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The effects of short versus long inter-set rest intervals in resistance training on measures of muscle hypertrophy: A systematic review

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Abstract
Although the effects of short versus long inter-set rest intervals in resistance training on measures of muscle hypertrophy have been investigated in several studies, the findings are equivocal and the practical implications remain unclear. In an attempt to provide clarity on the topic, we performed a systematic literature search of PubMed/MEDLINE, Scopus, Web of Science, Cochrane Library, and Physiotherapy Evidence Database (PEDro) electronic databases. Six studies were found to have met the inclusion criteria: (a) an experimental trial published in an English-language peer-reviewed journal; (b) the study compared the use of short (≤60 s) to long (>60 s) inter-set rest intervals in a traditional dynamic resistance exercise using both concentric and eccentric muscle actions, with the only difference in resistance training among groups being the inter-set rest interval duration; (c) at least one method of measuring changes in muscle mass was used in the study; (d) the study lasted for a minimum of four weeks, employed a training frequency of ≥2 resistance training days per week, and (e) used human participants without known chronic disease or injury. Current evidence indicates that both short and long inter-set rest intervals may be useful when training for achieving gains in muscle hypertrophy. Novel findings involving trained participants using measures sensitive to detect changes in muscle hypertrophy suggest a possible advantage for the use of long rest intervals to elicit hypertrophic effects. However, due to the paucity of studies with similar designs, further research is needed to provide a clear differentiation between these two approaches.

Keywords: *Exercise, fatigue, kinesiology, fitness*

Highlights

- Resistance training with both short (60 seconds or less) and long (more than 60 seconds) inter-set rest intervals can be effective when training for muscle hypertrophy.
- The use of long inter-set rest intervals (>60 sec) when training for muscle hypertrophy may be advantageous, as it allows training with a higher overall volume load. However, the approach may vary based on the level of exertion and exercise selection.
- For future research on this topic we suggest the following: (a) using a sensitive measure (e.g. ultrasound or MRI) of hypertrophy for tracking muscle growth, and (b) using participants with previous experience in resistance training.

Introduction

It has been hypothesized that increases in muscle mass are brought about by three primary factors: mechanical tension, metabolic stress, and muscle damage (Schoenfeld, 2013b). Mechanical tension may be considered as the most important factor, as it has been shown that mechanical tension alone can initiate mechano-chemically transduced molecular and cellular responses in myofibres and satellite cells required for muscular hypertrophy (Toigo & Boutellier, 2006). However, it is possible that all three components need to be emphasized to optimize the hypertrophic response to resistance training. Accordingly, coaches and practitioners need to manipulate several training variables, such as intensity, volume, frequency, exercise selection, exercise order, and inter-set rest intervals given that

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programme design is essential to maximize resistance training benefits (Kraemer, Ratamess, & French, 2002). Of all these variables, evidence-based guidelines for rest intervals are most lacking. Rest intervals denote the time dedicated to recovery between sets and exercises (Baechle & Earle, 2000) with the focus being mainly on inter-set rest intervals. Inter-set rest intervals may be deemed as a key variable of resistance training, as they directly influence fatigue, muscle recovery, the training goal, and training duration (Willardson, 2008).

Early research on inter-set rest intervals focused on the acute effects of short versus long rest intervals. Kraemer et al. (1990) showed that limiting rest intervals to 60 s in a whole-body training session resulted in greater post-exercise anabolic hormone elevations, mainly growth hormone. As noted in the latest position stand (ACSM, 2009), the acute hormonal responses are purported to be potentially more important for hypertrophy than chronic changes. In accordance, limiting rest intervals to 60 s is commonly recommended for maximizing hypertrophic effects (Willardson, 2008). However, it is important to note that short rest intervals also have been shown to acutely increase levels of the catabolic hormones corticotropin and cortisol (De Salles et al., 2009). Considering that West et al. (2010) found no association between exercise-induced elevations in the levels of anabolic hormones and muscular hypertrophy, the hypothesis of superior hypertrophic effects associated with shorter rest intervals remains questionable.

Rest intervals are often neglected by the athlete, coach, and/or practitioner. During a rest period, the following events take place: (a) replenishment of the ATP-CP system, (b) buffering of H+ from glycolytic energy metabolism, and (c) the removal of lactate accumulated in the muscles (Ratamess et al., 2007). Intramuscular acidosis may be relevant, as it is significantly related to the loss of force and tetanic tension (Vaughan-Jones, Eisner, & Lederer, 1987). Restricting the rest intervals may not allow for the full restoration of ATP and CP (McMahon & Jenkins, 2002), hindering subsequent performance. Shorter rest intervals may negatively affect performance (i.e. reduction in training volume (De Salles et al., 2009) and have a high metabolic demand (Ratamess et al., 2007). By contrast, longer duration rest intervals allow for a higher training volume, regeneration of high-energy phosphate bonds, and are also less metabolically demanding. However, they are more time consuming.

It is not entirely clear how the rest interval length may affect muscle hypertrophy responses. The current findings of the topic are mixed, with, for example, the study by Schoenfeld et al. (2016) indicating an advantage for longer duration rest intervals, and, by contrast, the study by Villanueva, Lane, and Schroeder (2015) supporting the use of shorter rest periods. The equivocal nature of the existing data may leave the reader confused and unable to draw practical conclusions.

While there are several review articles that have examined the issue of inter-set rest intervals in resistance training (De Salles et al., 2009; Henselmans & Schoenfeld, 2014; Willardson, 2008), none of them was a systematic review of longitudinal studies that compared the effectiveness of short versus long inter-set rest intervals on measures of muscle hypertrophy. To avoid a selection that is biased by preconceived ideas, it is important to adopt a systematic and standardized approach to the appraisal of studies (i.e. a systematic review) (National Health and Medical Research Council, 2000). Accordingly, the purpose of this paper was to systematically review the literature and objectively assess the effects of short versus long inter-set rest intervals in resistance training and their impact on long-term muscle hypertrophy. Based on a critical examination of the current body of research, evidence-based recommendations are provided for practitioners striving to optimize training regimens aimed at maximizing muscle growth.

Methodology

Inclusion criteria

Studies were assessed for eligibility based on the following inclusion criteria: (a) an experimental trial published in an English-language peer-reviewed journal; (b) the study compared the use of short inter-set rest intervals (≤60 s) to long inter-set rest intervals (>60 s) in a traditional dynamic resistance exercise using both concentric and eccentric muscle actions, with the only difference in resistance training among groups being the inter-set rest interval duration; (c) at least one method of measuring changes in muscle mass was used in the study; (d) the study lasted for a minimum of four weeks and employed a training frequency of ≥2 resistance training days per week, and (e) used human participants without known chronic disease or injury.

Search strategy

We performed the systematic literature search conforming to the guidelines set forth by the PRISMA Statement (Moher, Liberati, Tetzlaff, Altman, & PRISMA Group, 2009). We conducted a comprehensive search of the following databases: PubMed/

MEDLINE, Scopus, Web of Science and Cochrane Library. The search strategy encompassed the period from the inception of indexing concluding on 20 December 2016. We used the search terms for rest intervals with the wildcard symbol ("rest interval"*, "inter-set rest interval") in a combination with Boolean operators (AND, OR) and topic-related terms: "resistance training", "muscle hypertrophy", "muscular hypertrophy", "muscle mass", "training load", "strength training", "bodybuilding", "cross-sectional area", "growth", "muscular strength", "fitness", "recovery time", "recovery", "physiological changes", "weight-bearing exercise", "skeletal muscle", "muscle fibres", "measurement", "training intensity", "training volume", "hormonal response", "muscle thickness", "body composition", and "fat free mass". Additionally, we searched the PEDro database using the term "rest interval" in the fitness training and strength training categories. The search strategy was conducted independently by two authors (JG and BL) to reduce selection bias. Disagreements between the reviewers were resolved by mutual consensus, and any inter-reviewer disagreements were settled by consensus with the third investigator (PM). As a part of a secondary search, we scanned the reference list in each full text for additional studies.

Study coding and data extraction

Two authors who performed the search process (JG and BL) performed independent coding of the studies. Using the Microsoft Excel software (Microsoft Corporation, WA, USA), the following data were tabulated in a predefined coding sheet: (a) author(s), title and year of publication; (b) descriptive information of participants by group, including the number of participants in each group, gender, age (for age, the following classification was used: participants aged 18–35 were classified as young, participants aged 36–64 were classified as middle-aged, whereas the participants aged >65 were classified as older adults), and experience in resistance training (participants with less than one year of experience were defined as untrained, by contrast, participants were defined as trained if they had greater than one year of experience); (c) study characteristics (duration of the study, weekly training frequency, employed exercises, the set and repetition scheme used, and the exact rest intervals for both groups); (d) the method used for the assessment of changes in muscle mass (skinfolds, circumferences, ultrasound, magnetic resonance imaging – MRI, dual energy X-ray absorptiometry – DXA, bio-impedance analysis – BIA, and/or hydrostatic weighing) and the region of the body measured for studies that used circumference, ultrasound or MRI; and (e) pre- and post-treatment mean values for assessing changes in muscle hypertrophy. The coding sheets were crosschecked between coders, with any discrepancies resolved by mutual consensus.

Methodological quality

For the assessment of methodological quality, we used the 11-point PEDro scale (Maher, Sherrington, Herbert, Moseley, & Elkins, 2003) evaluated independently by the two authors (JG and BL), with an agreement for any observed discrepancies. The first item of the PEDro scale concerns external validity and is not included in the total score; hence, the values from the PEDro scale range from 0 to 10. However, as it is impossible to blind the participants in exercise interventions studies, and as the therapists and investigators are rarely blinded, we elected to remove the scale items 5, 6, and 7. With the removal of these items, the maximum result was 7 so we used the adjusted ratings, with results ranging from 6 to 7 being "excellent quality", 5 being "good quality", 4 being "moderate quality", and 0–3 being "poor quality", as done in previous exercise intervention reviews (Kümmel, Kramer, Giboin, & Gruber, 2016).

Results

We evaluated a total of 1960 studies based on the initial results of the search; removal of duplicates reduced this number to 1115. After scrutinizing the abstracts for relevance, we considered 46 full texts appropriate for detailed reviewing. A review of these studies revealed that six (Buresh, Berg, & French, 2009; Fink, Schoenfeld, Kikuchi, & Nakazato, 2017; Hill-Haas, Bishop, Dawson, Goodman, & Edge, 2007; Piirainen et al., 2011; Schoenfeld et al., 2016; Villanueava et al., 2015) studies met all the inclusion criteria. Papers that cited the six included studies were also scanned for additional studies (an additional 90 results). Finally, we wrote directly to the corresponding authors of the selected studies inquiring as to whether they knew of additional studies that might meet inclusion criteria. This action, however, did not yield additional studies. Figure 1 presents a flow diagram of the search process. Ethics approval from the local institutional review board was noted in all of the included studies.

Five of the studies involved untrained (Buresh et al., 2009; Fink et al., 2017; Hill-Haas et al.,

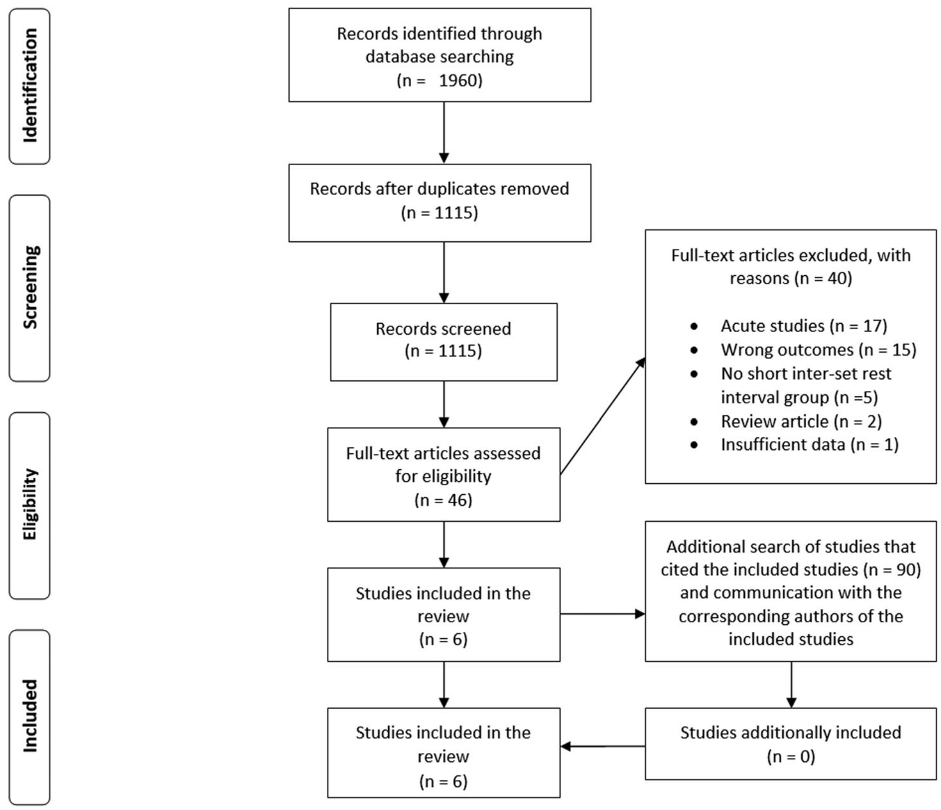

Figure 1. Flow diagram of the search process.

2007; Piirainen et al., 2011; Villanueva et al., 2015) and one study (Schoenfeld et al., 2016) involved trained individuals. The total number of participants was $n = 115$, with the sample comprising 97 men and 18 women. The studies were relatively short in duration with the mean duration of the studies amounting to 8.3 weeks. The length of rest intervals in the short inter-set rest interval groups varied from 20 to 60 s. For the long inter-set rest interval groups, the duration of rest intervals ranged from 80 to 240 s. The weekly training frequency varied from two to three training days per week. None of the studies reported using very high training intensities (>85% of one repetition maximum). A mixture of both free weight and machine-based multi-joint and single-joint isolation exercises were used in five of the studies (Buresh et al., 2009; Hill-Haas et al., 2007; Piirainen et al., 2011; Schoenfeld et al., 2016; Villanueva et al., 2015), while one study (Fink et al., 2017) used only free weight multi-joint exercises. The highest adherence (100%) to the programmes was reported in the study from Villanueva et al. (2015). All of the training programmes along with the exact duration of the rest intervals for each study including the percent change from pre- to post-training intervention in muscle hypertrophy is presented in Table I.

The mean PEDro score was 5.3, indicating high quality of the observed studies. Specifically, three studies were deemed to be of excellent quality, two studies were considered to be of good quality, and one study was rated to be of moderate quality.

Discussion

The purpose of the present study was to systematically review the effects of short versus long inter-set rest intervals on measures of muscle hypertrophy, with the intent of developing evidence-based guidelines for optimization of training regimens. We initially intended to quantify results by conducting a meta-analysis; however, the small number of studies meeting the inclusion criteria and heterogeneous designs of studies precluded our ability to obtain reliable estimates in a random-effects model. A robust variance regression analysis of the per cent changes comparing short and long inter-set rest intervals showed a non-significant advantage to the long inter-set rest condition (long: $9.2 \pm 0.1\%$; 95% confidence interval: 7.4%, 10.9%; short: $5.8 \pm 1.1\%$, 95% confidence interval: –8.1%, 19.7%; $P = .22$). However, these results should be interpreted with extreme caution due to the limited number of studies used in the regression.

Table I. Studies meeting the inclusion criteria.

Study	Participants characteristics; study design	Treatment groups	Duration; weekly training frequency	Training programme	Method of hypertrophy assessment	Relative effects (%)	Adherence to the programmes	Quality score[a]
Buresh et al. (2009)	Young untrained men; RT	Participants were assigned either to a SHORT (60 s) rest interval group ($n = 6$), or a LONG (150 s) rest interval group ($n = 6$) resistance training programmes with 16 different exercises. A mixture of both free weight and machine-based multi-joint and single-joint isolation exercises was used	10 weeks; 2 training days per week	Both of the group performed two different resistance training sessions using the following set and rep scheme: 3 × 10 and 2 × 10 repetitions	LBM via hydrostatic weighing, circumference and skinfolds performed at arm (AMR) and thigh (TMA)	• 3.2% in LBM for the SHORT group • 1.9% in LBM for the LONG group • 5.0% in AMA for the SHORT group • 11.5% in AMA for the LONG group • 3.2% in TMA for the SHORT group • 6.7% in TMA for the LONG group	Mean adherence to training of 89% with no changes between groups.	6
Fink et al. (2017)	Untrained young men; NRT	Participants were assigned either to a SHORT (30 s) rest interval group ($n = 11$), or a LONG (150 s) rest interval group ($n = 10$) resistance training programmes preforming two exercises (squat and bench press)	8 weeks; 2 training days per week	Both of the group performed the same resistance training sessions using 40% 1 RM preformed to muscular failure, for 4 sets	MRI preformed at the triceps and thigh (CSA)	• 9.1% in the triceps CSA for the SHORT group • 9.4% in the triceps CSA for the LONG group • 5.6% in the thigh CSA for the SHORT group • 8.5% in the thigh CSA for the LONG group	> 90% in both groups.	5

(*Continued*)

Table I. Continued.

Study	Participants characteristics; study design	Treatment groups	Duration; weekly training frequency	Training programme	Method of hypertrophy assessment	Relative effects (%)	Adherence to the programmes	Quality score[a]
Hill-Haas et al. (2007)	Untrained woman (exact age is unknown); RT	Participants were assigned either to a SHORT (20 s) rest interval group ($n = 9$), or a LONG (80 s) rest interval group ($n = 9$) resistance training programmes with 11 different exercises. A mixture of both free weight and machine-based multi-joint and single-joint isolation exercises was used	5 weeks; 3 training days per week	Both of the group performed the same resistance training sessions using the following set and rep scheme: 2-5 × 15–20 RM	Thigh and mid-thigh circumference	• 2.3% in thigh circumference for the SHORT group • 0.9% in thigh circumference for the LONG group • 4.4% in mid-thigh circumference for the SHORT group • 1.2% in mid-thigh circumference for the LONG group	Not reported	6
Piirainen et al. (2011)	Untrained young men; RT	Participants were assigned either to recovery time based on individual heart rate (on average 55 s) inter-set rest interval group ($n = 12$), or a LONG (120 s) rest interval group ($n = 9$) resistance training programmes with 14 different exercises. A mixture of both free weight and machine-based multi-joint and single-joint isolation exercises was used	7 weeks; 3 training days per week	Both of the group performed the same resistance training sessions using the following set and rep scheme: 3 × 10 repetitions and 3 × 15–20 repetitions	LBM via BIA	• 2.6% in LBM for the SHORT group • 2.5% in LBM for the LONG group	No significant differences between groups (exact values are not presented)	4

Schoenfeld et al. (2016)	Trained men (exact age is unknown); RT	Participants were assigned either to a SHORT (60 s) rest interval group ($n = 11$), or a LONG (180 s) rest interval group ($n = 10$) resistance training programmes with seven different exercises. A mixture of both free weight and machine-based multi-joint and single-joint isolation exercises was used	8 weeks; 3 training days per week	All of the group performed the same resistance training sessions using the following set and rep scheme: 3 × 8–12 RM	Ultrasound performed at the biceps, triceps, anterior quadriceps and vastus lateralis	• 2.8% in biceps thickness for the SHORT group • 5.4% in biceps thickness for the LONG group • 0.5% in triceps thickness for the SHORT group • 7.0% in the triceps thickness for the LONG group • 6.9% in anterior quadriceps thickness for the SHORT group • 13.3% in anterior quadriceps thickness for the LONG group • 10.0% in vastus lateralis thickness for the SHORT group • 11.5% in vastus lateralis thickness for the LONG group	Overall adherence to training of 86%	5
Villanueva et al. (2015)	Untrained older men; RT	Participants were assigned either to a SHORT (60 s) rest interval group ($n = 11$), or a LONG (240 s) rest interval group ($n = 11$) resistance training programmes with seven different exercises. A mixture of both free weight and machine-based multi-joint and single-joint isolation exercises was used	12 weeks; 3 training days per week	All of the group performed the same resistance training sessions with the first 4 weeks considered as a preparatory phase performing 2–4 sets with 8–15 repetitions, the reaming 8 weeks were performed using the following set and rep scheme: 2–3 × 4–6 repetitions. None of the repetitions were to failure	LBM via DXA	• 1.7% in LBM for the SHORT group • 0.5% in LBM for the LONG group	100% for both groups	6

Note: SHORT: short inter-set; LONG: long inter-set; RT: randomized trial; NRT: non-randomized trail; RM: repetition maximum; MRI: magnetic resonance imaging; BIA: bio-impedance analysis; AMR: arm muscle area; TMA: thigh muscle area; DXA: dual energy X-ray absorptiometry; LBM: lean body mass.

[a]The total score on the PEDro scale.

On the surface, evaluation of the per cent change for both groups indicates similar effects of short and long inter-set rest intervals on changes in hypertrophy, suggesting that both strategies can be used interchangeably to maximize muscle growth. However, it is unclear if the differences in hypertrophic responses to a rest interval duration may vary between trained and untrained individuals. A closer scrutiny of the study by Schoenfeld et al. (2016) indicates an advantage for the use of longer rest intervals. Specifically, the study showed a greater effect size for increases in muscle mass for the long (3 min) rest interval group, in three out of four sites used in the assessment. Results from Fink et al. (2017) support these findings (in untrained individuals) for lower body hypertrophy, with the effect size for thigh cross-sectional area favouring long versus short inter-set rest interval (Cohen's *d*: 0.93 vs. 0.58, respectively). Ratamess et al. (2007) showed that training with longer inter-set rest intervals allows an individual to train with higher overall volume. This may help to provide a possible mechanistic reason for a hypertrophic benefit to longer rest intervals, as training with higher volume has been shown to enhance both the acute anabolic response (Burd et al., 2010; Terzis et al., 2010) and long-term muscular adaptations (Schoenfeld, Ogborn, & Krieger, 2017) to resistance training. Higher volumes are speculated to be necessary for trained individuals, and, accordingly, it may be hypothesized that training status might play a role when planning rest interval duration. Limiting rest intervals to 60 s or less ultimately impairs recovery, and, consequently, results in a lower number of repetitions per set at a given load (Ratamess et al., 2007). Thus, short rest periods may be suboptimal for a trained individual seeking to maximize hypertrophy. This hypothesis merits further robust research.

A recent study from McKendry et al. (2016) provides further insights into the topic. Sixteen men were randomized to resistance training using either 1-min ($n = 8$) or 5-min ($n = 8$) inter-set rest intervals, with each group performing four sets of bilateral leg press and knee extension exercises at 75% of one repetition maximum (1 RM) to momentary muscular failure. Biopsy results showed that the 5-min rest interval group increased myofibrillar protein synthesis by 152%, while the group that rested for 1 min increased by only 76%. This lends support to a hypertrophic benefit of longer rest periods, as an increase in myofibrillar protein synthesis that exceeds muscle protein breakdown theoretically leads to a net gain in protein pool size (i.e. hypertrophy) (Phillips, 2014). Importantly, the 1-min rest group displayed significantly greater acute elevations in testosterone despite the blunted protein synthetic response, thus refuting the hypothesis that short rest intervals are needed to optimize muscle hypertrophy due to the post-exercise anabolic hormonal response. Given these findings, the results obtained from Schoenfeld et al. (2016) are not surprising. While shorter rest intervals have long been recommended for hypertrophy-oriented resistance training protocols, there seems to be a paradigm shift, as longer duration inter-set rest intervals might provide more benefits not only for strength, but also for muscular hypertrophy. That said, the lack of studies using direct measures of muscular hypertrophy diminishes our ability to draw strong evidence-based inferences on the topic.

The prescription of inter-set rest intervals depends greatly on the effort expended, as it may be advantageous to use longer rest intervals when training with maximal and near-maximal efforts (Wernbom, Augustsson, & Thomeé, 2007). As high levels of force and maximum recruitment of motor units are important factors in stimulating muscle hypertrophy, it appears beneficial to use longer inter-set rest intervals between sets of very high levels of effort (Wernbom et al., 2007). However, when a submaximal load is used, and repetitions are not performed to momentary muscular failure, the use of shorter rest intervals may be adequate. It is important to note that regular use of shorter rest intervals attenuates decreases in performance, and increases the ability to train with a higher percent of 1 RM (Kraemer, Noble, Clark, & Culver, 1987), possibly due to an increase in the number of capillaries per fibre with training (Campos et al., 2002). In that regard, de Souza et al. (2010) reported that decreasing rest intervals over time (i.e. from 2 min to 30 s) did not hinder hypertrophic effects, at least over a short-term training intervention (i.e. 6 weeks).

In addition to the level of exertion, the use of either type of rest intervals also depends on the exercise selection, as multi-joint free weight exercises induce a greater amount of fatigue and, as such, require more time to recover from than single-joint, machine-based exercises (Senna et al., 2011). This hypothesis is supported by the recent findings of Senna et al. (2016). The possible hypertrophy-related benefits of this approach were observed in the study by Fink, Kikuchi, and Nakazato (2016), who reported similar hypertrophic effects in a group that trained with a 30-second rest intervals compared with a group that trained with a 3-min rest intervals. Both training groups trained only the arm muscles using single-joint exercises. However, a caveat to the study is the use of different training loads between the groups (20 RM in the short rest group vs. 8 RM in the long rest group), which may have confounded results. Still, this raises the possibility

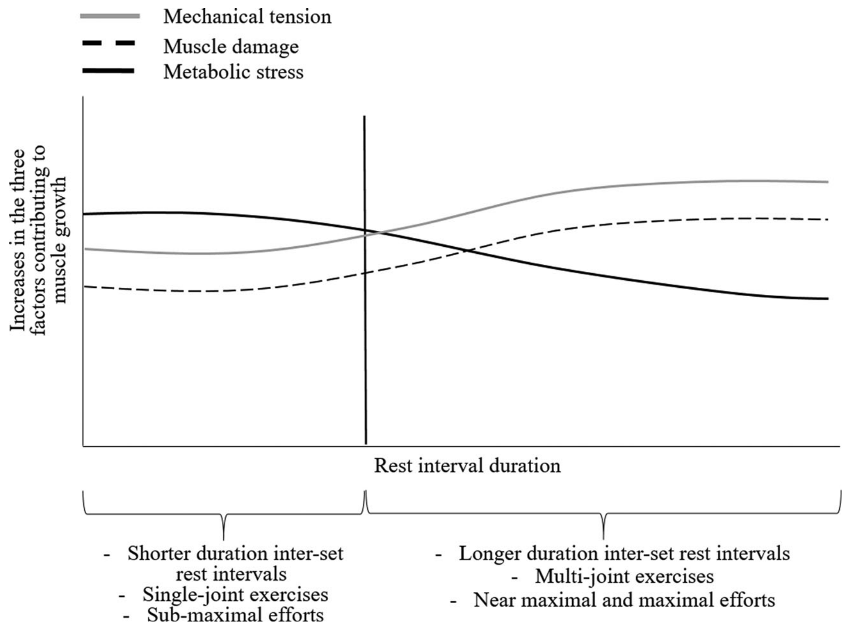

Figure 2. Hypothetical display of possible benefits of combining both short- and long-duration inter-set rest intervals during one training session on three factors contributing to muscle growth.

of a benefit to using long rest intervals when performing multi-joint exercises while employing shorter rest intervals when using single-joint exercises. Namely, the use of longer rest intervals enhances volume accumulation and directly impacts mechanical tension and muscle damage, while the use of short inter-set rest intervals influences metabolic stress. By limiting rest intervals, the body is not able to re-establish homeostasis (Henselmans & Schoenfeld, 2014), resulting in a heightened build-up of lactate, inorganic phosphate, and hydrogen ions (Schoenfeld, 2013a) possibly stimulating increased fibre recruitment, elevated systemic hormonal production, alterations in local myokines, heightened production of reactive oxygen species, and cell swelling (Schoenfeld, 2013b; Henselmans & Schoenfeld, 2014). Hypothetically, the combination of these factors may have a synergistic effect on enhancing muscle growth. A graphical display of the hypothesis may be observed in Figure 2. It should also be noted that the use of shorter rest intervals is certainly more time-efficient, which may allow a greater adherence to exercise in individuals with limited time to train. Additionally, shorter rest intervals may be more beneficial to females, as they seem to demonstrate better inter-set recovery compared to men (Ratamess et al., 2012). This may explain to an extent the superior hypertrophy observed for the short inter-set rest interval group in the study from Hill-Haas et al. (2007), which employed women as participants.

A rather novel topic in the research literature is the use of a self-suggested (SS) approach to inter-set rest intervals. It has been suggested that using a fixed rest interval may be an erroneous method due to differences among individuals and different performance behaviour for upper and lower body exercises (De Salles et al., 2016). As demonstrated by De Salles et al. (2016), a possible benefit of using an SS approach to rest intervals may be a greater time efficiency, with no decrease in the number of repetitions per set. However, the findings of De Salles et al. (2016) are in contrast with the results of Goessler and Polito (2013), who found that an SS approach compared to fixed rest intervals lasting 1 and 2 min resulted in a longer rest interval (157 ± 37 s). The differences may be attributed to the applied resistance training protocols, as De Salles et al. (2016) separated the protocol in sessions targeting upper and lower body, while Goessler and Polito (2013) employed a whole-body resistance training session. It may be hypothesized that resistance-trained individuals may efficiently auto-regulate their rest intervals and successfully maintain performance, rather than using a predetermined rest interval. Possible benefits of an SS approach, as it relates to muscle hypertrophy, other than increased time efficiency, remain unclear and warrant further investigation.

The most apparent drawback of the current body of literature relates to the total number of studies (and with small sample sizes) meeting the inclusion criteria, and the methods used to assess changes in muscle mass. Except for two studies, the proxy measurements for hypertrophy were all global measures (i.e. skinfolds, DXA, circumference). While measures such as DXA and hydrostatic weighing do provide useful insights in changes in lean body mass (and, consequently, in muscle hypertrophy), they are only a gross estimate and lack the sensitivity and specificity for a precise estimation of muscle growth (Nelson et al., 1996). Some measures, such as circumference and BIA, might be unpredictable when assessing changes in muscle mass. Accordingly, caution is needed when extrapolating the presented findings to practical settings. Finally, only one study involved resistance-trained individuals. While most of the studies were categorized as being of either good or excellent methodological quality, it is important to note that we did not include the items concerning blinding when assessing the methodological quality of the studies. While we do realize the challenges that the researchers face when conducting longitudinal studies, for future research, we suggest the following: (a) using a sensitive measure (e.g. ultrasound or MRI) of hypertrophy for tracking muscle growth, and (b) using participants with previous experience in resistance training.

Practical applications

The observed findings may suggest the use of longer inter-set rest durations (>60 s) when the goal is to maximize muscle hypertrophy, as it allows training with a higher overall volume load. However, the approach may vary based on the level of exertion and exercise selection. When the exertion is maximal or near maximal, a longer rest interval may be necessary to maintain the level of performance. By contrast, a sub-maximal exertion may allow training with shorter rest intervals. Exercise selection is also one of the key components that dictates optimal rest duration. Multi-joint free weight exercises are more demanding and more fatiguing, therefore warranting longer inter-set rest intervals. By contrast, single-joint machine-based exercises are less taxing and reduce the need for a long rest interval. The use of shorter rest intervals may be beneficial for metabolic stress accumulation – an important aspect to muscle growth. On a final note, the best approach to a hypertrophy-based resistance training session may be to focus on training volume by performing complex, multi-joint exercises and incorporating longer inter-set rest intervals in the first part of the training session, and then shift the focus to inducing a greater metabolic stress by performing isolation exercises and incorporating shorter inter-set rest intervals towards the end of the training session. This hypothesis requires further study.

Disclosure statement

No potential conflict of interest was reported by the authors.

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