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Review

Comparison of the Effects of Linear and Non-Linear Resistance Training Periodization on Morphofunctional Capacity of Subjects with Different Fitness Levels: A Systematic Review

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ABSTRACT

International Journal of Exercise Science 12(4): 666-690, 2019. Resistance training (RT) is recognized as an efficient method to improve muscle strength, power, hypertrophy; all are fundamental components of functional health and quality of life. Variables of RT such as volume, intensity, density, rest interval, duration, exercise order and selection, training frequency, and periodization models (i.e. linear periodization (LP), reverse linear periodization (RLP), block periodization (BP), and nonlinear periodization (NLP): undulating periodization (UP) and weekly undulating periodization (WUP)) are manipulated to potentiate musculoskeletal adaptations. The aim of the present study was to conduct a systematic review of studies comparing different periodization models on morphofunctional capacity in adults with different levels of physical activity. Databases from Ebsco, PubMed and Web of Science were searched between January 2007 and June 2017 using the following descriptors: RT; strength training; LP; UP; daily UP; NLP. From the 4337 articles found, 11 met the inclusion criteria. The mean number of sets in each RT model was 3 ± 1 for both (LP and UP), mean repetitions used was 10 ± 5, and the mean inter-set rest interval was 2 ± 1 minutes . The mean number of exercises was 7 ± 3 with training duration ranging from 45 to 90 minutes. The number of sets, repetitions, rest interval, and load intensity were minimally detailed in 12% of articles evaluated. In conclusion, RT programs that used LP and UP presented discrepant results, which precludes a consensus at this time. Most characteristics and differences between studies reported here should be used in future experimental designs to improve our understanding about periodization models.

KEY WORDS: Strength training, training age, undulating periodization

INTRODUCTION

Muscle strength can be defined by the capacity to produce force under a cluster of biomechanical conditions (1). Resistance training (RT) is recognized as an efficient method to improve muscle strength, power, hypertrophy, which are fundamental components of health and quality of life related physical fitness (1). The guidelines from the American College of Sports Medicine (ACSM) (1) recommends implementing RT with 2-3 sessions per week with 8-10 multijoint exercises targeting the main muscle groups in healthy adults. However, these recommendations are generalized and non-discriminant for subjects of various ages and with health conditions. Others recommend (7, 10, 11) experienced lifters (≥1 year of RT experience) deploy split routines, wherein one to three muscle groups are intensely trained per session (14). Induced responses by RT are based on limited extrapolations of evidence (13), and, their practical applications are questionable.

In this sense, the quantity of research on the effects of training variables and different periodization models on muscle strength and hypertrophy increased significantly over the past several decades (2-4, 23). RT variables such as volume, intensity, density, rest interval, duration, exercise order and selection, repetition velocity, training frequency, and periodization models, including linear periodization (LP), reverse linear periodization (RLP), nonlinear periodization ((NLP) including undulating periodization (UP) or weekly undulating periodization (WUP)) and block periodization (BP) are manipulated to potentiate musculoskeletal adaptations.

Linear Periodization gradually increases training intensity while decreasing volume with these changes being made approximately every four weeks (12). NLP is characterized by more frequent alterations (daily or weekly) in intensity and volume (12). Daily fluctuations in intensity and load are often categorized as daily UP, whereas weekly fluctuations is specified as WUP. It is traditional for investigators to focus on altering training load and volume (2, 3, 19, 20) and LP and NLP received more attention in research amongst periodization models (5). The divergence of RT interventions calls for a systematic review synthesizing the available literature. Of the published works, there appears to be a scarcity of evidence on different models of periodization, furthermore, it is noted that most programs limit analyzes to the effect on muscle strength and hypertrophy (5, 6, 13). Limiting focus to only a few programming styles and outcome variables leads to neglect of morphofunctional aspects of adaptation (hormonal variables, cardiometabolic variables, body composition, strength levels), which is considered an integral component of health.

Although regularly implemented and debated, a recent systematic review and meta-analysis revealed no differences between LP and NLP in muscle strength (6) and hypertrophic improvements (5). A more focused review in hypertrophic gains of individuals with different levels of physical fitness may promote practitioners to be more informed of these periodization schemes, increasing the likelihood of application when programming for those who desire to hypertrophy for recreation, sport, or personal health. Thus, the aim of the present study was: 1) to identify studies that used LP and NLP models of RT in adults; 2) to compare the effects of different periodization models on morphofunctional capacity in adults with different levels of physical activity.

METHODS

Protocol

This systematic review was conducted according to the recommendations described in previous studies (8,21): 1) frame questions for a review; 2) identify relevant studies; 3) evaluate the quality of the studies; 4) consolidate the evidence; and 5) interpret results. Moreover, the present review utilized the 27 PRISMA (Main Items for Reporting Systematic Reviews and Meta-analyzes) items to assure transparent and complete interpretation of the interventions. This systematic review of the literature was performed from bibliographic research of studies that analyzed the effects of different RT periodization models in adults. The search was conducted using Ebsco, PubMed and Web of Science databases, from January 2007 to June 2017. The selection of the descriptors followed the indicators of DeCS (descriptor of issues in health science from Bireme). The following descriptors were considered for the search: resistance training; strength training; linear periodization, undulating periodization; daily undulating periodization; non-linear periodization. Logical operators "AND", "OR" and "AND NOT" were used for the combination of the descriptors. After these criteria, there were 8893 studies that could be reviewed.

During phase one, potential studies were identified and duplicates were removed, totalling 4337 publications with potential for the review. Figure 1 presents the organogram that describes each phase and strategies used for the selection of the studies. In the event of disagreement, a third and fourth researcher performed the final analysis (AJFJ and CGSPM). The inclusion criteria applied by the researchers were as follows: studies comparing the effect of a training program with LP and UP. To be classified as an acceptable RT intervention, the training needed to use: a) free weight and machines, exercise with body weight resistance (including plyometrics), elastic tubes, isokinetic equipment; b) an adult only sample; c) subjects were submitted to RT with pre- and post-intervention. A full review of text reading was implemented if the aforementioned characteristics could not be identified by the abstract.

After the phase one, the studies were read denoting to the following parameters: year of publication; number of subjects; number of subjects per sex; mean age; height; body mass index; percentage body fat; percentage fat-free mass; physical activity level; weekly training frequency; groups; number of subjects per group; RT training method used in the intervention; duration of the intervention; session volume; load intensity; rest interval between sets; duration of the training session; number of exercises; type of exercises; test results and conclusions drawn. Twenty-two studies remained for possible inclusion. Following the initial evaluation, phase two applied the following exclusion criteria: articles that did not detail the sample, absence of detailed statistical analysis, and lack of appropriate training description.

RESULTS

After these criteria, 22 studies were selected, and 11 met the final revision process. Refer to Figure 1.

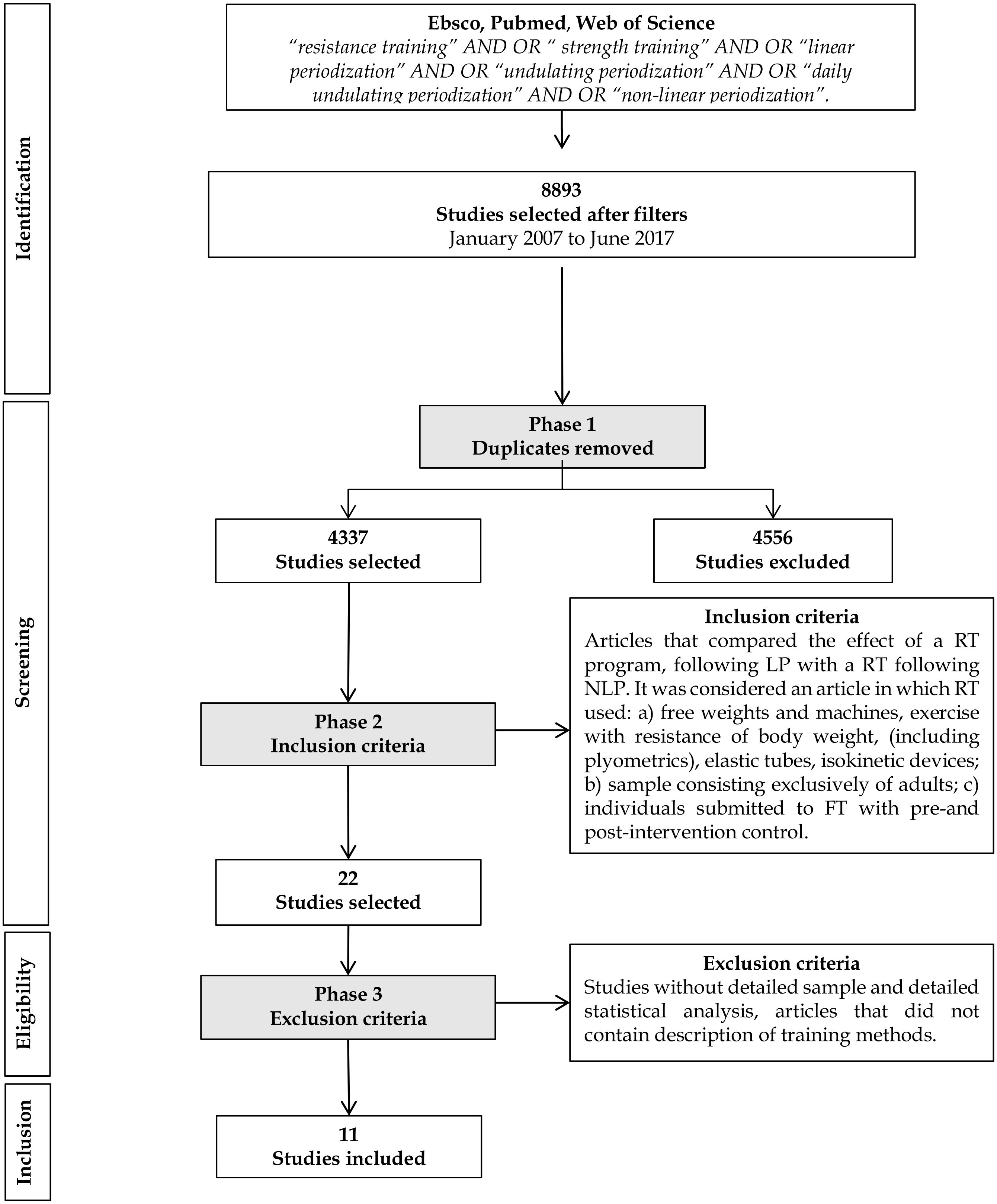

Figure 1. Organogram presenting the phases of the methods used for study selection and inclusion in the systematic review.

Eleven studies were included in the present review. Of those, two studies (12, 16) (18.2%) evaluated college athletes, two studies (15, 17) (18.2%) strength-trained men, two studies (18.2%) evaluated individuals who were sedentary (18, 22), two studies (18.2%) included individuals considered physically active (23, 24), one study (9) (9.1%) trained participants with clinical conditions, and two studies (4, 25) (18.2%) did not present this information.

Table 1 presents descriptive information of the included studies. The mean sample size across the included investigations was 35 ± 27. Two studies (4, 9) (18.2%) used mixed sample (men and women), five studies (12, 15, 17, 22, 23) (45.4%) exclusively with men and four studies (16, 18, 24, 25) with women (36.4%). The mean age of the subjects was 31.6 ± 17.4 years. One of the studies (9) (9.1%) reported the presence of disease, in this case severe chronic obstructive pulmonary disease (COPD).

Table 1. Descriptive information on included studies.

Author	Title	Purpose	N	Age (years)	♂	♀	Training Level	Condition	Dropouts
PRESTES et al. (2015).	Understanding the individual responsiveness to RT periodization	Compare the effects of LP and NLP on functional capacity, neuromuscular function, body composition, and cytokines in elderly sedentary women	49	**M** 67.2 **CTL** 66.9 ± 7.65 **LP** 69.2 ± 6.05 **NLP** 66.52 ± 4.72	0	49	Sedentary	-	23
ULLRICH et al. (2015).	Neuromuscular responses to 14 weeks of LP and NLP RT	Examine the effects of 2 periodized isometric strength training regimens for the knee extensors on MVC force production, muscle architecture, and EMG estimated maximum voluntary activation	10	**M** 24.4 ± 3.2	0	10	Recreational active	-	3
KLIJN et al. (2013).	NLP in advanced COPD is superior to traditional exercise training a randomized trial	Compare NLP and LP training in patients with severe COPD	110	**M** 61 **NLP** 61 ± 6 **LP** 61 ± 7	**NLP** 19 **LP** 36	**NLP** 19 **LP** 36	Pulmonary rehabilitation in patients with COPD	Severe COPD	8
SPINETI et al. (2013).	Comparison between different periodization models on MS and thickness in a muscle group increasing sequence	Compare LP and NLP on maximal strength and muscle hypertrophy	32	**M** 28,6 **NLP** 29.1 ± 2.9 **LP** 30.5 ± 1.7 **CTL** 25.9 ± 3.5	32	0	Active, no experience RT	-	0
PACOBAHYBA et al. (2012).	MS, serum basal levels of testosterone and urea in soccer athletes	Assess muscle strength and baseline serum levels of testosterone and urea in soccer athletes	24	**M** 17.6 **NLP** 17.7 ± 0.5 **LP** 17.5 ± 1.0	0	24	Athletes	-	0

Table 1. Descriptive information on included studies, *continued.*

Author	Title	Purpose	N	Age (years)	♂	♀	Training Level	Condition	Dropouts
SIMAO et al. (2012).	Comparison between NLP and LP RT: hypertrophic and strength effects	Investigate the effects NLP and LP muscle thickness and strength, 1RM	30	**M** 28.6 **NLP** 29.8 ± 1.9 **LP** 30.2 ± 1.1 **CTL** 25.9 ± 3.6	30	0	Untrained	-	0
MARQUES et al. (2011).	Training and detraining effects on strength parameters in young volleyball players: volume distribution implications	Compare the effects of RT and the respective detraining between two models of volume periodization (LP and NLP) in young volleyball players	12	**M** 17.1	12	0	Athletes	-	0
MIRANDA et al. (2011).	Effects of LP vs. NLP RT on maximal and submaximal strength gains	Verify the effect of 2 periodized RT methods on the evolution of 1RM and 8RM	20	**M** 25.75 **LP** 25 ± 6 **NLP** 26.5 ± 5	20	0	Strength-trained	-	0
VANNI et al. (2010).	Comparison of the effects of two RT regimens on muscular and bone responses in premenopausal women	Compare the effects of RT with NLP vs LP on BMD, muscle strength, anthropometrical variables, and muscle damage parameters in premenopausal women	27	**M** 39.6 ± 0.41 **LP** 39.5 ± 0.60 **NLP** 39.7 ± 0.59	0	27	NP	Pre-menopause	3
FOSCHINI et al. (2010).	Treatment of obese adolescents: the influence of periodization models and ace genotype	Compare the effects of two periodization models on metabolic syndrome risk factors in obese adolescents and verify whether the ACE genotype is important in establishing these effects	32	**M** 16.5 ± 1.74	15	17	NP	-	0
PRESTES et al. (2009).	Comparison between LP and NLP RT to increase strength	Compare the effects of LP and NLP RT on body composition and maximal strength levels	40	**M** 21.5 ± 8.3 **LP** 22.3 ± 7.5 **NLP** 21.2 ± 9.2	40	0	Strength-trained	-	0

Table 1 Notes: ACE: angiotensin-converting enzyme, ACT: active, ATL: athlete, BMD: bone mineral density, COPD: chronic obstructive pulmonary disease, CTL: control group, DIS: disease, DROP: dropouts, EMG: electromyographic, LP: linear periodization, M: mean, MS: muscular strength, MVC: maximum voluntary strength, NCAA: National Collegiate Athletic Association, NP: no presence, NPer: non periodized, RM: repetitions maximum, RT: resistance training, SED: sedentary, STr: Strength trained, UP: undulating periodization.

Table 2 presents the descriptive statistics of the samples included in this review. Among the anthropometric characteristics of the included sample, mean height was 169.3 ± 8.5 cm, while one study (9) (9.1%) did not report this information. The mean body mass index was 25.41 ± 4.4 kg/m². Data revealed that six studies (12, 15, 16, 22, 24, 25) (54.5%) used normal weight subjects according to a World Health Organization (26) (18.5-24.9 kg/m²), four studies (9, 17, 18, 23) (36.7%) overweight (25.5-29.9 kg/m²), and one study (25) (9.1%) obese (≥30 kg/m²). The mean body fat percentage was 22.13 ± 16.5%, while five studies (9, 12, 15, 24, 25) (45.4%) did not report this information. The mean fat-free mass value was 54.20 ± 30.01% reported in four studies (4, 9, 17, 18) (36.4%). Among studies, three studies (18, 22, 23) (27.3%) included a control group. From UP models, two studies (24, 25) (18.2%) followed weekly changes, and eight studies (4, 9, 12, 15, 16, 17, 18, 23) (72.7%) daily changes, known as, “Weekly Undulating Periodization (WUP)” and “Daily Undulating Periodization (DUP)” respectively, while one study (22) did not report the undulating method used.

Table 2. Descriptive information of the samples included.

Author	Purpose	Body Mass (kg)	Height (cm)	BMI	Body Fat (%)	Muscle Mass (%)	Group
PRESTES et al. (2015)	Compare the effects of LP and NLP on functional capacity, neuromuscular function, body composition, and cytokines in elderly sedentary women	**M** 62.78 **CTL** 58.94 ± 6.66 **LP** 62.69 ± 12.03 **NLP** 66.71 ± 9.5	**M** 152 **CTL** 152 ± 0.5 **LP** 152 ± 0.6 **NLP** 152 ± 0.5	**M** 26.99 **CTL** 25.11 ± 3.43 **LP** 27.06 ± 3.78 **NLP** 28.80 ± 3.78	**M** 40.34 **CTL** 37.76 ± 6.03 **LP** 40.62 ± 6.39 **NLP** 42.65 ± 6.83	**M** 59.68 **CTL** 62.24 ± 6.03 **LP** 59.37 ± 6.39 **NLP** 57.42 ± 6.82	G1: CTL G2: LP G3: NLP
ULLRICH et al. (2015)	Examine the effects of 2 periodized isometric strength training regimens for the knee extensors on MVC force production, muscle architecture, and EMG estimated maximum voluntary activation	**M** 66.3 ± 11.9	**M** 167.3 ± 6.1	**M** 23.76	NP	NP	G1: LP G2: NLP
KLIJN et al. (2013).	Compare NLP and LP training in patients with severe COPD	NP	NP	**M** 25.5 **LP** 26 ± 6 **NLP** 25 ± 5	NP	**M** 15 **LP** 15 ± 3 **NLP** 15 ± 2	G1: NLP G2: NLP
SPINETI et al. (2013).	Compare LP and NLP on maximal strength and muscle hypertrophy	**M** 78.03 **LP** 81.8 ± 15.4 **NLP** 78.4 ± 9.0 **CTL** 73.9 ± 9.9	**M** 173.3 **LP** 173.0 ± 6.5 **NLP** 175.9 ± 7.1 **CTL** 171.0 ± 5	**M** 26.09 **LP** 27.35 **NLP** 25.37 **CTL** 25.3	**M** 15.36 **LP** 17.2 ± 6.1 **NLP** 13.6 ± 3.3 **CTL** 15.3 ± 6.9	NP	G1: NLP G2: LP G3: CTL
PACOBAHYBA et al. (2012).	Assess muscle strength and baseline serum levels of testosterone and urea in soccer athletes	**M** 65.4 **NLP** 66.1 ± 4.8 **LP** 64.7 ± 6.6	**M** 174.75 **NLP** 177.2 ± 6.1 **LP** 172.3 ± 5.9	**M** 21.65 **NLP** 21.05 **LP** 21.85	**M** 5.2 **NLP** 5.1 ± 1.2 **LP** 5.2 ± 2.8	NP	G1: NLP G2: LP

Table 2. Descriptive Information of the Samples Included, *continued.*

Author	Purpose	Body Mass (kg)	Height (cm)	BMI	Body Fat (%)	Muscle Mass (%)	Group
SIMAO et al. (2012).	Investigate the effects NLP and LP muscle thickness and strength, 1RM	**M** 77.76 **NLP** 79.9 ± 10.6 **LP** 79.5 ± 13.1 **CTL** 73.9 ± 9.9	**M** 172.26 **NLP** 172.0 ± 6.8 **LP** 173.6 ± 7.2 **CTL** 171.2 ± 6.3	**M** 24.6 **NLP** 27.0 **LP** 26.32 **CTL** 25.3	**M** 14.73 **NLP** 13.8 ± 4.1 **LP** 15.1 ± 5.1 **CTL** 15.3 ± 6.9	NP	G1: NLP G2: LP G3: CTL
MARQUES et al. (2011)	Compare the effects of RT and the respective detraining between two models of volume periodization (LP and NLP) in young volleyball players	**M** 68.85 **LP** 65.8 ± 7.1 **NLP** 71.9 ± 11.4	**M** 181.9 **LP** 179.0 ± 4.3 **NLP** 184.8 ± 9.6	**M** 20.55 **LP** 20.4 ± 2.1 **NLP** 20.7 ± 1.5	NP	NP	G1: LP G2: NLP
MIRANDA et al. (2011).	Verify the effect of 2 periodized RT methods on the evolution of 1RM and 8RM	**M** 73 **LP** 72 ± 5.4 **NLP** 74 ± 5.2	**M** 176 **LP** 174 ± 6.4 **NLP** 178 ± 7.8	**M** 23.6 **LP** 23.8 **NLP** 23.4	NP	NP	G1: LP G2: NLP
VANNI et al. (2010).	Compare the effects of RT with NLP vs LP on BMD, muscle strength, anthropometrical variables, and muscle damage parameters in premenopausal women	**M** 58.55 **LP** 58.9 ± 1.69 **NLP** 58.2 ± 1.41	**M** 160.4 **LP** 158.8 ± 1.64 **NLP** 162 ± 1.29	**M** 22.7 **LP** 23.3 ± 0.49 **NLP** 22.1 ± 0.22	NP	NP	G1: LP G2: NLP
FOSCHINI et al. (2010).	Compare the effects of two periodization models on metabolic syndrome risk factors in obese adolescents and verify whether the ACE genotype is important in establishing these effects	**M** 103.25 **LP** 98.9 ± 13.5 **NLP** 107.6 ± 12.2	**M** 167.05 **LP** 165 ± 8 **NLP** 169.1 ± 8.0	**M** 37.1 **LP** 36.5 ± 5.6 **NLP** 37.7 ± 4.4	**M** 45.3 **LP** 45.5 ± 8 **NLP** 45.1 ± 8.3	**M** 54.22 **LP** 53.8 **NLP** 54.64	G1: LP G2: NLP
PRESTES et al. (2009).	Compare the effects of LP and NLP RT on body composition and maximal strength levels	**M** 75.49 **LP** 76.17 ± 3.3 **NLP** 74.82 ± 1.43	**M** 168.15 **LP** 167.81 ± 6.3 **NLP** 168.5 ± 7.41	**M** 26.95 **LP** 27.4 ± 2.3 **NLP** 26.53 ± 1.18	**M** 11.88 **LP** 12.94 ± 1.17 **NLP** 10.83 ± 0.43	**M** 87.91 **LP** 86.8 **NLP** 89.02	G1: LP G2: NLP

Table 2 Notes: ACE: angiotensin-converting enzyme, BMD: bone mineral density, COPD: chronic obstructive pulmonary disease, CTL: control group, EMG: electromyographic, HW: Healthy weight, kg: kilograms, LP/NLP: Comparing the LP model with NLP in the study, LP: linear periodization, M: mean, MS: muscular strength, MVC: maximum voluntary strength, NCAA: National Collegiate Athletic Association, NP: No presence, NPer: non periodized, OB: obesity, OW: overweight, RM: repetitions maximum, RT: resistance training, UP: undulating periodization, WUP: weekly undulating periodization.

Table 3 presents the RT protocols implemented in the selected investigations. The mean number of sets in each RT model was 3 ± 1 for both (LP and UP), and the mean repetitions used was 10 ± 5. The mean rest interval between sets used was 2 ± 1 minutes. The mean number of exercises used was 7 ± 3, while the lowest number of exercises used in a study was three, and the highest was 10. Training duration ranged from 45 to 90 minutes. Load intensity was determined by 1 RM percentage in two studies (22, 24) (18.2%), while nine studies (4, 9, 12, 15, 16, 17, 18, 23, 25) (81.9%) used repetitions maximum (RM) zone to determine the RT intensity.

Table 3. Description of implemented resistance training protocols.

Author	Exercise(s)	Sets	Repetitions	Rest Duration	Load Intensity
PRESTES et al. (2015).	10 Bench press, 45° leg press, seated low row, leg extension, leg curl, triceps pulley extension, adduction and abduction machines, standing arm curl and seated calf raise.	**LP** **Weeks** 1-16: 3 sets **NLP** 1-16: 3 sets	**LP** **Weeks** 1-4: 12-14 rep 5-8: 10-12 rep 9-12: 8-10 rep 13-16: 6-8 rep **NLP** **DUP** 12-14 rep 10-12 rep 8-10 rep 6-8 rep	**LP** **Weeks** 1-4: 1 min 5-8: 1min20s 9-12: 1min40s 13-16: 2 min **NLP** **DUP** 1 min 1min20s 1min40s 2 min	**RM**
ULLRICH et al. (2015).	1 Leg press	**LP** 1-2: 3 sets 3-5: 5 sets 6-8: 5 sets 9: 5 sets 10: REST 11-13: 5 sets 14-16: 5 sets **NLP** NP	**LP** 1-2: 10 rep 3-5: 10 rep 6-8: 6 rep 9: 6 rep 10: REST 11-13: 10 rep 14-16: 6 rep **NLP** NP	**LP** 1-9: 2min30s 10: REST 11-16: 2min30s **NLP** 2min30s	**LP** 1-2: 60%1RM 3-5: 60%1RM 6-8: 80%1RM 9: 80%1RM 10: REST 11-13: 60%1RM 14-16: 80%1RM **NLP** daily changes 60% and 80% of 1RM
KLIJN et al. (2013).	5 Leg press, leg extension, pull down, chest press, cycle exercise.	**LP** **Weeks** 1-4: 2 sets 5-8: 3 sets 9-12: 4 sets **NLP** **Weeks** 1-12: Day 1: 2 sets Day 2: 3 sets Day 3: 4 sets	**LP** **Weeks** 1-4: 12-15 rep 5-8: 8-10 rep 9-12: 3-5 rep **NLP** **Weeks** 1-12: Day 1: 12-15 rep Day 2: 8-10 rep Day 3: 3-5 rep	**LP** **Weeks** 1-4: 1 min 5-8: 2 min 9-12: 3 min **NLP** **Weeks** 1-12: Day 1: 1 min Day 2: 2 min Day 3: 3 min	**RM**
SPINETI et al. (2013).	4 Biceps, triceps, pulley and bench press.	**LP** **Weeks** 1–4: 2 sets 5–8: 3 sets 9–12: 4 sets **NLP** **Weeks** 1-12: Day 1: 2 sets Day 2: 3 sets Day 3: 4 sets	**LP** **Weeks** 1–4: 12-15 rep 5–8: 8-10 rep 9–12: 3-5 rep **NLP** **Weeks** 1-12: Day 1: 12-15 rep Day 2: 8-10 rep Day 3: 3-5 rep	**LP** **Weeks** 1–4: 1 min 5–8: 2 min 9–12: 3 min **NLP** **Weeks** 1-12: Day 1: 1 min Day 2: 2 min Day 3: 3 min	**RM**

Table 3. Description of implemented resistance training protocols, *continued.*

Author	Exercise(s)	Sets	Repetitions	Rest Duration	Load Intensity
PACOBAHYBA et al. (2012).	10 Extensor chair, flexor table, adductor chair, ankle flexion, development of shoulders in the machine, pulley, bench press, leg press and abdominals	**LP** **Weeks** 1-12: 3 sets **NLP** **Weeks** 1-12: Day 1: 4 sets Day 2: 3 sets Day 3: 3 sets	**LP** **Weeks** 1-12: 10 rep **NLP** **Weeks** 1-12: Day 1: 4-6 rep Day 2: 8-10 rep Day 3: 12-15 rep 6-8 rep	**NP**	**RM**
SIMAO et al. (2012).	4 Bench press, lat-pull down, triceps extension, biceps curl.	**LP** **Weeks** 1-8: BP: 3 sets LEG: 3 sets SCM: 3 sets LBM: 2-3 sets **NLP** **Weeks** 1-8: BP: 2-4 sets LEG: 2-4 sets SCM: 2-4 sets LBM: 1-4 sets	**LP** **Weeks** 1-8: BP: 3-8 rep LEG: 6-10 rep SCM: 5-6 rep LBM: 6-10 rep **NLP** **Weeks** 1-8: BP: 3-8 rep LEG: 5-10 rep SCM: 5-6 rep LBM: 6-10 rep	**LP** 2 min **NLP** 2 min	**LP** **Weeks** 1-8: BP: 60-85% 1RM LEG: 50-80% 1RM SCM: NP LBM: NP **NLP** **Weeks** 1-8: BP: 60-85% 1RM LEG: 50-80% 1RM SCM: NP LBM: NP
MARQUES et al. (2011).	4 Bench press, leg press, jumps, medicinal ball launches.	**LP** **Weeks** 1-8: BP: 3 sets LEG: 3 sets SCM: 3 sets LBM: 2-3 sets **NLP** **Weeks** 1-8: BP: 2-4 sets LEG: 2-4 sets SCM: 2-4 sets LBM: 1-4 sets	**LP** **Weeks** 1-8: BP: 3-8 rep LEG: 6-10 rep SCM: 5-6 rep LBM: 6-10 rep **NLP** **Weeks** 1-8: BP: 3-8 rep LEG: 5-10 rep SCM: 5-6 rep LBM: 6-10 rep	**LP** 2 min **NLP** 2 min	**RM**
MIRANDA et al. (2011).	10 **Session A:** Bench press, chest fly, inclined bench press, shoulder abduction, upright deltoid rows, shoulder press, triceps extension, barbell triceps press, and abdominal crunches **Session B:** Leg press, leg extension, leg curl, lat pull-down, seated row, fly back, arm curl with free weights, biceps preacher curl, and back extension.	**LP** **Weeks** 1-12: 3 sets **NLP** **Weeks** 1-12: 3 sets	**LP** **Weeks** 1-12: 8-10 rep **NLP** **Weeks** 1-12: Day 1: 8-10 rep Day 2: 6-8 rep Day 3: 4-6 rep	**NP**	**RM**

Table 3. Description of implemented resistance training protocols, *continued.*

Author	Exercise(s)	Sets	Repetitions	Rest Duration	Load Intensity
VANNI et al.(2010).	8 leg press 45°, abdominal chair, hack 45°, waist, hip abduction, bench press, hip adduction, and rowing.	**LP** **Weeks** 1-28: 3 sets **NLP** **Weeks** 1-12: 3 sets 13-28: 4 sets	**LPLP** **Weeks** 1-4: 18-20 rep 5-8: 16-18 rep 9-12: 14-16 rep 13-16: 14-12 rep 17-20: 10-12 rep 21-24: 8-10 rep 25-28: 6-8 rep **NLP** **Weeks** 1-4: 18-20 rep 5-8: 10-12 rep 9-12: 6-8 rep 13-16: 10-12 rep 17-20: 6-8 rep 21-24: 10-12 rep 25-28: 6-8 rep	**LP** **Weeks** 1-28: 1-2 min **NLP** **Weeks** 1-28: 1-2 min	**RM**
FOSCHINI et al. (2010).	10 Bench press, lower back, leg press, military press, sit-ups, calf raises, lat pull-down, arm curls, hamstring curls, triceps pushdown.	**L LP** **Weeks** 1-14: 3 sets **NLP** **Weeks** 1-14: 3 sets	**LP LP** **Weeks** 1-2: 15-20 rep 3-6: 15-20 rep 7-10: 10-12 rep 11-14: 6-8 rep **NLP** **Weeks** 1-14: Day 1: 15-20 rep Day 2: 10-12 rep Day 3: 6-8 rep	**LP** **Weeks** 1-2: 45s 3-6: 45s 7-10: 1min 11-14: 1min30s **NLP** **Weeks** 1-14: Day 1: 45s Day 2: 1min Day 3: 1min30s	**RM**
PRESTES et al. (2009).	9 **Session A:** Bench press, incline bench dumbell press, flat bench dumbbell fly, standing arm curl, allternating dumbell arm curl, barbell wrist curl, shoulder press, barbell shoulder. row, lateral raise. **Training B:** front lat pull-down, single arm dumbbell row, reverse cable, crossover, triceps barbell extension, triceps pushdown, backsquat, leg press, leg curl, stading calf raise.	**LP** **Weeks** 1-12: 3 sets **NLP** **Weeks** 1, 3, 5, 7, 9, 11: Day 1-2: 3 sets Day 3-4: 3 sets 2, 4, 6, 8, 10, 12: Day 1-2: 3 sets Day 3-4: 3 sets	**LP** **Weeks** 1, 5, 9: 12 rep 2, 6, 10: 10 rep 3, 7, 11: 8 rep 4, 8, 12: 6 rep **NLP** **Weeks** 1, 3, 5, 7, 9, 11: Day 1-2: 12 rep Day 3-4: 10 rep 2, 4, 6, 8, 10, 12: Day 1-2: 8 rep Day 3-4:6 rep	**LP** **Weeks** 1, 5, 9: 45s 2, 6, 10: 1 min 3, 7, 11: 1min20s 4, 8, 12: 1min40s **NLP** **Weeks** 1, 3, 5, 7, 9, 11: Day 1-2: 45s Day 3-4: 1 min 2, 4, 6, 8,10,12: Day 1-2: 1min20s Day 3-4: 1min40s	**RM**

Table 3 Notes*:* BP: bench press, DUP: daily undulating, H: hypertrophy training, LBM: Launches with medicinal balls, LEG: Leg press, LP: linear periodization, Min: minutes, NLP: non linear periodization, NP: no presence, NPer: non periodized model, P: power training, Rep: repetition, RM: repetitions maximum, s: seconds, S: strength training, SCM: vertical jump.

Table 4 presents data from external load, exercise number and classification, variables used in the evaluation, duration of the intervention, weekly frequency, and results. Daily external load (DEL) was calculated by the following equation: DEL = number of sets x repetitions x number of exercises. Weekly external load (WEL) was obtained by the following equation: WEL = DEL x weekly frequency. The total external load (TTL) was calculated as follows: TTL = WEL x duration of the intervention in weeks. The duration of the studies varied from 12 to 28 weeks, while the mean duration of the studies was 14 ± 5 weeks. The mean weekly frequency was three sessions**.** The mean DEL was 201 ± 3 AU, 199 ± 118 AU for LP, and 203 ± 111 AU for UP. The mean WEL was 658 ± 6 AU, 654 ± 445 AU for LP, and 662 ± 403 for UP. The mean TTL was 9.905 ± 120 AU, 9.821 ± 8285 AU for LP, and 9.990 ± 7870 AU for UP. The main variables evaluated in the studies were: muscle strength (100%) determined by 1RM in nine studies studies (4, 9, 12, 15, 16, 17, 18, 23, 25) (90.9%), 8RM in one study (15) (9.1%), vertical jump and medicine ball throws in one study (12) (9.1%), body fat percentage in six studies (4, 16, 17, 18, 22, 23) (36.4%) and fat mass in four studies (4, 8, 17, 18) (54.5%), hormonal response by testosterone, cortisol, and cytokines responsivity in one study (18) (9.1%), and biochemical blood markers by total cholesterol and fractions, homeostasis model assessment of insulin resistance (HOMA-IR), and glycaemia in one study (4) (9.1%).

Table 4. Consolidation of evaluated variables.

Author	Day Load (AU)	Week Load (AU)	Total Load (AU)	Parameter Evaluation	Training Weeks	Training Frequency	Results
PRESTES et al. (2015).	**LP** 300 **NLP** 300	**LP** 1200 **NLP** 1200	**LP** 19200 **NLP** 19200	Functional capacity, anthropometric and body composition, maximal strength, cytokines, responders and nonresponders for cytokines.	16	4	**Functional capacity** LP and NLP ↑ in chair stand and arm curl repetitions (P=0.001); NLP ↓ the time to complete the time-up and go test as compared with the control group (P=0.03). **Anthropometrics and body composition** ↔ differences between groups (p>0.05) **Maximal strength** NLP and LP ↑ 45° leg press strength as compared with the control group before training. (p=0.001) **Cytokines** LP ↑ levels of irisin as compared with the control group before training (p=0.014).
ULLRICH et al. (2015).	**LP** 36 **NLP** NP	**LP** 71 **NLP** NP	**LP** 1140 **NLP** NP	MVC force production, muscle architecture, and EMG estimated maximum voluntary activation.	16	2	**MVC** LP: 24%; NLP: 23%. **QF-EMG** LP: 45 %; NLP:46 %. **Muscle thickness** LP: 17 %; NLP: 16%. **Fascicle length** TP: 16%; NLP: 17 %.
KLIJN et al. (2013).	**LP** 115 **NLP** 110	**LP** 345 **NLP** 329	**LP** 4140 **NLP** 3948	Resting pulmonary function, subdivisions of lung volume by body plethysmography, bio-impedance, constant work rate cycle test at 75% maximal work rate, 1rm, health-related	12	3	**NLP ↑ improvements in cycling endurance time compared with LP.** **NLP:** +300.6 s ($p \leq 0.001$). **NLP ↑ signal do mains of the Chronic Respiratory Questionnaire compared with LP:** Domain Emotion: +0.48 UA. Dyspnea: +0.96 UA.

Table 4. Consolidation of evaluated variables, *continued.*

Author	Day Load (AU)	Week Load (AU)	Total Load (AU)	Parameter Evaluation	Training Weeks	Training Frequency	Results
SPINETI et al. (2013).	**LP** 96 **NLP** 92	**LP** 192 **NLP** 184	**LP** 2304 **NLP** 2208	1RM in biceps, triceps, pulley, Maximum voluntary isometric contraction and Muscular thickness in extensors and flexors of elbow, ANOVA of two paths with repeated measurements and effect size.	12	2	**NLP ↑ effect size in 1RM for exercises triceps and bíceps.** LP: PRE - RT r = 0,95 e RB r = 0,95; POST - RT r = 0,93 e RB r = 0,95. NLP: PRE - RT r = 0,97 e RB r = 0,99; POST - RT r = 0,96 e RB r = 0,94. **NLP ↑ mucular thickness in flexors and extensors of elbow, but ↔ between in groups LP and NLP** LP: Extensors of elbow: 0,47; Flexors elbow: 0,26. NLP: Extensors of elbow: 1,14; Flexors elbow: 0,80. **↔ in effect size for bench press and pulley** LP: Bench press: 1,47; Pulley: 1,12. NLP: Bench Press: 3,70; Pulley: 2,04.LP ↑ levels of irisin as compared with the control group before training (p=0.014).
PACOBAHYBA et al. (2012).	**LP** 286 **NLP** 300	**LP** 860 **NLP** 900	**LP** 10320 **NLP** 10800	Testosterone, urea, 1RM for bench press and squat.	12	3	**↑ Testosterone levels in NLP than compared LP POST.** (Δ = 2,13ng/dl; p = 0,009). **↓ Urea levels only NLP than compared LP POST.** (Δ = –3,08mg%; p = 0,0001). **↔ intergroups for 1RM test.**
SIMAO et al. (2012).	**LP** 92 **NLP** 92	**LP** 276 UA **NLP** 276 UA	**LP** 3312 **NLP** 3312	Bench press, machine front lat-pull down, machine triceps extension, straight-bar standing, biceps curl, muscle thickness of the right biceps and triceps.	12	3	**Both groups ↑ 1RM strength gains in lat pull down, biceps curl e effect size (with the exception of the bench press in LP)** (p≤ 0.05). **The 1RM of the NLP ↑ than LP for bench press and biceps curl POST** (p≤ 0.05). **↔ differences in biceps and triceps muscle thickness between baseline and POST for any group;** Triceps: (p = 0.046); Biceps: (p = 0.014). **The effect sizes ↑ in NLP for the majority of observed variables.** LP (small magnitudes) Bench press: 0.60 Effect size: 0.81 NLP (moderate magnitude) Bench press: 1.74 Effect size: 1.53; NLP (higher elbow flexor) Muscle thickness effect size: 0.61–small LP (0.35–trivial).

Table 4. Consolidation of evaluated variables.

Author	Day Load (AU)	Week Load (AU)	Total Load (AU)	Parameter Evaluation	Training Weeks	Training Frequency	Results
MARQUES et al. (2011).	**LP** 70 **NLP** 67	**LP** 140 **NLP** 134	**LP** 1120 **NLP** 1072	Vertical maximum thrust test, launches medicine ball test, maximum dynamic strength test (bench press, leg press).	12 (8 training + 4 detraining)	2	**The results indicated significant differences between the groups only for the launches medicinal ball test of 5kg** LP T1: 513.3 ± 71.5 cm; T12: 533.3 ± 58.9 cm. NLP T1: 540.0 ± 67.8 cm; T12: 598.3 ± 50.4 cm. (p=0.029). training (p=0.014).
MIRANDA et al. (2011).	**LP** 270 UA **NLP** 158 UA	**LP** 1080 **NLP** 630	**LP** 12960 **NLP** 7560	1RM and 8RM loads in leg press and bench press exercises.	12	4	**in 1RM loads on leg press and bench press, but ↔ difference between groups was observed.** LP Leg press: 10%; Bench press: 15. NLP Leg press: 18%; Bench press: 16%. **↑ in 8RM loads on leg press and bench press.** LP Leg press: 17%; Bench press:18%. NLP Leg press: 23%; Bench press: 19%. **NLP group presented superior effect size in 1RM and 8RM loads for leg press and bench press exercises when compared to the LP group.** LP Leg press: 1RM: 1.23; 8RM 1.04. LP Bench press: 1RM 0.75; 8RM 0.93. NLP Leg press: 1RM: 1.55; 8RM: 1.54. NLP Bench press: 1RM: 1.02 8RM: 1.1.

Table 4. Consolidation of evaluated variables.

Author	Day Load (AU)	Week Load (AU)	Total Load (AU)	Parameter Evaluation	Training Weeks	Training Frequency	Results
VANNI et al. (2010).	**LP** 312 **NLP** 291	**LP** 936 **NLP** 874	**LP** 26208 **NLP** 24480	Lumbar spine and femoral neck bmds , maximal and submaximal dynamic muscle strengths , anthropometrical and muscle damage parameters, and delayed-onset muscle soreness.	28	3	**↔ in muscle strength (1RM and 20 RM)** LP: 37–73% NLP: 40–70%. **Delayed-onset muscle soreness** LP 1º mesocycle: 64.3%; 2º mesocycle: 14.3%; 3º mesocycle: 26.2%; 4 mesocycle: 21.4%. NLP 1º mesocycle: 66.7%; 2º mesocycle: 10.3%; 3º mesocycle: 15.4%; 4 mesocycle: 2.6%.training (p=0.014).
FOSCHINI et al. (2010).	**LP** 373 **NLP** 373	**LP** 1118 **NLP** 1118	**LP** 15660 **NLP** 15660	Body composition, visceral and subcutaneous fat, glycemia, insulinemia, HOMA-IR, lipid profiles, blood pressure, VO2max, RMR, muscular endurance.	14	3	**Body mass** LP PRE: 98.9 ± 13.5 kg; POST: 90.3 ± 12.7 kg; NLP PRE: 107.6 ± 12.2 kg; POST: 96.9 ± 11.4 kg. **BMI** LP PRE: 36.5 ± 5.6 kg/m² POST: 33.2 ± 5.2 kg/m² NLP PRE: 37.7 ± 4.4 kg/m² POST: 33.8 ± 4.4 kg/m² **Percent-body fat** LP PRE: 45.5 ± 8 %; POST: 38.3 ± 9.5 %; NLP PRE: 45.1 ± 8.3 %; POST: 31.7 ± 10.1 %. **Systolic blood pressure (SBP)** LP PRE: 130.4 ± 14.5 mmHg; POST: 111.8 ± 6.7 mmHg; NLP PRE: 136.7 ± 17.2 mmHg; POST: 118.3 ± 9.0 mmHg. **Diastolic blood pressure (DBP)** LP PRE: 81.4 ± 10.8 mmHg POST: 71.8 ± 5.4 mmHg NLP PRE: 85.3 ± 5.1 mmHg POST: 74.0 ± 5.1 mmHg

Table 4. Consolidation of evaluated variables.

Author	Day Load (AU)	Week Load (AU)	Total Load (AU)	Parameter Evaluation	Training Weeks	Training Frequency	Results
FOSCHINI et al. (2010).	**LP** 373 **NLP** 373	**LP** 1118 **NLP** 1118	**LP** 15660 **NLP** 15660	Body composition, visceral and subcutaneous fat, glycemia, insulinemia, HOMA-IR, lipid profiles, blood pressure, VO2max, RMR, muscular endurance.	14	3	**Total cholesterol** LP PRE: 163 ± 30.9 mg/dl POST: 146 ± 30 mg/dl NLP PRE: 178.6 ± 30.5 mg/dl POST: 155.2 ± 18.2 mg/dl **Low-density lipoprotein cholesterol** LP PRE: 104 ± 26.9 mg/dl; POST: 89.8 ± 27.5 mg/dl; NLP PRE: 117.1 ± 27.2 mg/dl; POST: 94.2 ± 16 mg/dl. **Visceral fat** LP PRE: 4.3 ± 0.2 kg; POST: 2.8 ± 0.8 kg; NLP PRE: 4.4 ± 1.5 kg; POST: 3.2 ± 1 kg. **Fat-free mass** LP PRE: 53.3 ± 6 kg; POST: 55.1 ± 7.7 kg; NLP PRE: 58.8 ± 9.9 kg; POST: 60.2 ± 9.6 kg. **VO2max** LP PRE: 27.5 ± 6.8 ml.kg.min; POST: 30.3 ± 8.1 ml.kg.min; NLP PRE: 24.7 ± 5 ml.kg.min; POST: 28 ± 6.6 ml.kg.min. **NLP was effective in promoting a reduction in the insulinemia and HOMA-IR** Insulin PRE: 19.7 ± 4.7 POST: 14 ± 3.9 HOMA-IR PRE: 4.3 ± 1.3 POST: 3.1 ± 1.2 (P < 0.01).

Table 4. Consolidation of evaluated variables.

Author	Day Load (AU)	Week Load (AU)	Total Load (AU)	Parameter Evaluation	Training Weeks	Training Frequency	Results
PRESTES et al. (2009).	**L LP** 243 **NLP** 243	**LP** 972 **NLP** 972	**LP** 11664 **NLP** 11660	Maximal strength in bench press, leg press and arm curl.	12	4	↑ **Bench press** **At T3 compared with T1** LP 15.16 kg - 18.2%. (p = 0.041) NLP 22.4 kg - 25.08%. (p = 0.002) ↔ **statistically significant differences between T1 and T2 or between T2 and T3, for LP and NLP groups in bench press.** ↑ **Leg press** **At T3 compared with T1.** LP 24.71%. NLP 40.61%. **At T2 compared with T1** NLP 12.23%. **At T3 compared with T2** NLP 25.48%. ↑ **Arm curl** **at T3 when compared with T1** LP 14.15%. NLP 23.53%. **at T2 when compared with T1** NLP 20%.

Table 4 Notes: 1RM: one maximum repetition test, 8RM: eight repetitions maximum test, AU: arbitrary units, BMD: bone mineral density, BMI: body mass index, DEL: (daily external load = number of sets x repetitions x number of exercises), EMG: electromyographic, HOMA-IR: homeostasis model assessment of insulin resistance, LP: linear periodization, MRFD: Maximal of rate force development, MVC: maximal voluntary contraction, MVC: maximum voluntary strength, N: newton, NLP: non-linear periodization, POST: post periodization, PRE: pre-periodization, rep: repetition, RMR: resting metabolic rate, T1: pre-first-week training, T12: post-twelfth-week training, T2: medium periodization, T3: post periodization, TTL: The total external load = WEL x duration of the intervention in weeks), TV: total volume, Vmax: maximal movement velocity, VO_2max: maximal oxygen consumption, WEL: weekly external load = DEL x weekly frequency).

DISCUSSION

The purpose of this systematic review was to evaluate the impact of various RT periodization schemes on morphofunctional factors in adults with different levels of physical activity. This investigation identified: (i) the number of studies focusing on periodization has intensified in the last 10 years; (ii) investigators improved by providing detailed subjects characteristics; (iii) few studies precisely reported training load and volume quantification; (iv) great variety of RT protocols existed (number and exercise classification, number of sets, rest interval between sets, and training load used); (v) results were also discrepant. Due to the dramatic discrepancy in the samples studied and RT protocols implemented, conclusions regarding optimal programming became difficult to resolve.

On average, RT programs (LP and NLP) implemented three sets per session, however, those (22, 23) using UP adopted two sets for the first training day, three sets for the second, and four sets for the third training day. When physically active or trained individuals were evaluated both periodization styles found superior results in strength for UP versus LP.

The mean total number of repetitions used for LP and UP was 10. However, studies (17, 22, 23) that used UP adopted 12 to 15 repetitions for the first training session, 8 to 10 repetitions in the second, and 3 to 6 repetitions in third training day. These confirmative results indicate superior improvements in strength from UP versus LP (% improvement) although other studies included in this review used UP, there was no standardization in repetitions used, which makes comparisons very hard. For example, one study (18) adopted an UP implementing the following: 12 to 14, 10 to 12, 8 to 10, and 6 to 8 repetitions for each RT session. Similarly, another study (16) reported the use of 4 to 6, 8 to 10, and 12 to 15 repetition schemes for each training day, while other (15) used 8 to 10, 6 to 8, and 4 to 6 repetitions per day and other (4) used 15 to 20, 10 to 12,and 6 to 8 repetitions. Despite the wide variety of undulations used, all studies point to superior results in strength for UP versus LP, regardless of the initial physical activity level, sex, and age.

The mean duration of rest interval between sets was 2 minutes, while three UP studies (17, 22, 23) adopted 1, 2, and 3 minutes rest intervals according to each RM zone in RT sessions. One study (18) reported the use of 1min, 1min 20s, 1min 40s, and 2min in each training session. Other (4) limited rest to 45s, 1min, and 1min 30s in each RT session. To note, the change in rest interval may change training density, which could influences the results.

The mean number of exercises used was 7 ± 3, four studies (4, 15, 16, 18) used ten exercises and three studies (12, 22, 23) used 4-5 exercises. Although manipulation of this training variable would change total volume, it appears to have little impact on muscle strength relating to periodization models.

One study (17) reported that daily modifications in intensity was an effective stimulus to increase muscle strength and reduce training monotony, suggesting that UP would produce higher stress to the neuromuscular system. Thus, control of external loads is necessary to better identify RT adaptations. Supporting this theory, nearly half of the included studies reported superior improvements in muscle strength following UP when compared to LP (4, 8, 12, 15, 16, 23). Specific to body composition, reported as either body mass and/or BMI, there appeared to be no difference between periodization models. Few studies evaluated hormonal response (16, 18). These authors reported an improvement in insulin levels and HOMA-IR favoring UP versus LP, alternatively, improvement in irisin levels favored LP versus UP. We hypothesize that, independently of training models used (LP or NLP), the training load has a direct influence on the response induced by strength training.

The present systematic review investigated the available data in the literature comparing the effects of different periodization models (LP and UP) and their subdivisions. Authors provided details specific to the intervention design so that comparisons could be made, a confounding issue in previously published systematic reviews. Although comparisons were possible, current literature involving periodized RT following LP or UP presented discrepant results, which undermines the potential for a consensus or recommendations at this time. Moreover, RT duration of most studies is quite short and this should be considered prior to making conclusions. Most characteristics and differences between studies reported here should continue to be used in future experimental designs to improve our understanding about periodization models. It seems that both periodization models are effective for adults and may be implemented in RT individuals to avoid monotony, training dropouts, and improve progressive overload.

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