RECOVERY BETWEEN SETS IN STRENGTH TRAINING: SYSTEMATIC REVIEW AND META-ANALYSIS

RECUPERAÇÃO ENTRE SÉRIES NO TREINO DE FORÇA: REVISÃO SISTEMÁTICA E META-ANALISE

RECUPERACIÓN ENTRE SERIES EN EL ENTRENAMIENTO DE FUERZA: REVISIÓN SISTEMÁTICA Y META-ANÁLISIS

SYSTEMATIC REVIEW
REVISÃO SISTEMÁTICA
REVISIÓN SISTEMÁTICA

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ABSTRACT

Introduction: The recovery interval (RI) between sets and exercises has received attention from strength training (ST) researchers, to understand the relationship of rest on performance maintenance, especially the total load in a training session. It is known that each individual responds in a specific way to the training stimulus. So, what would be the effect of the different recovery interval strategies on the strength performance? Objective: Compare the different recovery intervals in strength training volume, considering the number of repetitions in healthy adults. Methods: We conducted a systematic review and meta-analysis based on methodological criteria, comparing fixed and self-selected RI on training volume, identified by the number of repetitions performed in a weight training program. Three electronic databases (Pubmed, VHL Virtual Health Library, Ebsco Sportdiscus) were analyzed, combining the expressions "resistance training", "resistance exercise", "strength exercise", "recovery interval", "rest interval", "interval auto suggested", "auto range selected" with "AND" and "OR" combination. Results: Pooled data from five studies showed a large significant effect in favor of the experimental group (>2 minutes) (MD: 1.24; 95%-CI [0.78; 1.71]; z: 5.25, Q:1.08; p < 0.01), since in the studies, recovery interval allowed a greater training volume. Conclusion: Longer RI seems be better, for maintaining total training volume, although there is no consensus for different training objectives against the self-selected RI. Thus, we imagine that this strategy may be important in the organizing a bodybuilding exercise program. ***Level of Evidence I; Systematic Review and Meta Analysis.***

Keywords: Resistance Training; Rest; Health Strategies.

RESUMO

Introdução: O intervalo de recuperação (IR) entre séries e exercícios, tem recebido atenção dos pesquisadores de treinamento de força (TF), contribuindo no entendimento dessa variável em relação a manutenção do rendimento, em especial da carga durante o treinamento de musculação. Sabe-se que cada indivíduo responde de modo específico ao estimulo do treinamento, desta forma, qual o efeito das diferentes estratégias do intervalo recuperação no desempenho da força? Objetivo: Comparar diferentes intervalos de recuperação no treinamento de força no volume de treino, identificado pelo número de repetições na musculação em adultos saudáveis. Métodos: Realizamos, pelos critérios metodológicos, revisão sistemática e meta-análise, comparando o IR fixo e auto selecionado em função do volume de treino, identificado pelo número de repetições realizados em programa de musculação. Foram analisados os registros de três bases de dados eletrônicas (Pubmed, Biblioteca Virtual da Saúde BVS, Ebsco Sportdiscus), combinando as expressões "treinamento de resistência", "exercício resistido", "exercício de força", "intervalo de recuperação", "intervalo de descanso", "intervalo auto sugerido", "intervalo auto selecionado" com combinação "AND" e "OR". Resultados: Os dados reunidos de cinco estudos mostraram um grande efeito significante a favor do grupo experimental (>2 minutos) (MD: 1.24; 95%-IC [0.78; 1.71]; z: 5.25, Q:1.08; p < 0.01), uma vez que nos estudos em questão, esse intervalo de recuperação possibilitou maior volume de treino. Conclusão: Intervalos mais longos parecem ser melhores no volume total do treinamento, embora não haja consenso para diferentes objetivos do treinamento frente ao IR auto selecionado. Dessa forma, imaginamos que essa estratégia possa ser importante na organização do programa de exercício de musculação. ***Nível de Evidencia I; Revisão Sistemática e Meta Análise.***

Descritores: *Treinamento de Força; Descanso; Estratégias de Saúde.*

RESUMEN

Introducción: El intervalo de recuperación (IR) entre series y ejercicios ha recibido atención por parte de los investigadores del entrenamiento de fuerza (EF), contribuyendo a la comprensión de esta variable en relación con el mantenimiento del rendimiento, especialmente la carga durante el entrenamiento con pesas. Se sabe que cada individuo responde de manera específica al estímulo del entrenamiento, entonces, ¿cuál es el efecto de las diferentes estrategias de intervalos de recuperación sobre el rendimiento de fuerza? Objetivo: Comparar diferentes intervalos de recuperación en entrenamiento de fuerza en volumen de entrenamiento, identificados por el número de repeticiones en musculación en adultos sanos. Métodos: Realizamos una revisión sistemática y un metanálisis basado en criterios metodológicos, comparando IR fijo y autoseleccionado en función del volumen de entrenamiento, identificado por

Associate Editor responsible for the review process: Paulo Zogaib

el número de repeticiones realizadas en un programa de entrenamiento con pesas. Se analizaron los registros de tres bases de datos electrónicas (Pubmed, Biblioteca Virtual en Salud de la BVS, Ebsco Sportdiscus), combinando las palabras "entrenamiento de resistencia", "ejercicio de resistencia", "ejercicio de fuerza", "intervalo de recuperación", "intervalo de descanso", "intervalo auto sugerido", "rango automático seleccionado" con la combinación "AND" y "OR". Resultados: Los datos agrupados de cinco estudios mostraron un gran efecto significativo a favor del grupo experimental (> 2 minutos) (DM: 1,24; IC del 95 % [0,78; 1,71]; z: 5,25, Q: 1,08; p < 0,01), ya que, en los estudios en cuestión, este intervalo de recuperación permitió un mayor volumen de entrenamiento. Conclusión: Los intervalos más largos parecen ser mejores, en el volumen total de entrenamiento, aunque no hay consenso para diferentes objetivos de entrenamiento frente al RI autoseleccionado. Por lo tanto, imaginamos que esta estrategia puede ser importante en la organización del programa de ejercicios de musculación. ***Nivel de Evidencia I; Revisión Sistemática y Meta Análisis.***

Descriptores: *Entrenamiento de Fuerza; Descanso; Estrategias de Salud.*

DOI: http://dx.doi.org/10.1590/1517-8692202430012021_0037i Article received on 02/15/2021 accepted on 10/18/2022

INTRODUCTION

Strength training (ST) has become one of the most popular physical activities in improving muscle strength, hypertrophy and power,[1,2] resulting in different health and performance benefits, such as improved body composition, improved performance in sports, strengthening of tendons[1] and can be used in cardiovascular and pulmonary rehabilitation programs or in the management of metabolic diseases,[3] as well as the effectiveness of ST in improving strength, hypertrophy.[4] Skeletal muscle consists of muscle fibers, classified as Type I and Type II. Type I muscle fibers, or commonly known as red fibers, are slow to contract, generating small amounts of strength but with a long duration. Type II muscle fibers (IIA and IIB), or white fibers, of rapid contraction, with a high capacity in the production of strength, speed or power.[5] These physiological responses to exercise are highly variable and depend on genetic predisposition. It can also be affected by sex, physical status, nutrition, type of exercise or protocol and training period.[6] However, neuromuscular adaptations are maximized by manipulating ST variables, such as volume, intensity, training frequency, choice and order of exercises, execution speed, muscle actions, range of motion and RI.[2,7] In the past two decades, the RI between the series has received a lot of attention from ST researchers.[8] The RI between sets and exercises is an important variable in the acute ST program,[7,9] in addition to being used for different training purposes, directly affecting the number of repetitions during the progression of series, the total number of repetitions per exercise and the total repetition of the session.[10] The fact is that intervals equal to or less than 1 min limit the recovery of creatine phosphate (CP) and ATP (Adenosine Triphosphate) reserves. It is estimated that the total recovery of ATP lasts, on average, from 3 to 5 min after strenuous exercise, while the CP for total recovery needs, on average, 8 min.[11] Another important factor that can influence recovery between sets is the increase in lactate levels during intense ST.[4,12] The time required to decrease lactate after ST performed at high intensity should be between 4 and 10 min; times shorter than the aforementioned range lead to a high concentration of hydrogen ions (H +), decreasing the intracellular pH, resulting in muscle fatigue.[13] The recommendations of the American College of Sports Medicine (ACMS),[2] involve times between 2 to 3 minutes in the IR between series in multiarticular exercises and between 1 to 2 minutes for monoarticular exercises.[2] However, even with the recommendation in the definition of RI, we know that each individual responds to the training stimulus in a specific way. So, why have a fixed break time for different people?

Thus, there is a gap in the literature considering which would be the most recommended IR for each individual. However, in the last few years, a recovery perspective has emerged between series that considers the self suggested duration, which we call the Selected Auto Interval. In this case, the individual chooses the duration of the interval that will rest between sets and exercises,[14] which can favor the final performance in training.[15]

However, we still do not know the self-selected IR imposes on the result of strength and hypertrophy associated with ST. In this way, we understand that it is necessary to analyze the literature in search of the results and effects of this new methodology to the ST, which may contribute to future studies and even to practitioners of this modality. Therefore, the objective of this review is to compare different recovery intervals in strength training in the training volume, identified by the number of repetitions in weight training in healthy adults.

METHODS

The systematic review was carried out according to the recommendations of Khan et al.[16] considering: 1) framing the questions for a literature review; 2) identify relevant research; 3) evaluate the quality of the studies; 4) summarize the evidence; 5) interpret the results. The research questions were defined by the PICOS model according to the PRISMA guidelines, as follows:

1. Population: Men with experience in strength training.
2. Intervention: Strength training with comparison of recovery intervals
3. Comparator: Comparison between recovery intervals with different durations
4. Results: Absolute load and total volume
5. Study design: Controlled and randomized designs, counterbalanced crossings or repeated measurement designs that investigated the effects of the recovery interval on strength training.

Database search method

During the period from March to July 2020, the records of 3 electronic databases were analyzed (Pubmed, Virtual Health Library BVS, Ebsco Sportdiscus).

The keywords were obtained using the query by PubMed "mesh terms". The research was conducted with the terms in English for: strength training, recovery interval and self-selected with combination "AND" and "OR". We follow the path: "resistance training" OR "resistance training" OR "Strength Training" OR "Strength Training" OR "Training, Strength" OR "Weight-Lifting Strengthening Program" OR "Strengthening Program, Weight-Lifting" OR "Strengthening Programs , Weight-Lifting "OR" Weight Lifting Strengthening Program "OR" Weight-Lifting Strengthening Programs "OR" Weight-Lifting Exercise Program "OR" Exercise Program, Weight-Lifting "OR" Exercise Programs, Weight-Lifting "OR" Weight Lifting Exercise Program "OR" Weight-Lifting Exercise Programs "OR" Weight-Bearing Strengthening Program "OR" Strengthening Program, Weight-Bearing "OR" Strengthening Programs, Weight-Bearing "OR" Weight Bearing Strengthening Program "OR" Weight-Bearing Strengthening Programs "OR" Weight-Bearing Exercise

Program "OR" Exercise Program, Weight-Bearing "OR" Exercise Programs, Weight-Bearing "OR" Weight Bearing Exercise Program "OR" Weight-Bearing Exercise Programs "AND" recovery periods "OR" interval "OR" recovery "OR "rest intervals" OR "rest periods" AND "self-selected" OR "self-selected" OR "self-selection" OR "self-selection" OR "rest self-selection".

Inclusion and exclusion criteria

The inclusion criteria for the articles were: 1) studies that compare different recovery intervals between the series; 2) used strength training as a training method; 3) individuals practicing strength training with a minimum experience of 1 year; 4) research published in a peer-reviewed journal. The exclusion criteria were: 1) Studies that contained aerobic training as an intervention; 2) used less time of experience in strength training; 3) Articles that had women, elderly or adolescents in their sample; 4) articles that used supplementation in the intervention

Review process

The analysis and categorization of each article was carried out, separating the data in the excel spreadsheet following the order: names of the authors and year of publication, description of the sample, description of the intervention, results and conclusion. The first stage of the research resulted in 2789 articles and by reading only the titles and removing duplicate articles, 114 papers were selected. In this phase, all abstracts were read, observing the objectives, interventions with strength training and different interval times and experience in strength training. If the abstract did not provide these details, the article was separated for full reading. 51 articles were selected in full, but only 18 articles entered for qualitative review and only 5 for quantitative. In addition, only 5 articles were found with a self-selected recovery interval.

Statistical analysis

Articles were selected that had the supine exercise as intervention and that used recovery intervals <2 minutes and> 2 minutes. They were grouped and these data were compared. The random effect of the meta-analysis was driven by a variable of the recovery interval of> 2 minutes (experimental group) and <2 minutes (control group) associated with training load. The present results were analyzed as differences in standardized means (DMP) ± standard deviation (SD) and 95% confidence interval (CI). Therefore, the effect of the recovery interval was determined by the DMP value and then calculated by the inverse of the variance.[17,18]

Heterogeneity was estimated by the estimator (the DerSimonian-Laird estimator) and incorporated up to the standard error and estimated for the mean of the effect corresponding to the confidence interval. Heterogeneity was assessed using the Cochran Q test and the I2 index, which indicates the percentage of variance between studies, with corresponding cutoff points for low (0–25%), moderate (26–50%) and high (51 –100%).[19] The funnel and cut and fill charts were used to assess publication bias using Egger regression tests in which non-significant asymmetry did not indicate bias.[20] In addition, we conducted an adjusted cut and fill analysis[21] to remove the small studies from the positive side of the funnel graph, and recalculated the effect size (ES) in each iteration, until the funnel graph was symmetrical over the (new) ES. Finally, the fail-safe number of negative studies that would be needed to cancel (that is, make p> 0.05), the TE was calculated.[22] All analyzes were performed using the meta package in version R 1.0.4.4 - © 2009- 2016 RStudio, Inc (The R Foundation for Statistical Computing, Vienna, Austria). An α level of p <0.05 was used to determine statistical significance. (Chart 1)

Chart 1. Methodological quality and strength of evidence for meta-analysis.

	(0-10)	Scale PEDro										
Authors		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Ahtiainen et al,[23] 2005	6	S	N	N	S	N	N	N	S	S	S	S
Ammar et al,[36] 2019	6	S	N	N	S	N	N	N	S	S	S	S
De Salles et al,[33] 2016	7	S	S	N	S	N	N	N	S	S	S	S
De Souza et al,[09] 2010	7	S	S	N	S	N	N	N	S	S	S	S
Fink et al,[27] 2016	7	s	S	N	S	N	N	N	S	S	S	S
Ibbot et al,[15] 2019	7	S	S	N	S	N	N	N	S	S	S	S
Ibbot et al,[34] 2019 II	7	S	S	N	S	N	N	N	S	S	S	S
Lemos et al,[37] 2018	7	S	S	N	S	N	N	N	S	S	S	S
Machado et al,[41] 2012	7	S	S	N	S	N	N	N	S	S	S	S
Maia et al,[39] 2015	7	S	S	N	S	N	N	N	S	S	S	S
Miranda et al,[32] 2007	6	S	N	N	S	N	N	N	S	S	S	S
Miranda et al,[30] 2009	6	S	N	N	S	N	N	N	S	S	S	S
Paz et al, 2019	7	S	S	N	S	N	N	N	S	S	S	S
Rahimi,[29] 2005	6	S	N	N	S	N	N	N	S	S	S	S
Senna et al,[08] 2016	7	S	S	N	S	N	N	N	S	S	S	S
Shoenfeld et al,[38] 2016	7	S	S	N	S	N	N	N	S	S	S	S
Sosciarelli et al,[35] 2019	6	S	N	N	S	N	N	N	S	S	S	S
Tibana et al,[31] 2013	6	S	N	N	S	N	N	N	S	S	S	S

Chart 1. PEDro Scale scores of articles selected for systematic review. ** Y = yes; N = no - Scores of 6 or more are considered indicative of high quality; scores below 6 considered to indicate low quality.* - PEDro scale items: (a) eligibility criteria and source of participants; (b) random allocation; (c) hidden allocation; d) Baseline comparability; (e) blind subjects; (f) blind therapists; (g) blind advisors; (h) adequate follow-up; (i) intention to treat; (j) comparisons between groups; k) point estimates and variability.

RESULTS

The present study compared different recovery intervals in strength training in training volume, identified by the number of repetitions in weight training in healthy adults. The results of the meta analysis demonstrated a positive effect in the groups that used RI> 2 minutes, as this generated a greater number of repetitions and, consequently, a greater volume of training, which can stimulate physiological responses associated with signaling pathways of muscle hypertrophy, resulting in an increase of strength and muscle mass.[23,24] These results are consistent with the study by Senna et al, 2016,[8] which compared several RIs between sets with the supine and crucifix exercise and found a greater number of repetitions in the 2-minute intervals (12.60 ± 2.35 repetitions; p = 0.027), 3 minutes (13.66 ± 1.84 repetitions; p = 0.001) and 5 minutes (12.93 ± 2.25 representatives; p = 0.001) vs. 1-minute protocol (10.33 ± 2.60 repetitions). From the results in the present study, it is clear that the longer RI promotes greater training volume. (Figure 1)

DISCUSSION

Considering that both the volume and the intensity of training are variables that are directly related to the stimulation of neuromuscular adaptations,[25] it was speculated that longer rests could provide greater volumes of training compared to 2 minutes, contrary to the data obtained in the review by GRGIC.[26] Like AHTIAINEN,[23] who used RI of 2 and 5 minutes, but found no significant changes in the total training load during the training period. However, there was a significant increase of 6.8 ± 8.7% (from 3,370 ± 748 to 3,613 ± 949 N) (p, 0.05) in the maximum strength of the extensor chair in isometry in the total group of subjects.

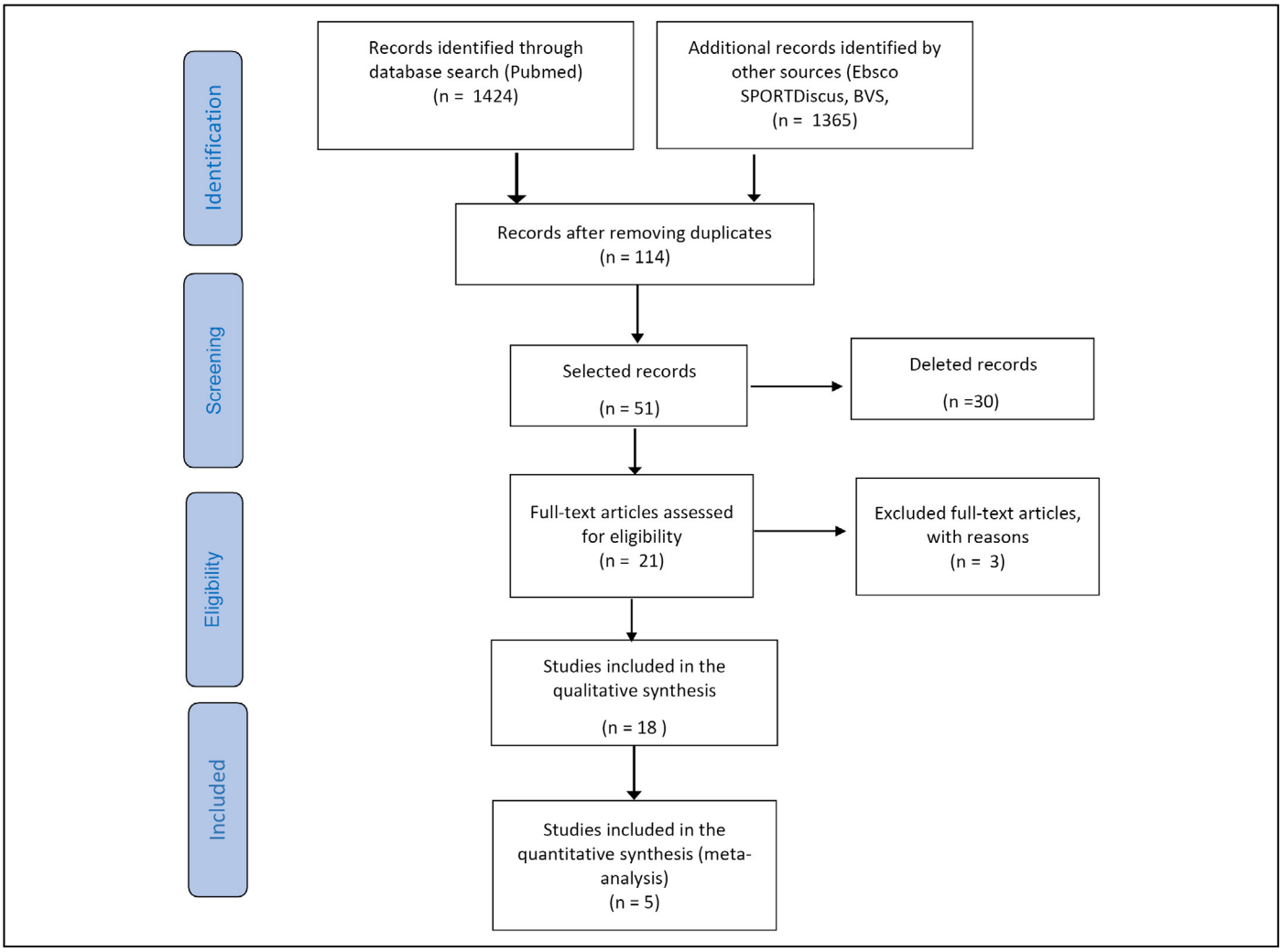

Figure 1. Flowchart shows the methodology used in the selection of studies for systematic review and meta-analysis.

The IR between series is still a major unknown in the literature, as there is still no consent among the authors, and perhaps there will not be, on how long the individual will need to rest in order to obtain better results for hypertrophy or maximum strength. What is known is that the recovery interval guidelines presented by RATAMES,[2] indicated by the American College of Sports Medicine (ACMS) are between 2 to 3 minutes for multiarticular exercises and between 1 to 2 minutes for monoarticulars. In a study with monoarticular exercises,[27] short (30 seconds) and long (3 minutes) IR were compared under the hormonal responses of GH and cross section with high loads. The results showed that the group with short intervals demonstrated significant increases in GH (7704.20 ± 11833.49%, P <0 05) immediately after training. Regarding the cross section, there were significant increases in both groups [Short: 9.93 ± 4.86% (P <001), Long: 4.73 ± 3.01% (P <0 05)]. For this study, the RI was not sufficient to enable muscle hypertrophy in these muscle groups.

Although the interval between series may not alter the hypertrophic conditions of individuals, it is possible that it contributes to the increase in maximum strength, as shown in the study by Villanueva.[28] The author found no differences in body composition, but there were differences in the intensity of the 1-RM test in the groups that trained with intervals between 1 minute compared to 4 minutes in the leg press and bench press exercises.

MIRANDA; RAHIMI; TIBANA[29-32] compared different intervals in strength training, and like the studies already presented here, obtained similar results, with a higher number of repetitions and a greater total volume, less fatigue, as a response when the recovery interval was over 3 minutes, confirming the physiological hypothesis associated with the recovery of ATP concentrations, CP[11] that takes place between 3 and 5 minutes and the removal of lactate, after 4 minutes, after high intensity exercise.[13] (Chart 2 and Figure 2)

The studies in this review showed that short intervals promote a higher concentration of GH and lactate, which is associated with the hypertrophy process. On the other hand, lactate can be associated with reduced performance in strength training. Considering the longer intervals, a greater number of repetitions, less fatigue, greater training volume and improved performance were found. Among these results, there is only one question: What is the best recovery interval? Although it is a complex question, there is no consensus in the literature. Thus, this review aimed to compare fixed IR and self-selected RI, as an alternative that promotes autonomy and uses the practitioner's perception when choosing the RI that he deems necessary.

Five studies were found that used the RI Auto Selected methodology as a recovery strategy between series. De Salles[33] compared the selected auto with a fixed interval of 2 minutes and found no differences in the selected auto RI in relation to the total number of repetitions keeping the average and total training volume. On the other hand, Ibbott,[34] showed that the RI AS increased according to series progression, remaining close to 5 minutes (207.52s> 277.71 s; p = 0.01). However, power (210 W; 8.03%) and speed (0.03 m.s-1; 6.73%) decreased as the sets progressed to all conditions (p <0.001), regardless of the IR used.

Similar to the study by De Salles, Sosciarelli and Polito[33,35] compared the self-selected RI with recovery ranges (1 to 2; 2 to 3 minutes).

Chart 2. Data from articles selected for systematic review.

ID	Authors	Sample	Objective	Design	Exercises	Rest interval	Output
1	De Souza et al[09] (2010)	20 young people trained recreationally	Compare the effect on strength and hypertrophy of 8 weeks of resistance training using constant rest intervals (Cri) and decreasing rest intervals (Dri)	8 training weeks with 6 weekly training sessions, A and B training sessions, with constant and decreasing intervals. 2 first weeks 3x 10 to 12RM with 2 min interval. After 3 weeks, the Constant group used a 2-minute interval and 4x 8 at 10RM.	Dumbbell bench press, dumbbell incline bench press, front pull, Dumbbell Shoulder press, side elevation, biceps curl, tríceps pulley, barbell triceps extension, lever leg extension lying leg curl	constant rest intervals and decreasing rest intervals	The total training volume (resistance series x for all training sessions) during the 8 weeks of training for the bench press, the Cri group (21,257.9 ± 172.7 kg) was significantly higher (p = 0.043) than the group Dri (19,250.4 ± 343.8 kg). Likewise, the total volume of training in the squat performed by the Cri group (27,248.2 ± 293.8 kg) was significantly higher (p = 0.000) than the Dri group (23,453.6 ± 299.4 kg).
2	Ammar et al[36] (2019)	9 Olympic weightlifters	Examine the effect of intermaximal repetition of 3 vs. 2-minute rest period in maintaining technical efficiency and the production of energy during 2 successive maximum repetitions of Clean & Jerk (C&J)	2 warm-up sessions 4 clean and jerk lifting sessions with 2 and 3 minutes intervals between attempts, analyzing technique and power	Clean and jerk	2 e 3 minutes	Statistical analysis showed that 1-minute RI improved the maintenance of the ideal pushing technique, evidenced by the reduction of falls in the vertical peak displacement bar (2.74%; p = 0.03), maximum bar speed (2.89% %; p = 0.03) and peak of the knee (1.61%; p = 0.03) and hip extensions (1.59%; p = 0.03) during the push movement phase. In addition, the 3 min IR led to the maintenance of the ideal elevation strategy, reducing the increase in horizontal displacement during the descending (3.85%; p = 0.04) and ascending (5.42%; o = 0 , 02).
3	Senna et al[08] (2016)	15 trained men	To investigate the acute effects of different rest intervals between sets on the performance of and multi-joint exercises with near maximum loads	8 sessions in total, 2 per week. Each session 5 series of 3RM until exhaustion. Rest intervals 1, 2, 3 and 5min	Chest fly machine and bench press dumbbell	1, 2, 3 and 5 minutes	In the crucifix exercise, there were significantly> total repetitions> completed for 2- (12.60 ± 2.35 repetitions; p = 0.027), 3- (13.66 ± 1.84 repetitions; p = 0.001) and 5 minutes (12.93 ± 2.25 representatives; p = 0.001) vs. 1 minute protocol (10.33 ± 2.60 reps). For BP, a significantly> total number of repetitions was completed for 3- (11.66 6 2.79 repetitions; p = 0.002) and 5 minutes (12.93 ± 2.25 repetitions; p = 0.001) vs. 1 minute (7.60 ± 3.52 reps). In addition, the subjects completed a total number of significantly> repetitions in the 5-minute protocol (12.93 ± 2.25 repetitions; p = 0.016) vs. 2 minutes (9.53 ± 3.11 representatives).
4	Rahimi et al[29] (2005)	20 college men	Compare the effect of 3 different rest intervals on the completed squat volume during a workout	4 sets of squats with rest intervals of 1, 2 and 5 min between sets at 85% of 1RM	Squat	1, 2 and 5 minutes	The completed volume for the squat was significantly different between the 1 and 5 minute rest conditions and between the 2 and 5 minute rest (p <0.001, 0.002; however, the completed volume was not significantly different between the resting conditions of 1 and 2 minutes (p = 0.190; intra-class reliability for the squat was 0.97. The 5-minute rest allowed greater volume when training with 85% of 1RM of the load, stimulating greater adaptation of force
5	Miranda et al[30] (2009)	12 recreational trained men	Compare the volume exercise (series x load x repetitions per series) completed during two resistance exercise sessions that incorporated rest intervals of 1 minutes vs 3 minutes between sets and exercises	3 training sessions, one for evaluation and 2 for effective training. 5 upper body exercises with a maximum load of 8RM with 1 and 3 minutes of intervals between sets comparing the total training volume related to rest	Bench press,bench press inclined, pec deck, barbell triceps extension, tríceps pulley	1 and 3 minutes	The total volume of training completed (sets x load x repetitions per set) for all exercises was significantly higher for the 3-minute resting condition versus the 1-minute resting condition (p <0.05;). Within each resting condition, there were significant differences in the repetitions completed for each series of exercises (p <0.05;). In addition, there were significant differences between resting conditions in completed repetitions for most sets of exercises (p <0.05)

6	Miranda et al[32] (2007)	14 recreational trained men	Compare the effects of 2 different rest periods during a resistance training session with the number of repetitions completed per set of each exercise, the volume completed in 3 sets of each exercise, and the total volume during a training session	2 exercise sessions separated by 48 to 72 hours in a balanced crossover design. 3 sets until exhaustion with a load of 8 RM for each exercise.	Cable pulldown closed handle, Cable pulldown open handle, seated row, barbell bench press, dumbbell biceps curl, biceps curl machine	1 and 3 minutes	The total training volume (total number of repetitions in all sets of all exercises) in SEQ 3 (107.2 3.03 repetitions) was significantly higher than SEQ 1 (78.9 3.28 repetitions). Sequence 1 demonstrated significantly lower values for the number of completed repetitions in all 3 sets for all exercises compared to SEQ 3 As the rest interval increases, the total number of completed repetitions also increases. The number of repetitions was greater in the 3-minute rest compared to 1 minute.
7	De Salles et al[33] (2016)	27 healthy young people	Analyze the effects of the Fixed versus Self Rest Interval Suggested Between Sets on Performance in Lower and Upper Body Exercises	They were divided into 2 groups: G1 squat and leg press, G2 bench press and barbell curl. After the 1RM tests, they trained 3 sets to failure with 75% of 1RM at 2 min intervals and auto suggested on separate days. Performance was assessed for the number of repetitions	squat,*leg press*, bench pres, bíceps curl	2 minutes, self selected	There were no significant differences between a 2-min recovery interval and self-selected for total repetitions in all exercises. There were significant differences between the intervals for leg press, bench press and biceps curl ($p < 0.05$). No significant differences were found between different RI for all exercises. For squats, the suggested RI results in a significant reduction in the number of repetitions from the first set to the second and third
8	Tibana et al[31] (2013)	10 recreational trained men	Compare two different rest intervals between sets of resistance exercises	5x smith bench press with 60% 1RM with 1.5m and 3min intervals	Bench press machine	1, 3 and 5 minutes	In general, the performance was better and the fatigue was lower in the IR 3 min, supporting all hypotheses, except Hypothesis 4. Overall, the performance was better and the fatigue was lower in the 3 min. IR, supporting all hypotheses, except Hypothesis 4. The 3-minute interval protocol showed higher values for power, training volumes, average speed and peak power
9	Fink et al[27] (2016)	20 young athletes	Compare short rest intervals combined with low-load RT and long rest intervals combined with high-load RT in relation to muscle hypertrophy and strength results.	Two groups of 10 men took two types of intervals, 30s with 20RM and 3 minutes with 8RM, for 8 weeks, 3x a week until failure. Cross section and acute GH effects were evaluated. 3 exercises for biceps and triceps	Bíceps curl and tríceps extension	30 seconds and 3 minutes	Only the SL group showed significant increases in GH (7704.20 11833 49%, P <0 05) and MT (35 2 16 9%, P<0 05) immediately after training. After 8 weeks, the CSAs of the arm in both groups increased significantly [SL: 9 93.4 86% (P <001), LH: 4 73 3 01% (P <0 05)]. No significant correlation between acute elevations in GH and increases in CSA can be observed. The data showed a tendency for greater increases in the muscular CSA in the SL group compared to the LH group, despite the similarity in the training volume.
10	Lemos et al[37] (2018)	15 trained men	To compare the effect of a strength training session performed with different exercise orders and rest intervals in BP and HRV in a normotensive trained man	6 exercises with a load of 15RM in two sequences of exercise execution, with Seq A from large to small and Seq B from small to large, both with 40 and 90 sec of rest interval between sets	Bench press,front pulldown,seated row, Upright row, triceps extension, biceps curl	40 and 90 seconds	The total load volume did not differ significantly between protocols, therefore, the total amount of work performed in all sequences was similar ($p > 0.05$). A comprehensive upper body TF session, with 90 sec IR between sets and exercises promoted a longer HPE, specifically in SBP, compared to a 40-second rest interval between sets and exercises regardless of the order of exercise

11	Shoenfeldet al[38] (2016)	21 trained university men	To investigate the effects of short rest intervals normally associated with training hypertrophy versus long rest intervals traditionally used in TF on muscle adaptations in a cohort of young lifters	Separated into two groups, one with 1 min and the other with 3 min intervals. 8 weeks with 3x training per week and 3x from 8 to 12 RM 7 exercises	Bech press and squat	1 and 3 minutes	The total volume of aggregate load in the 8 weeks was higher on an absolute basis for LONG compared to SHORT (51,385 x 9420 vs 44,755 x 12,166 kg, respectively): These results were not significantly different between groups (p = 0.18),
12	Maia et al[39] (2015)	14 recreational trained men	Examine the length of the rest interval between agonist-antagonist (PS) training, maximum repetition performance, classification of perceived exertion and neuromuscular fatigue.	2 strength training protocols using the agonist vs. antagonist method. With two intervals (2 and 4 minutes of rest) with a load of 8RM until failure.	Dumbell inverted fly, bíceps curl,bench press, tríceps extension	2 and 4 minutes	No significant differences were found in the total number of repetitions completed between the rest interval protocols for the bench press (P2 ¼ 22.9 ± 1.3 and P4 ¼ 22.6 ± 0.8) and sitting row (P2 ¼ 25.4 ± 1.7 and P4 ¼ 25.1 ± 1.3). At the However, a significantly higher fatigue index was found for all muscles under the P2 versus P4 protocol. The current study demonstrated similar repetition performance with PS agonist-antagonist training protocols that used 2 or 4 minute rest intervals between the OS with a moderate load (for example, 8-RM)
13	Paz et al[40] (2019)	15 recreational trained men	To investigate the effect of different paired joint rest intervals (PS) on the total volume of work and training, efficiency (training volume load / session duration time) and myoelectric activity.	4 protocols of training with 30, 60, 90 and 120 sec intervals with 10 RM load	Bench press (BP)/lat pull downl (LPD), bench press inclined (BP30)/ seated row (SR), and triceps extension (TE)/ Bíceps curl (BC).	30, 60, 90 e 120 seconds	The volume load (repetitions x series x loads) was significantly lower at P30 (5385.8 ± 1224 kg) versus P60 (6755.6 ± 1398.5 kg), P90 (7358.3 ± 1490.3 kg) and P120 Protocols (7463 ± 1310 kg). There were no significant differences in sEMG activity between the protocols. The efficiency (kg $ min 1) of P30 (633.6 ± 144) was significantly higher compared to P60 (397.4 ± 82.2), P90 (288.5 ± 58.4) and P120 (219.5 ± 38.5) significantly less total work in protocols P30 versus P60, P90 and P120 for all exercises, (b) lower total volume of training observed in P30 versus protocols P60, P90 and P120; and (c) a similar total volume was observed for the P60, P90 and P120 protocols. However, higher efficiency (TTV / time) was observed at P30 versus protocols P60, P90 and P120.
14	Sociarelli et al[35] (2019)	12 trained men	Compare the effect of fixed and self-suggested recovery intervals during bench press exercise under the number of repetitions and training density in trained men	4 series until exhaustion at 70% of 1RM with intervals of 1 to 2 min, 2 to 3 and self suggested	Bench press	1 a 2, 2 a 3, self suggested	The analysis of the results showed that INT1 had a lower number of repetitions (28.9 ± 4.7) only in relation to the AS interval (34.0 ± 7.2; P = 0.02). On the other hand, the training density of INT1 was higher (5.6 ± 1.8) than INT2 (4.5 ± 1.3; P = 0.002) and AS (3.8 ± 1.4; P = 0.004) There was no difference for PSE
15	Machado et al[41] (2012)	50 adult men	Examine creatine kinase (CK) activity after resistance exercise sessions in subjects classified as high (HiR), medium (MeR) or low responders (LoR).	4 x direct thread to failure with 85% 1RM with 1 and 3 minutes interval between sets	Biceps curl	1 and 3 minutes	For all groups (ie LoR, MeR and HiR), the number of repetitions and volume decreased similarly in the 3 groups indicated by the main non-significant effect for the group (F2.376 = 1.58, p = 0.208 for repetitions; F2.376 = 2.31, p = 0.101 for completed volume), non-significant interaction for group3 rest interval (F2.376 = 0.542, p = 0.582 for repetitions; F2.376 = 0.376, p = 0.687 for the completed volume) and the non-significant interaction for group 3 (F6.376 = 1.06, p = 0.385 for repetitions; F6.376 = 0.537, p = 0.780 for completed volume).

16	Ahtiainen et al[23] (2005)	13 recreational trained men	Investigate acute hormonal and neuromuscular responses and recovery 2 protocols of hypertrophic heavy resistance performed with a similar general volume of exercise;	Two training sessions, with 3 months for each group to carry out the two protocols. 5x leg press, 4x squat, with 2 minutes rest. The second session was 4x leg press and 3 squat loads of 10RM	*Leg press* and squat	2 and 5 minutes	No significant changes occurred in body mass (from 83.9 ± 11.7 kg to 84.6 ± 12.9 kg) or body fat percentage (from 14.8 ± 3.9% to 15.3 ± 3.6 %) during the 6-month experimental training period in the total group of subjects. There were no statistically significant differences in the total training load. In 6 months, a significant increase of 6.8 ± 8.7% (from 3,370 6 748 to 3,613 6 949 N) (p, 0.05) was recorded in the maximum isometric extension of the leg strength in the total group of subjects
17	Ibbot et al[15] (2019)	16 male athletes	Evaluate stimulation strategies using rest periods between prescribed and self-selected intervals and their influence on performance in trained athletes in strength.	3 5x 5rep training sessions with different intervals 3 and 5 and self suggested	squat	3, 5 and self suggested	Self suggested rest time between sets increased from sets 1 to 4 (207.52s> 277.71 s; p = 0.01). There is not differences in mechanical performance was shown between the different conditions of the rest period between sets. Power (210 W; 8.03%) and speed (0.03 m.s-1; 6.73%) decreased as the sets progressed for all the conditions (p <0.001) from set 1 to set 5.
18	Ibbot et al[34] (2019b)	16 male athletes	To investigate the variability of self-selected rest periods for strength-trained athletes between squat training sets heavy	2 training sessions with self selected 5x5RM squat intervals. At the end of each series, the individual indicated his / her perceived effort scale	squat	Self selected	Only one participant was unable to complete the necessary repetitions until the end. The average duration of rest was 283 ± 101 for session 01 and 249 ± 76 for session 02. The average rest was shorter in AS2 than in AS1. The rest period increased significantly after series 3 and 4 in relation to series 1 There was no significant difference between sessions for PSE

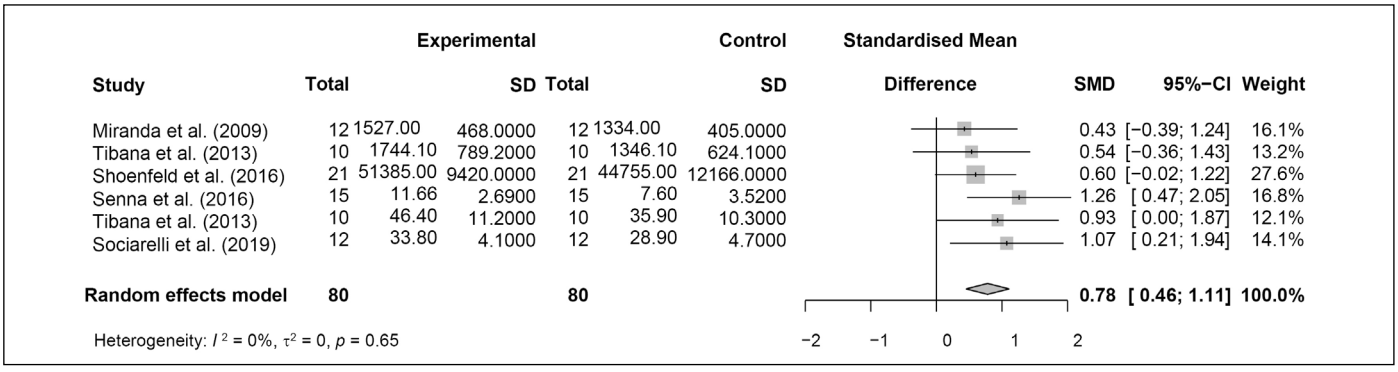

Figure 2. Forest plot of studies used for meta analysis.

The analysis of the results showed that the interval range from 1 to 2 minutes presented a lower number of repetitions (28.9 ± 4.7 min) only in relation to the self-selected RI (34.0 ± 7.2 min; P = 0.02), while the range of 2 to 3 minutes there were no significant differences (33.8 + 4.1). There was no difference in the subjective perception of effort.

Ibbott,[34] compared two situations of self-selected RIs with high loads. It was found an average duration of RI of 283 ± 101 for session 01 and 249 ± 76 for session 02. Even in the case of the same individual, the responses to the same training condition were different. Only one individual was unable to conclude performing the 5 predetermined repetitions, possibly the RI was insufficient to recover the energy sources.[11] The rest period increased significantly after series 3 and 4 in relation to series 1. There was no significant difference between the sessions for PSE. During the selection of studies that would be part of this review, we can notice the difference in the presentation of the data of the articles. This determined the choice of only 5 articles for the meta analysis, because in these studies the information was clearer with similar data that could be compared and analyzed.

CONCLUSION

The studies presented here have shown that the recovery interval between 3 and 4 minutes is effective between sets for training with high intensities. This applies to trained adults who are already familiar with the methodology. The benefits of the self-selected interval for strength training performance are not yet clear. Studies show that when individuals had this methodology available, they used times close to 3 and 4 minutes between sets. The subjective perception of effort can be a strategy to this recovery methodology, indicating which subjective intensity of the practitioner.

All authors declare no potential conflict of interest related to this article

AUTHORS' CONTRIBUTIONS: SWJ: writing, revising and searching the databases, preparing the entire research project; BDS: data analysis and writing; CEC: statistical analysis and review; JGA: statistical analysis and review; AIP: writing and proofreading; JAF: writing, statistical analysis and intellectual concept.

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