are warranted for the purpose of determining if ART is superior to DCE RT for improving muscular strength and power.

7. REFERENCES

Aloui, G., Hammami, M., Fathloun, M., Hermassi, S., Gaamouri, N., Shephard, R. J., & Chelly, M. S. (2019). Effects of an 8-week in-season elastic band training program on explosive muscle performance, change of direction, and repeated changes of direction in the lower limbs of junior male handball players. *Journal of Strength and Conditioning Research 33*(7), 1804-1815.

Aloui, G., Hermassi, S., Hammami, M., Gaamouri, N., Bouhafs, E. G., Comfort, P., Shephard R. J., Schwesig, R., & Chelly, M. S. (2019). Effects of an 8-week in-season upper limb elastic band training programme on the peak power, strength, and throwing velocity of junior handball players *Sport verl Sportschaden*, *33*, 1-9.

Andersen, V., Finland, M. S., Kolnes, M. K., & Saeterbakken, A. H. (2015). Elastic bands in combination with free weights in strength training: neuromuscular effects. *Journal of Strength and Conditioning* Research, *29*(10), 2932-2940.

Anderson, C. E., Sforzo, G. A., & Sigg, J. A. (2008). The effects of combining elastic and free weight resistance on strength and power in athletes. *Journal of Strength and Conditioning Research*, *22*(2), 567-574.

Arazi, H., & Asadi, A. (2011). Effects of 8 weeks equal-volume resistance training with different workout frequency on maximal strength, endurance and body composition. *International Journal of Sports Science and Engineering*, *5*(2), 112-118.

Ataee J., Koozehchian, M. S., Kreider, R. B., & Zuo, L. (2014). Effectiveness of accommodation and constant resistance training on maximal strength and power in trained athletes. *PeerJ*, 2, E441.

Baechle, T. R., & Earle, R. W. (2008). *Essentials of strength training and conditioning*. 3rd ed. Champaign, IL: Human Kinetics.

Baker D. (2000). Comparison of upper–body strength and power between professional and college–aged rugby league players. *Journal of Strength and Conditioning Research*, *15*(1), 30-35.

Barbieri, D., Zaccagni, L. (2013). Strength training for children and adolescents: Benefits and risks. *Collegium Anthropologicum*, *37*(2), 219-225.

Beckman, G., Lamont, H., Sato, K., Ramsey, M., Haff, G., & Stone, M. (2012). Isometric strength of powerlifters in key positions of the conventional deadlift. *Journal of Trainol*, *1*(2), 32-35.

Bellar, D. M., Muller, M. D., Barkley, J. E., Kim, C. H., Ida, K., Ryan, E. J., Bliss, M. V., Glickman, E. L. (2011). The effects of combined elastic- and free-weight tension vs. free-weight tension on one-repetition maximum strength in the bench press. *Journal of Strength and Conditioning Research, 25*(2), 459-463.

Berning, C. & Adams, K. J. (2004). Using chains for strength and conditioning. *Strength & Conditioning Journal*, *26*(5), 80-84.

Chirosa, J. I., Baena, S., Soria, A. M., Bautista, J. I., & Rios, L. J. C. (2014). Intra-repetition variable resistance training: Part 1. An overview. *European Journal of Human Movement,* 32, 48-60.

Del Vecchio, A., Casolo, A., Negro, F., Scorcelletti, M., Bazzucchi, I., Enoka, R., Felici, F., & Farina, D. (2019). The increase in muscle force after 4 weeks of strength training is mediated by adaptations in motor unit recruitment and rate coding. *The Journal of Physiology*, *597*(7), 1873-1887.

Dohoney, P., Chromiak, J. A., Lemire, D., Abadie, B. R., & Kovacs, J. (2002). Prediction of one repetition maximum (1-RM) strength from 4-6 RM and a 7-10 RM submaximal strength test in healthy young adult males. *JEPonline, 5*(3), 54-59.

Faigenbaum, A. D., Milliken, L. A., & Westcott, W. L. (2003). Maximal strength testing in healthy children. *Journal of Strength and Conditioning Research*, *17*(1), 162-166.

Fleck, S. J., & Kraemer, W. J. (2014). *Designing resistance training programs*. 4th ed. Champaign, IL: *Human Kinetic*s.

Galpin, A. J., Malyszek, K. K., Davis, K. A., Record, S. M., Brown, L. E., Coburn, J. W., . . . & Manolovitz, A. D. (2015). Acute effects of elastic bands on kinetic characteristics during the deadlift at moderate and heavy loads. *Journal Strength and Conditioning Research*, *29*(12), 3271–3278.

Ghigiarelli, J. J., Nagle, E. F., Gross, F. L., Robertson, R. J., Irrgang, J. J., & Myslinski, T. (2009). The effects of a 7-week heavy elastic band and weight chain program on upper-body strength and upper-body power in a sample of division 1-AA football players. *Journal of Strength and Conditioning Research, 23*(3), 756-764.

Hermassi, S., Laudner, K., Schwesig, R. (2020). Effects of circuit strength training on the development of physical fitness and performance-related variables in handball players. *Journal of Human Kinetics*, 71, 191-203.

Hunter, G. R., McCarthy, J. P., & Bamman, M. M. (2004). Effects of resistance training on older adults. *Sports Medicine, 34*(5), 329-348.

Izadi, M., Arazi, H., Ramirez-Campillo R., Mirzaei, M., Saidei, P. (2020). In-season in-field variable resistance training: effects on strength, power, and anthropometry of junior soccer players. *Journal of Sports Medicine Physical Fitness, 60*(2), 220-228

Kumaravelu, P. & Govindasamy, K. (2018). Impact of circuit resistance training on leg strength among university players from different disciplines. *International Journal of Yogic, Human Movement and Sports Sciences*, *3*(1), 158-159.

Mayer F., Scharhag-Rosenberger, F., Carlsohn, A., Cassel, M., Muller, S., & Schurhag, J. (2011). The intensity and effects of strength training in the elderly. *Deutsches Arzteblatt International*, *108*(21), 359-364.

McCurdy K., Langford G., Ernest J., Jenkerson, D., & Doscher M. (2009). Comparison of chain- and plate-loaded bench press training on strength, joint pain, and muscle soreness in division II baseball players. *The Journal of Strength & Conditioning Research*, *23*(1), 187-195.

McMaster, D. T., Cronin, J., & McGuigan, M. (2009). Forms of variable resistance training. *Strength and Conditioning Journal*, *31*(1), 50-64.

Neelly, K. R., Terry, J. G., & Morris, M. J. (2010). A mechanical comparison of linear and double-looped hung supplemental heavy chain resistance to the back squat: A case study. *The Journal of Strength & Conditioning Research*, *24*(1), 278-281.

Peters, M. D. J., Godfrey, C., McInerney, P., Munn, Z, Tricco, A. C., & Khalil, H. (2020). Chapter 11: Scoping Reviews (2020 version). In: Aromataris E, Munn Z (Editors). *JBI Manual for Evidence Synthesis*, JBI, 2020. https://doi.org/10.46658/JBIMES-20-12

Rhea, M. R., Ball, S. D., Phillips, W. T., & Burkett, L. N. (2002). A comparison of linear and daily undulating periodized programs with equated volume and intensity for strength. *Journal of Strength and Conditioning Research*, *16*(2), 250-255.

Rhea, M.R., Kenn, J.G., & Dermody, B.M. (2009). Alterations in speed of squat movement and the use of accommodated resistance among college athletes training for power. *Journal of Strength and Conditioning Research, 23(9),* 2645-2650.

Soria-Gila, M. A., Chirosa, I. J., Bautista, I. J., Baena, S., & Chirosa, L. J. (2005). Effects of variable resistance training on maximal strength: a meta-analysis. *Journal of Strength Conditioning Research, 29*(11), 3260-3279.

Shoepe, T. C., Ramirez, D. A., Rovetti, R. J., Kohler, D. R., Almstedt, H. C. (2011). The effects of 24 weeks of resistance training with simultaneous elastic and free weight loading on muscular performance of novice lifters. *Journal of Human Kinetics, 29*, 93-106.

Suchomel, T.J., Comfort, P., & Lake, J. P. (2017). Enhancing the force-velocity profile of athletes using weightlifting derivatives. *Strength & Conditioning Journal*, *39*(1), 10-20.

Tillaar, RV. & Saeterbakken, A. (2012). The sticking region in three chest press exercises with increasing degrees of freedom. *Journal of Strength and Conditioning Research, 26(11)*, 2962-2969.

Vivekanth, B. & Vallimurugan, V. (2018). Effects of strength training on physical fitness variables of intercollegiate volleyball players. *International Journal of Applied Research*, *5*(6), 442-444.

Wallace, B. J., Winchester, J. B., & McGuigan, M. R. (2006). Effects of elastic bands on force and power characteristics during the back squat exercise. *Journal of Strength and Conditioning Research, 20*(2), 268–272.

Wisløff, U., Castagna, C., Helgerud, J., Jones, R., & Hoff, J. (2004). Strong correlation of maximal squat strength with sprint performance and vertical jump height in elite soccer players. *British Journal of Sports Medicine, 38*(3), 285-288.

Zunker, W., (2008). The influence of chain resistance on power output during the squat exercise. *ProQuest Information and Learning Company. UMI Number: 140622.*

Appendix 1: Search strategy used for each electronic database searched

Database	Date searched	Search strategy	# of results
MEDLINE	19/11/2020	"chain training" OR "weight chains" OR "chain resistance" AND "muscular power" OR "Muscular strength" And "elastic band" OR "rubber band" OR "variable resistance training" OR "variable resistance" OR "accommodating resistance training" OR "accommodating resistance" AND "cams" OR "levers" AND "athletic performance" AND "high school athletes" AND "collegiate athletes" AND "Professional athletes"	334
CINHAL	19/11/2020	"chain training" OR "weight chains" OR "chain resistance" OR "elastic band" OR "rubber band" OR "variable resistance training" OR "variable resistance" OR "accommodating resistance training" OR "accommodating resistance" OR "cams" OR "levers" AND "athletic performance" AND "high school athletes" AND "collegiate athletes" AND "Professional athletes"	279
Sports Discus with Full text	19/11/2020	"variable resistance training" OR "variable resistance" OR "accommodating resistance training" OR "accommodating resistance" AND "chain training" OR "weight chains" OR "chain resistance" AND "muscular power" OR "Muscular strength" And "elastic band" OR "rubber band" AND "cams" OR "levers" AND "athletic performance" AND "high school athletes" AND "collegiate athletes" AND "Professional athletes"	156
APA PscInfo	19/11/2020	"chain training" OR "weight chains" OR "Chain training" AND "muscular power" AND "Muscular strength" And "elastic band" OR "rubber band" AND "variable resistance training" OR "variable resistance" AND "accommodating resistance training" OR "accommodating resistance" AND "cams" AND "levers" AND "athletic performance" AND "high school athletes" OR "collegiate athletes" OR "Professional athletes" AND "force output" AND "Maximal power" AND "maximal strength"	478