Effect of Interset Strategies on Acute Resistance Training Performance and Physiological Responses: A Systematic Review

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Abstract

Latella, C, Grgic, J, and Van der Westhuizen, D. Effect of interset strategies on acute resistance training performance and physiological responses: a systematic review. *J Strength Cond Res* XX(X): 000–000, 2019—The purpose of this systematic review was to evaluate the evidence surrounding the implementation of interset strategies to optimize acute resistance training performance. Searches of PubMed/MEDLINE, Scopus, and SPORTDiscus electronic databases were conducted. Studies that met the following criteria were included: (a) compared an interset strategy with a traditional passive rest interval in resistance training, (b) the assessed outcomes included performance or physiological responses, (c) resistance training was performed in a traditional dynamic fashion, (d) the study had an acute design, and (e) was published in English and in a peer-reviewed journal. A total of 26 studies were included in the review. When a given interset strategy was used, several studies reported improvements in the number of performed repetitions (i.e., greater total volume load), attenuation of the loss in velocity and power, reduced lactate levels, and in some cases, a decrease in perceived exertion. Dynamic agonist/static antagonist stretching, cooling, aerobic exercise, vibration, and individualized heart rate–based intervals seem to be the most effective strategies. However, the heterogeneity between study designs and methodologies suggests that careful consideration should be given to the type and specific application of the interset method being used. Given the acute nature of studies, extrapolation to any long-term benefits of using a given interset strategy remains limited. Collectively, coaches and sports scientists may consider using the most effective strategies based on practicality and equipment availability to optimize performance during the resistance training component of strength and conditioning programs.

Key Words: strength training, rest period, active, work volume, force, power, recovery

Introduction

Rest intervals in resistance training are commonly defined as the time dedicated to recovery between sets and exercises (3). Although the vast majority of the literature has focused on the optimal rest interval duration to elicit specific training adaptations (15,19,20,62), guidelines regarding specific methods to optimize the interset period are lacking. From a fundamental perspective, a single resistance training session involves intermittent bouts of work and rest. During the work portion of the training session, the necessary stimuli required for adaptations occur. However, a significant proportion of a resistance training session is spent in rest. For example, in a training session lasting 60 minutes, with a rest interval of 60–90 seconds between sets and exercises, the total duration of rest will range from 20 to 40 minutes (depending on the number of sets and exercises performed) (34). Most commonly, the interset rest period is spent passively (i.e., with no activity). However, given the abundance of time spent in rest during a training session, several authors have highlighted the importance of developing strategies for use in the interset rest period to increase total work output or enhance recovery between sets (5,8,9,21,34,35).

A growing body of evidence has investigated the inclusion of aerobic exercise, heating/cooling, stretching, vibration, self-massage/foam rolling (FR), individual heart rate (HR)-based intervals, and electromyostimulation during the interset period compared with passive rest (1,9,12,13,16,21,27,29,33,37,42,48). In particular, evidence has suggested that the total number of repetitions can be increased (13,16,21,27,33), with some evidence also suggesting that kinetic (force and power) (12,21,29), kinematic (velocity) outcomes (50), muscle activation (33), lactate removal (2,29), and perceived exertion (59) can be improved using active interset strategies. Despite these reports, there seems to be no scientific consensus regarding the optimal interset strategy for improving within-session recovery and performance. Therefore, the present article aims to review and collate the available evidence on interset interventions and evaluate their effect on acute resistance training performance and associated physiological responses. As a secondary aim, we have endeavored to provide evidence-based recommendations for exercise professionals to optimize the interset period based on the collective findings of this review.

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Methods

Experimental Approach to the Problem

The PRISMA guidelines were followed for this systematic review (36). Searches for this review were performed through PubMed/MEDLINE, Scopus, and SPORTDiscus electronic databases without any year restriction. The following key words were combined and used for the searches through article title, abstract, and key words: ("resistance training" OR "strength training") AND ("inter-set" OR "rest interval" OR "rest period") AND ("foam roll*" OR "stretching" OR "PNF" OR "active" OR "passive" OR "aerobic" OR "vibration" OR "massage" OR "elevation" OR "cooling" OR "myofascial release") AND ("strength" OR "power" OR "repetition*" OR "kinetic*" OR "kinematic*" OR "EMG" OR "electromyography" OR "range of motion" OR "force" OR "output" OR "hormon*" OR "torque" OR "volume" OR "damage" OR "lactate"). The initial search was performed independently by 2 authors (C.L. and J.G.) in November of 2017 and updated in March of 2018. After the removal of duplicates, the title and abstract of each article were initially screened for suitability. Full-text articles were retrieved to determine inclusion or exclusion in the review. In each full-text read, the reference list was screened for additional articles. In addition, the list of articles that cited the included studies (i.e., forward citation tracking) was screened through the Scopus and Google Scholar databases. In the case of any disagreement between the 2 reviewers, a third reviewer (D.V.d.W.) was included.

Inclusion Criteria. Studies were included in this review if they met the following criteria: (a) compared an interset strategy with a traditional passive rest interval in resistance exercise, (b) the assessed outcomes included performance or physiological responses, (c) resistance training was performed in a traditional dynamic fashion, (d) the study had an acute design, and (e) the study was published in English and in a peer-reviewed journal.

Summary of the Evidence. From each included study, the following information was extracted: name(s) of the author(s), year of publication, subject characteristics, exercise selection, resistance training protocol(s), methodology of the interset interventions(s) used, outcome measures, and main findings.

Methodological Quality. Study quality was evaluated using a modified 11-point (Physiotherapy Evidence Database) PEDro scale. The quality of each study was assessed independently by 2 authors (C.L. and D.V.). Given that it is not possible to blind the subjects and investigators in supervised exercise interventions, items 5–7 from the scale, which are specific to blinding, were removed. This approach has also been used in other systematic reviews focusing on resistance exercise (26,55). With the omission of these items, the maximum result on the modified PEDro 8-point scale was 7 because the first item is not included in the total score. These ratings were adjusted similar to those used in previous exercise-related systematic reviews (26,55) and were as follows: 6–7 = excellent; 5 = good; 4 = moderate; and 0–3 = poor.

Results

Search Results

Our search identified 396 potential articles. After the removal of duplicates, 307 articles remained. Two hundred seventy-nine articles were excluded after title and abstract screening, and additional 10 articles were included following manual searching, resulting in 38 full-text articles read. From this pool, 12 studies that did not meet the inclusion criteria were excluded, and thus, 26 studies were included in the final review. A flow chart of the systematic review process can be found in Figure 1.

Methodological Quality

The scores on the modified PEDro scale for the studies ranged from 4 to 6 (mean: 5.7 ± 0.6) (see Table 1, Supplemental Digital Content 1, http://links.lww.com/JSCR/A127). Seventeen studies were classified as having an "excellent" methodological quality, 8 studies were classified as having a "good" methodological quality, whereas one study was classified as having a "moderate" methodological quality.

Study Characteristics

Stretching. A total of 7 studies investigated interset stretching with 5 studies conducted in resistance-trained (1,12,18,33,48) and 2 in untrained (41,42) individuals, respectively. Static stretching (SS) of the agonist muscle was used in 3 studies (1,12,17), 2 studies used SS of the antagonist muscle (33,48), and 3 studies investigated dynamic stretching (DS) of the agonist muscle (1,41,42). Ballistic stretching and proprioceptive neuromuscular facilitation (PNF) were used in 2 studies (17,48), respectively. The most commonly assessed performance outcome was the total number of repetitions performed. Other outcomes included peak torque, maximal voluntary contraction, the percentage of muscle activation or coactivation via electromyography (EMG), and movement kinetics. Two studies reported an increase in the total number of repetitions and agonist EMG activity with antagonist interset stretching (33,48). Only one study reported an impaired performance (i.e., decrease in average velocity) when stretching was used (17) (Table 1). This brief review was conducted at Edith Cowan University in Perth Australia, and ethical approval was not necessary.

Heating and Cooling. Six studies investigated heating or cooling, with cooling used in all 6 studies (2,4,10,16,27,28) and heating concurrently investigated in 3 studies (4,27,28). Three studies used resistance-trained individuals (16,27,28) and 2 used untrained individuals (2,4), whereas the resistance training experience was not described in one study (10). The number of repetitions was assessed in 5 of the 6 studies with 4 studies showing an increase with heating or cooling (2,16,27,28). Other outcomes included HR, blood pressure, rating of perceived exertion (RPE), EMG activity, and lactate and creatine kinase levels (Table 1).

Aerobic Exercise. Of the 5 studies investigating aerobic exercise (12,13,21,29,34), 2 were performed in resistance-trained individuals (12,13), one in untrained individuals (29), whereas the resistance training experience was not fully described in 2 studies (21,34). The number of repetitions performed was assessed in 3 studies, with other outcomes including peak torque, maximal voluntary contraction/force, the percentage of muscle activation or coactivation via EMG, blood lactate, and RPE. In some instances, an increase in the total number of repetitions, lower blood lactate, or RPE values were reported with interset aerobic exercise (13,21,29). None of the studies reported impaired performance with interset aerobic exercise (Table 1).

Massage and Foam Rolling. One study investigated massage (11), whereas 3 studies investigated FR (37–39). The study

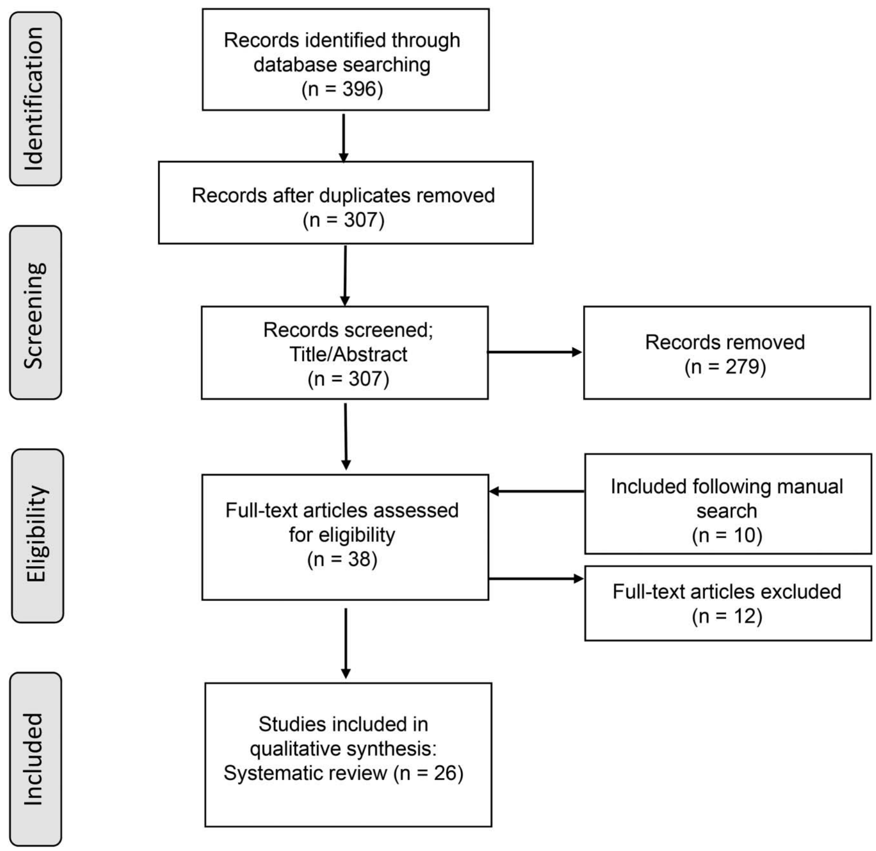

Figure 1. PRISMA flow chart of literature search strategy.

investigating massage was conducted in resistance-trained individuals, whereas the FR studies were conducted in untrained individuals. The assessed outcomes included total work, number of repetitions, and fatigue resistance. An impairment in repetition performance and fatigue resistance reported in all studies (Table 1).

Vibration. Three studies investigated vibration (30,50,59). All studies included resistance-trained individuals, whereas one study also included a group of untrained individuals (59). The assessed outcomes included the number of repetitions, blood lactate, velocity, power, acceleration, and RPE. All studies reported at least some benefit of vibration during the interset period on resistance exercise performance. Only one study (30) reported impaired repetition performance with interset vibration when the agonist/exercising muscle groups were targeted (Table 1).

Heart Rate–Based Intervals. One study investigated the prescription of rest intervals based on HR (9). The study included resistance-trained individuals. The assessed outcome was the number of completed repetitions. Compared to passive rest, the study reported that exercising with individualized HR-based intervals increased the total number of repetitions performed (Table 1).

Posture-related Position. One study investigated posture-related position (i.e., supine position, seated position, and walking) and was conducted in resistance-trained individuals (45). The assessed outcomes included work performed and HR, respiratory rate, and volume of oxygen consumed. Compared to walking, being seated or in a supine position during the interset period increased work and decreased HR (Table 1).

Electromyostimulation. One study investigated electromyostimulation in resistance-trained individuals (12). The assessed outcomes included peak torque, maximal voluntary contraction, and the percentage of muscle activation/coactivation via EMG. No benefit of electromyostimulation was reported over traditional passive rest (Table 1).

Discussion

The present article is, to the best of our knowledge, the first systematic review to investigate interset strategies and their effect on acute resistance training performance and associated physiological responses. Overall, the current body of literature provides several important findings, which are likely to offer practical evidence-based information for optimizing the rest period during resistance training sessions.

Stretching is often used in exercise programs as a part of a warm-up or cool-down (52). However, SS performed before exercise has been shown to acutely impair strength, power, and evoked contractile properties (44). The detrimental effects of SS may likely be attributed, at least partly, to reductions in musculotendinous stiffness (44). Thus, it is possible that stretching of the agonist muscle during the interset period may also impair subsequent performance. That being said, only García-López et al.

Table 1
Summary of the included studies.*

Study	Sample	Rest interval duration	Interset strategy	Resistance exercise(s)	Resistance training protocol	Assessed outcomes	Results
Stretching							
Arazi et al. (1)	Young resistance-trained men ($n = 18$)	3 and 5 min	SS and DS of the agonist and synergist musculature for 34 s (during the 3-min rest) or 64 s (during the 5-min rest).	Bench press and leg press	4 sets performed to momentary failure with 80% of 1RM.	No. of repetitions.	No. of repetitions: ↔ between dynamic stretching, SS, and passive rest.
Cometti et al. (12)	Young resistance-trained men ($n = 12$)	3 min	SS of the agonist musculature for 60 s.	Knee extensions	6 sets of 10 maximal isokinetic contractions.	Peak torque; MVC; percentage of muscle activation/coactivation via EMG; and maximal M-wave amplitude.	↔ between SS and passive rest in any of the analyzed variables.
García-López et al. (17)	Young resistance-trained men ($n = 18$) and women ($n = 7$)	4 min	SS of the agonist and synergist musculature for 50 s. Ballistic stretching of the agonist and synergist musculature for 180 s.	Bench press	2 sets performed to momentary failure with 60% of 1RM.	No. of repetitions; barbell acceleration; and average barbell velocity.	No. of repetitions: ↔ between ballistic stretching, SS, and passive rest. Barbell acceleration: ↔ between ballistic stretching, SS, and passive rest. Average velocity: ↓ with SS compared to ballistic stretching and passive rest during the second set.
Miranda et al. (33)	Young resistance-trained men ($n = 10$)	2 min	SS of the antagonist musculature for 40 s.	Seated row	3 sets performed to momentary failure with a load. Corresponding to 10RM.	No. of repetitions; EMG activity (latissimus dorsi, biceps brachii, and pectoralis major).	No. of repetitions: ↑ with SS compared to passive rest. EMG amplitude: ↑ for the agonist musculature with SS compared to passive rest; ↔ for the antagonist musculature between SS and passive rest.
Nasiri et al. (41)	Young untrained men ($n = 15$)	3 and 4 min	DS of the agonist and synergist musculature for 34 s (during the 3-min rest) or 50 s (during the 4-min rest).	Bench press	3 sets performed to momentary failure with 50% and 75% of 1RM.	No. of repetitions.	No. of repetitions: ↑ with dynamic stretching compared to passive rest both when using 3 and 4 min of rest and with loads of 50% and 75% of 1RM.
Nasiri et al. (42)	Young untrained men ($n = 15$)	3 and 4 min	DS of the agonist and synergist musculature for 34 s (during the 3-min rest) or 50 s (during the 4-min rest).	Leg press	3 sets performed to momentary failure with 75% of 1RM.	No. of repetitions.	No. of repetitions: ↔ between dynamic stretching and passive rest.
Paz et al. (48)	Young resistance-trained men ($n = 15$)	2 min	SS of the antagonist musculature for 40 s; PNF of the antagonist musculature for 40 s (4 × 6-s isometric contraction followed by a 4-s relaxation).	Seated row	3 sets performed to momentary failure with a load corresponding to 10RM.	No. of repetitions; EMG activity (latissimus dorsi, biceps brachii, triceps brachii, and pectoralis major).	No. of repetitions: ↑ with SS compared to PNF stretching and passive rest. EMG amplitude: ↑ for the agonist musculature with SS and PNF compared to passive rest; ↔ for biceps brachii and triceps brachii between SS, PNF, and passive rest; ↓ for pectoralis major with SS and PNF compared to passive rest.

Table 1
Summary of the included studies.* *(Continued)*

Study	Sample	Rest interval duration	Interset strategy	Resistance exercise(s)	Resistance training protocol	Assessed outcomes	Results
Heating and cooling							
Bacon et al. (2)	Untrained young men ($n = 9$)	19 min	Cooling of the forearms, biceps brachii, triceps, and deltoids for 17 min.	Open and closed hand pull-ups	3 sets performed with 50% of body mass for 20 repetitions per minute to momentary failure.	No. of repetitions; hand-grip strength; HR; RPE; perceived recovery; and comfort rating.	No. of repetitions: ↑ during sets 2 and 3 of open-handed pull-ups with cooling compared to passive rest; ↔ between cooling and passive rest for close-handed pull-ups. Hand-grip strength, HR, RPE, perceived recovery, and comfort ratings: ↔ between cooling and passive rest.
Batra et al. (4)	Young untrained men ($n = 13$)	3 min	Heating or cooling of the soles for 2.5 min.	Squat	4 sets performed to momentary failure with a load corresponding to 90% of 10RM.	No. of repetitions; RPE; and EMG activity (vastus medialis obliquus and rectus femoris muscles).	No. of repetitions: ↔ between cooling, heating, and passive rest. RPE: ↓ with cooling compared to heating and passive rest in sets 2, 3, and 4. EMG amplitude: ↔ between cooling, heating, and passive rest.
Caruso et al. (10)	Young men ($n = 17$) and women ($n = 18$)†	2 min	Cooling of the palms for 100 s.	Leg press	4 sets of 8 repetitions (not performed to momentary failure).	Average power; HR; systolic and diastolic blood pressure; blood lactate; thigh, forearm, and hand skin temperature.	Average power: ↑ with cooling compared to passive rest in set 4. HR: ↔ between cooling and passive rest. Systolic blood pressure: ↔ between cooling and passive rest. Diastolic blood pressure: ↓ with cooling compared to passive rest. Blood lactate: ↓ with cooling compared to passive rest. Thigh/forearm/hand skin temperature: ↔ between cooling and passive rest.
Galoza et al. (16)	Young resistance-trained men ($n = 16$)	1 min	Cooling of the biceps for 1 min.	Biceps curl	4 sets performed to momentary failure with 70% of 1RM.	No. of repetitions; creatine kinase; and myoglobin.	No. of repetitions: ↑ with cooling compared to passive rest for sets 3 and 4. Creatine kinase/ myoglobin: ↔ between cooling and passive rest.

Table 1
Summary of the included studies.* *(Continued)*

Study	Sample	Rest interval duration	Interset strategy	Resistance exercise(s)	Resistance training protocol	Assessed outcomes	Results
Kwon et al. (27)	Young resistance-trained men ($n = 16$)	3 min	Heating or cooling of the palms for 2.5 min.	Bench press	4 sets performed to momentary failure with 85% of 1RM.	No. of repetitions; EMG activity (pectoralis major, anterior deltoid, and triceps brachii); RPE; palm temperature; and HR.	No. of repetitions: ↑ with cooling compared to heating and passive rest for sets 2, 3, and 4. EMG amplitude: ↑ for triceps with cooling compared to heating and passive rest; ↔ for pectoralis major and anterior deltoid between cooling, heating, and passive rest RPE: ↓ with cooling as compared to heating and passive rest in sets 2 and 4. HR: ↑ with cooling compared to passive rest but not compared to heating during the second set; ↑ with heating compared to cooling and passive rest but not as compared to heating during the rest period between the second and third sets, between the third and fourth sets, and at 1 min following exercise.
Kwon et al. (28)	Young resistance-trained women ($n = 8$)	3 min	Heating or cooling of the palms for 2.5 min.	Bench press	4 sets performed to momentary failure with 85% of 1RM.	No. of repetitions; EMG activity (pectoralis major, anterior deltoid, and triceps brachii); palm temperature; and HR.	No. of repetitions: ↑ with cooling and heating compared to passive rest. EMG amplitude: ↑ for triceps and anterior deltoid with cooling and heating compared to passive rest; ↔ for pectoralis major between cooling, heating, and passive rest. HR: ↔ between heating, cooling, and passive rest.
Aerobic exercise							
Cometti et al. (12)	Young resistance-trained men ($n = 12$)	3 min	"Light cycling" on a stationary cycle ergometer.	Knee extensions	6 sets of 10 maximal isokinetic contractions.	Peak torque; MVC; percentage of muscle activation/coactivation via EMG; and the maximal M-wave amplitude.	↔ between aerobic exercise and passive rest in any of the analyzed variables.

Table 1
Summary of the included studies.* *(Continued)*

Study	Sample	Rest interval duration	Interset strategy	Resistance exercise(s)	Resistance training protocol	Assessed outcomes	Results
Corder et al. (13)	Young resistance-trained men ($n = 15$)	4 min	Cycling at 25% or 50% OBLA for 4 min.	Squat	6 sets of 10 repetitions (not performed to momentary failure) with a load corresponding to 85% of 10RM and 1 set performed to momentary failure with 65% of 10RM.	No. of repetitions; blood lactate; and RPE.	No. of repetitions: ↑ with cycling at 25% OBLA compared to cycling at 50% OBLA and passive rest. Blood lactate: ↓ with cycling at 25% OBLA compared to cycling at 50% OBLA and passive rest in 6 of the 8 assessed conditions; ↓ with cycling at 50% OBLA compared to passive rest in 3 of the 8 assessed conditions. RPE: ↓ with cycling at 25% OBLA compared to passive rest in 2 of the 8 assessed conditions; with cycling at 25% and 50%; ↓ with cycling at 25% OBLA compared to cycling at 50% OBLA in 6 of the 8 assessed conditions.
Hannie et al. (21)	Young men and women ($n = 15$)†	2 and 5 min	Cycling at 45% of $\dot{V}O_2$peak for 1 min.	Bench press	4 sets performed to momentary failure with 65% of 1RM.	No. of repetitions; MVC; and blood lactate.	No. of repetitions: ↑ with cycling compared to passive rest. Blood lactate: ↔ between cycling and passive rest. MVC: ↔ between cycling and passive rest.
Lopes et al. (29)	Young untrained men ($n = 12$)	3 min	Bench stepping for 3 min at an intensity corresponding to the lactate threshold.	Bench press	4 sets performed to momentary failure with 80% of 1RM.	No. of repetitions; mean/peak power; and blood lactate.	No. of repetitions: ↔ between bench stepping and passive rest. Mean/peak power: ↔ between bench stepping and passive rest. Blood lactate: ↓ with bench stepping as compared to passive rest.
Mohamad et al. (34)	Young men ($n = 12$)†	1.5 min	Cycling at 50–60% of maximum HR for 90 s.	Squat	3 sets performed for 12 repetitions (not performed to momentary failure) at 70% 1RM and 6 sets performed for 12 repetitions (not performed to momentary failure) at 35% 1RM.	Average/peak force; average/peak power; work; total impulse; and blood lactate.	Average/peak force: ↔ between cycling and passive rest. Average/peak power: ↔ between cycling and passive rest. Work: ↔ between cycling and passive rest. Total impulse: ↔ between cycling and passive rest. Blood lactate: ↔ between cycling and passive rest.

Table 1
Summary of the included studies.* *(Continued)*

Study	Sample	Rest interval duration	Interset strategy	Resistance exercise(s)	Resistance training protocol	Assessed outcomes	Results
Massage and FR							
Caruso et al. (11)	Young resistance-trained men ($n = 27$) and women ($n = 3$)	1 min or 30 s	Massage and body elevation of the exercised muscle group for 30 s.	Leg press, knee flexion, shoulder press, and barbell curl	8 sets performed to momentary failure with 65–90% of 1RM.	Total work/elapsed time and cumulative no. of repetitions.	Total work/elapsed time: ↓ with passive 30-s rest, massage, and body elevation compared to 1-min passive rest. Cumulative no. of repetitions: ↓ with passive 30-s rest, massage and body elevation compared to 1-min passive rest.
Monteiro et al. (37)	Young untrained females ($n = 25$)	4 min	FR of the agonist muscle for 60 or 120 s.	Knee extensions	3 sets performed to momentary failure with a load corresponding to 10RM.	No. of repetitions.	No. of repetitions: ↓ with any FR condition compared to passive rest.
Monteiro et al. (38)	Young untrained females ($n = 25$)	4 min	FR of the agonist muscle for 60, 90, or 120 s.	Knee extensions	3 sets performed to momentary failure with a load corresponding to 10RM.	Fatigue resistance.	Fatigue resistance: ↓ for FR lasting 90 s or 120 s compared to passive rest; ↓ for FR for 120 s compared to FR for 60 s.
Monteiro et al. (39)	Young untrained females ($n = 25$)	4 min	FR of the antagonist muscle for 60 or 120 s.	Knee extensions	3 sets performed to momentary failure with a load corresponding to 10RM.	No. of repetitions.	No. of repetitions: ↓ with both FR conditions compared to passive rest.
Vibration							
Marin et al. (30)	Resistance-trained men ($n = 6$) and women ($n = 3$)	3 min	Push-up or squat on a vibration platform for 30 s.	Bench press	3 sets performed to momentary failure with 60% of 1RM.	No. of repetitions; blood lactate; and mean/peak velocity.	No. of repetitions: ↑ with squat vibration compared to push-up vibration and passive rest in sets 2 and 3; ↓ with push-up vibration compared to passive rest. Blood lactate: ↔ between squat vibration, push-up vibration, and passive rest. Mean/peak velocity: ↔ between squat vibration, push-up vibration, and passive rest.
Rhea and Kenn (50)	Resistance-trained men ($n = 16$)	3 min	Body-weight squat on a vibration platform for 30 s.	Squat	2 sets of 3 repetitions (not performed to momentary failure) with 75% of 1RM.	Mean power.	Mean power: ↑ with squat vibration compared to passive rest in set 2.
Timon et al. (59)	Young resistance-trained ($n = 10$) and untrained men ($n = 9$)	2 min	Vibration of the upper-body musculature for 30 s.	Bench press	3 sets performed to momentary failure with 75% of 1RM.	No. of repetitions; mean velocity; acceleration; blood lactate; and RPE.	No. of repetitions: ↔ between vibration and passive rest. Mean velocity: ↑ with vibration compared to passive rest in untrained but not in trained individuals.

Table 1
Summary of the included studies.* *(Continued)*

Study	Sample	Rest interval duration	Interset strategy	Resistance exercise(s)	Resistance training protocol	Assessed outcomes	Results
							Acceleration: ↑ with vibration compared to passive rest in untrained but not in trained individuals. Blood lactate: ↔ between vibration and passive rest. RPE: ↓ with vibration compared to passive rest in untrained but not in trained individuals.
HR-based intervals							
Buskard et al. (9)	Resistance-trained men ($n = 34$)	1 min	Rest interval duration based on the recovery of HR.	Bench press	8 repetitions (not performed to momentary failure) with 60% of 1RM (sets were repeated until the subject could not perform 8 repetitions).	No. of repetitions.	No. of repetitions: ↑ with HR-based intervals compared to passive rest.
Posture-related position							
Ouellette et al. (45)	Resistance-trained men ($n = 5$) and women ($n = 10$)	2 min between sets and 5 min between exercises	Rest period spent walking, in a supine position, or in a seated position.	Thruster and deadlift	Thruster: 3 sets performed for 10 repetitions (not performed to momentary failure) with a load corresponding to 80% of 3RM; deadlift: 3 sets performed for 8 repetitions (not performed to momentary failure) with a load corresponding to 80% of 3RM.	Joules or work; HR; respiratory rate; and volume of oxygen consumed.	Joules or work: ↑ with supine and seated positions compared to walking. HR: ↓ with supine and seated positions compared to walking. Respiratory rate: ↓ with supine and seated positions compared to walking. Volume of oxygen consumed: ↓ with supine and seated positions compared to walking.
Electromyostimulation							
Cometti et al. (12)	Young resistance-trained men ($n = 12$)	3 min	Low-frequency stimulation of the quadriceps muscle.	Knee extensions	6 sets of 10 maximal isokinetic contractions.	Peak torque; MVC; percentage of muscle activation/coactivation via EMG; and the maximal M-wave amplitude.	↔ between electromyostimulation and passive rest in any of the analyzed variables.

*1RM = 1 repetition maximum; $\dot{V}O_2$peak = peak oxygen consumption; ↔ = no significant difference; ↑ = significant increases; ↓ = significant decreases; SS = static stretching; DS = dynamic stretching; MVC = maximal voluntary contraction; EMG = electromyography; PNF = proprioceptive neuromuscular facilitation; HR = heart rate; RPE = rating of perceived exertion; OBLA = onset of blood lactate accumulation; FR = foam rolling.
†Resistance training experience was not described.

(17) reported a negative effect of interset agonist SS on bench press performance. In particular, the authors observed a reduction in barbell velocity of 18% (0.46–0.37 m·s^{-1}) with SS, compared to passive rest (11%). Given that mechanical stimuli such as peak velocity are important factors in maximizing muscular power adaptations (60), the results suggest that agonist SS should be avoided if the primary training aim is to improve muscular power. Importantly, these negative effects may be, at least partly, due to the duration of the stretching protocol prescribed. For example, García-López et al. (17) used a protocol in which the muscle was stretched for 50 seconds, in contrast to the 34 seconds used in other studies that did not negatively affect performance (1,12). However, this hypothesis is not substantiated by Arazi et al. (1) who reported no negative effects on repetition performance in the bench and leg press exercises using a 64-second interset SS protocol. Thus, the relationship between the duration of agonist SS and acute performance is unclear at this stage.

In contrast to agonist SS, antagonist stretching has been shown to have a positive effect on exercise performance (57). For example, an increase in jump height has been demonstrated following SS of the hip flexors and dorsiflexors (57). Although only investigated in 2 studies thus far (34,48), SS of the antagonist muscle during the interset period allowed a greater number of repetitions (+1 to 3) to be performed in the seated row exercise with a concurrent increase in agonist EMG activity. Thus, the benefit of antagonist SS may serve to increase muscle activity and training volume. Although longitudinal research is lacking, these findings may be of interest given that volume is considered as an important factor in muscular hypertrophy adaptations with resistance training (56).

Dynamic stretching has been shown to acutely increase power, sprint, and jump performance (44). Of the 3 studies exploring this method of stretching, only one reported an increase in the number of performed repetitions (41). In that report, the authors noted that following a passive 3-minute rest, 15 (50% 1 repetition maximum [1RM]) and 13 (75% 1RM) repetitions were performed, respectively. However, when agonist DS was used, maximum repetitions increased to 27 (50% 1RM) and 24 (75% 1RM), respectively. Such large increases in performance with interset stretching should be interpreted with caution, especially given that others have reported no benefit of DS when using the same resistance exercise task (1) and similar loading schemes (42).

Based on the current literature, it can be inferred that interset SS of the antagonist musculature may improve session work volume. The results of agonist stretching protocols are less clear. However, if performed during interset intervals, DS seems to be comparatively more advantageous than SS if the completion of more repetitions is desired. Further research is required to establish the efficacy of PNF and ballistic stretching protocols before sound recommendations can be made. Furthermore, we suggest that effect of antagonistic stretching on velocity and power outcomes should also be investigated, as these are likely to hold important implications for sports performance.

An excessive increase in core body temperature can negatively impact exercise performance (8). As a method to counteract thermal stress, techniques such as cooling-vests, cooling-packs, and cold-water immersion are used to improve exercise performance (8). Owing to the proposed benefits, pre-, per-, and post-cooling strategies are commonly used in sports settings (8). Specifically, evidence indicates that cooling strategies in hot environments can enhance endurance performance and reduce subjective measures of exertion (51).

The application of cooling has also been shown to increase performance in resistance training (10). Therefore, it is plausible that cooling of the musculature during the interset period may also augment resistance exercise performance. Indeed, most of the studies that used cooling as an interset strategy reported an increase in the number of repetitions/volume ranging from 16.8% to 25.8% (2,16,27,28) or power output (6.1%) (10) in the upper-body musculature. However, the evidence is less conclusive in the lower limbs (4).

Mechanistically, these findings hold important implications. For example, it is well established that neuromuscular adaptations occur specific to the training stimulus (40). In particular, volume is considered an important factor in muscular hypertrophy (56), and likewise, mechanical stimuli (e.g., velocity and power) are important variables in facilitating explosive strength adaptations (60). From a physiological perspective, the benefit of cooling during exercise may be due to: (a) increased local muscle reflexes, (b) increased muscle excitability, (c) increased release of neurotransmitters, and (d) a reduction in RPE (22,46). In support, RPE was reported as being lower with cooling compared with passive rest in set 2 (6.2 ± 0.9 vs. 6.6 ± 2.5, respectively) and heating in set 4 (7.6 ± 1.1 vs. 8.2 ± 1.1, respectively) (27). Thus, it can be argued that decreases in RPE with cooling might allow the individual to perform more work because of a reduced subjective strain. Conversely, Bacon et al. (2) did not observe any reductions in RPE; however, their sample size was relatively small ($n = 9$), which might have impacted the statistical power of the study. In addition, Galoza et al. (16) reported greater repetitions with agonist cooling, despite no additional increase in indicators of muscle damage (i.e., serum creatine kinase activity and myoglobin), which may have important implications for long-term muscular adaptations.

It is important to note that the majority of evidence is from studies that have investigated the upper-body musculature, which is relevant to highlight given that the fatigue response may differ between upper and lower limbs (61). Thus, further studies focusing on lower-body exercises are required before drawing more generalized conclusions regarding interset cooling. Based on the available evidence, cooling strategies may be an inexpensive and practical tool to facilitate upper-body resistance training performance. However, it is theorized that potential benefits would be more strongly observed where thermoregulation is compromised, such as resistance training during the heat, and thus, should be investigated further.

Compared to cooling, the evidence for heating is less conclusive. Although interset heating did not seem to be effective in males (27), it has been suggested that women may benefit more so (28). The study by Kwon et al. (28) conducted in resistance-trained women reported that both heating and cooling increased acute session performance by 16.8% and 13.6%, respectively. In support of these findings, sex-related differences in fatigue are known to exist, with females being generally more fatigue resistant than males (24). Therefore, it may be possible that females respond more favorably to any attempt to attenuate the fatigue response. Furthermore, there also seems to be a difference in thermal perception between the sexes, which might explain the disparity between the studies (31). However, given the current lack of resistance training, and specific interset thermal studies conducted in females, future work in this population is needed before recommendations for interset heating strategies can be developed.

It has been suggested that light aerobic exercise, which preferentially innervates type I slow-twitch fibers, can maintain muscle temperature leading to enhanced neural transmission (18,32), mechanical efficiency (6), and may enhance venous return. Two of the three studies using aerobic exercise during the interset period reported a significant increase in the number of performed repetitions (+4 to 5), compared with passive rest (13,21). By contrast, the study by Lopes et al. (29) did not report any benefit of aerobic exercise on the number of completed bench press repetitions. Importantly, Lopes et al. (29) used bench stepping as the mode of aerobic exercise in contrast to the other studies that used interset cycling. Although minimal evidence is available, based on the findings by Lopes et al. (29), suggest that the nature of the aerobic task used during the interset period may be an important factor for strength and conditioning professionals to consider.

More likely, the intensity of aerobic exercise used during the interset period should be controlled. For example, Corder et al. (13) compared cycling at both 25% of the onset of blood lactate accumulation (OBLA) and at 50% OBLA. Cycling at 25% OBLA during the interset period improved performance, whereas cycling at 50% OBLA did not. It is possible that cycling at 50% OBLA resulted in a greater accumulation of fatigue, which, therefore, impaired subsequent performance. This may also, at least partly, explain why no benefit was observed by Lopes et al. (29), in which the aerobic exercise was performed at an intensity corresponding to the lactate threshold. However, it is difficult to ascertain whether these findings can be attributed to the accumulation of metabolites. That being said, several authors have also investigated blood lactate levels during the interset period with the inclusion of aerobic exercise (13,21,29). Both Corder et al. (13) and Lopes et al. (29) reported lower blood lactate levels compared with passive rest (10%–16.7%: 0.6–0.9 mmol/L and 20.6%: 1.2 mmol/L, respectively), despite disparate results in performance. Therefore, if lactate accumulation is considered an indicator of peripheral fatigue, then low-intensity interset aerobic exercise should be considered to attenuate this response. However, an accumulation of blood lactate may be beneficial if the aim is to induce muscular hypertrophy (53,54). Specifically, lactate is believed to stimulate myogenesis protein synthesis (43,63) via increased fiber recruitment, alterations in local myokines, and cell swelling (14,54). Therefore, the accumulation of blood lactate may be beneficial for adaptation, however should be considered in conjunction with the potentially greater mechanical stress induced (i.e., more repetitions) when lactate is reduced.

Overall, the inclusion of aerobic exercise seems promising to improve the recovery of voluntary force, lactate clearance, and the total number of performed repetitions if the selected intensity is low enough to avoid lactate accumulation (47). A lower intensity seems to be particularly important if the aerobic exercise is conducted in the same musculature that is used during the resistance training task (12,34). As all of the studies (12,14,21,29,34) used external loads up to 85% of 1RM future studies might consider including maximal loads (i.e., 1RM attempts), as such study designs could provide useful information to athletes in powerlifting or other strength-based sports requiring brief maximal efforts, interspersed with longer rest periods. In addition, although no changes in power were observed during the bench press (29) and squat (34) exercises, the efficacy of interset aerobic exercise on power output should also be investigated in explosive tasks that are not performed to failure.

There is evidence to suggest that acute massage and self-myofascial release/FR may improve performance when used before and after exercise. These improvements likely occur due to a greater range of motion, decreased soreness, and improved perceptual outcomes (5,25,58). In particular, the popularity of FR can be attributed to its low-cost and practicality. Three different articles investigated FR (37–39); however, all of the trials were performed in the same cohort. Collectively, the findings suggest that FR during the interset rest period is likely detrimental to force production, fatigue resistance, and repetition performance when performed on the agonist (37,38) and antagonist musculature (39) in the lower limbs. In particular, the negative effect was exacerbated with longer FR durations (i.e., 120 seconds compared with 60 seconds), which strongly suggests that interset FR should be avoided, at least when overall work volume is the focus.

In addition, the literature surrounding interset massage in resistance exercise is scarce. In the only study investigating massage (11), subjects performed 4 exercises: leg press, leg curl, seated shoulder press, and the standing barbell curl with one of the following: (a) 1-minute passive rest, (b) 30 seconds of passive rest, and (c) 30 seconds of concurrent massage and body part elevation. The cumulative number of repetitions for each exercise was greater in the 1-minute condition, compared with the two 30-second strategies. This study highlights that simply prolonging the interset rest duration, compared with a massage intervention, might have a greater effect on subsequent resistance exercise performance. Despite the limited evidence, the similarity between 30 seconds of passive rest and massage also suggests no additional benefit of this interset method and, thus, likely would not be warranted in resistance training programs.

Whole-body vibration has been widely investigated in the sports science literature, with some evidence suggesting an improvement in acute mechanical and neuromuscular performance (23). Specifically, Rhea and Kenn (50) investigated the effect of 120 seconds of rest followed by 30 seconds of dynamic body-weight squats on a vibration platform during the interset period, compared with 180 seconds of passive rest alone. A significant increase in power was observed during the squat exercise with vibration compared to passive rest (5.2% vs. 0.6%, respectively). In addition, Marín et al. (30) investigated 9 elite judo athletes who performed 3 sets of the bench press exercise to momentary failure at 60% of 1RM with 180 seconds of interset recovery. Three protocols were used: (a) 150-second rest followed by 30 seconds of push-up vibration exercise, (b) 150-second rest plus 30 seconds of body-weight squat vibration exercise, or (c) 180 seconds of passive rest. Although bench press kinematics and blood lactate concentration were not affected, the squat vibration strategy resulted in a significant increase in the number of repetitions compared with passive rest (+3 repetitions, 5.7%) and push-up vibration (+7 repetitions, 24.0%), respectively. Although the mechanisms underpinning the increase in repetitions following squat vibration are somewhat unclear, it has been suggested that vibration exercise can increase motor unit activation and corticospinal excitability, alter intracortical processes, and attenuate force loss (7,30). Conversely, the push-up vibration strategy resulted in a 17.3% reduction (5 repetitions) in bench press performance compared with passive rest. The direct application of vibration to the agonist muscle using the push-up exercise likely resulted in the accumulation of fatigue, which may explain the unfavorable findings. In addition, Timon et al. (59) used vibration of the upper-body musculature (with no other concurrent activity) and observed an increase in mean velocity, acceleration, and a decrease in perceived effort in the bench press compared with passive rest. Interestingly, the benefit was observed in untrained but not trained individuals despite no logical explanation as to why this effect would occur. Therefore, these results should be interpreted with caution given that advanced training techniques such as the inclusion of interset protocols are more likely to be used by experienced individuals. Collectively, the studies suggest vibration can improve power and repetition performance if agonist fatigue is minimized and should be considered during strength and conditioning programs. However, interest vibration may not be warranted in commercial gym settings because of the equipment required and the complexity of the training design.

It is common for endurance athletes to program their training based on HR. Although the use of HR for exercise prescription is a mainstay among endurance athletes, its application has been scarce in resistance training. Buskard et al. (9) compared rest intervals based on individual HR recovery with traditional passive rest. The prescription of the HR rest interval consisted of resting until the HR dropped back down to the “start rate” (HR recorded 45 seconds after the first working set). Heart rate–based rest intervals resulted in the completion of more repetitions in the bench press exercise compared with a fixed rest interval (55 vs. 40 repetitions, respectively). While providing only acute findings, it may be hypothesized that if continued over time, training with HR-based rest intervals would result in greater muscular adaptations because of the dose-response relationship between total training volume and both muscular strength and hypertrophy adaptations (49,56). However, it is relevant to emphasize that during the HR-based condition, in most of the sets, the individuals rested for 2 or more minutes, which has been shown to allow for the completion of more repetitions compared to training with a 1-minute rest interval (57). Thus, although the HR-based method of prescribing rest intervals does seem promising, much of the perceived benefit may be due to the longer rest period duration elicited. Despite limited evidence, the HR-based interval method may at the very least provide an individualized approach to determine the optimal individual interset rest interval. Given the accessibility and relatively low cost of HR trackers, it may also serve as a viable option in practical resistance training settings.

At least anecdotally, coaches commonly insist that athletes maintain an upright posture during the interset period with the thought that this enhances recovery. However, there is little evidence to support this idea in resistance training. Only one study assessed the recovery rates using different postural positions (i.e., lying supine, sitting on a flat bench, and walking) (45). The study reported that passive rest (i.e., sitting or lying) resulted in an increase in work rate (3.6%–5.0%), compared with walking. The increase in work rate is likely associated with the observed superior recovery of HR, respiratory rate, and oxygen consumption. The sample consisted of individuals practicing CrossFit, and furthermore, the training session included some of the most common CrossFit training activities (i.e., thruster exercise, deadlifts, and rowing). Therefore, these results provide initial evidence for the potential benefit of postural positioning during the interset period when training using high-volume, short-recovery training regimes.

In the only study that used this technique (12), electromyostimulation was administered to the knee extensors and was performed for 2-minute out of a 3-minute rest period with a self-selected moderate stimulation intensity (i.e., 20–30 mA). No benefit was observed compared to passive rest for the recovery of torque or any other assessed outcome (Table 1). Given that the rest periods were relatively long (i.e., 3 minutes), future studies may consider investigating electromyostimulation in shorter interset rest periods where the accumulation of fatigue might progressively hinder torque production. Although it is clear more evidence is needed on this strategy to draw substantial conclusions, it is likely to have a poor feasibility and practicality for use in applied settings because of the equipment required.

Although the included studies were deemed to be of "good-excellent" methodological quality, some methodological aspects require consideration. For instance, several studies (10,21,34) did not adequately explain the previous resistance exercise experience of the subjects, thus limiting the extrapolation of their findings. More importantly, in several of the included studies, it was not clear if the order of testing (i.e., interset session vs. the passive rest session) was randomized (2,17,27,30,41,42). Thus, it is unclear whether an order or learning effect may have contributed to their findings.

In addition, it needs to be made clear that the total length of the interset rest period is likely to be a more fundamental variable before considering the implementation of a given interset strategy. For example, Willardson and Burkett (62) compared the effect of 3 different rest interval durations (1, 2, and 3 minutes) on acute resistance exercise performance. The authors observed that the 3-minute rest interval, compared with 1 and 2 minutes of rest, allowed the completion of a greater number of repetitions in the bench press exercise. Thus, in many cases, simply prolonging the rest interval duration would allow for recovery and either a maintenance or improvement in resistance exercise performance. However, longer rest periods are not always feasible, particularly in sports requiring multimodal training regimes where specific conditioning and skill-related practice usually take precedence over resistance training sessions. In support, 8 of the 10 studies that used an interset strategy and a rest period of less than 3 minutes reported a benefit in performance (i.e., number of repetitions, power, or velocity) and decreases in HR or RPE (9,10,16,21,33,45,48,59). Therefore, the use of a given interset strategy might be more important when training with shorter rest intervals, especially when time constraints are an issue.

Finally, most of the included studies investigated changes in resistance training performance by assessing the maximal number of repetitions performed until momentary failure. However, in practical settings, this is not always the case, especially where the focus is optimizing velocity and power output. In addition, given that strength and conditioning programs may also use fixed repetition per set paradigms, it is unclear how interset strategies, which mainly demonstrate an increased ability to perform additional repetitions, would be feasible in such circumstances. Therefore, future studies that focus on the effects of interset strategies on kinetic and kinematic variables should be investigated for greater translatability across a multitude of strength and conditioning programs.

Practical Applications

Collectively, the findings suggest that dynamic agonist or antagonist SS, cooling (and in some cases heating), aerobic exercise, vibration, and HR-based intervals seem to be the most effective interset strategies to improve acute resistance training performance. In particular, programs emphasizing the number of repetitions/work volume performed, or the development of voluntary force, velocity and power may benefit from such interset strategies. However, the heterogeneity between study designs and methodologies suggests that careful consideration should be given to the type and specific application of the interset method being used. Given the acute nature of studies, extrapolation to any long-term benefits of using a given interset strategy remains limited. That said, based on the collective findings, coaches and sports scientists may consider using the most effective strategies based on practicality and equipment availability to optimize performance during the resistance training component of strength and conditioning programs.

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