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EFEITO AGUDO DE DIFERENTES CONFIGURAÇÕES DE PRESCRIÇÃO NO TREINAMENTO DE FORÇA COM A RELAÇÃO ESFORÇO:PAUSA EQUALIZADOS NAS RESPOSTAS HEMODINÂMICAS E AUTONÔMICAS: UMA REVISÃO SISTEMÁTICA

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Resumo: O estudo teve como objetivo realizar uma revisão sistemática sobre a influência de diferentes configurações de prescrição com a relação esforço:pausa (E:P) equalizados nas respostas hemodinâmicas e autonômicas durante e após o treino de força (TF). **Métodos:** Os artigos foram selecionados a partir do Portal de Periódicos Capes, PubMed, Medline, LILACS, Cochrane library, Scopus e Google Scholar, publicados entre 2012 a 2019. Os critérios de inclusão foram: Estudos aleatórios publicados em inglês com participantes adultos (total: 71; Mulheres: 15; Homens: 56) (≥18 anos de idade) envolvendo intervenção de TF; com a relação E:P equalizado e detalhado. **Resultados:** Foram encontrados cinco estudos envolvendo o TF com a relação E:P equalizados. Séries com a configuração com um maior tempo sob tensão (TST) parecem induzir respostas metabólicas mais expressivas do que TST curtos. Estes resultados podem levar a respostas hemodinâmicas e autonômicas distintas durante as sessões de TF. **Conclusões:** Quando a relação E:P é equalizado entre diferentes configurações de prescrição, séries com um TST mais longo parecem induzir uma maior resposta hemodinâmica e uma retirada vagal durante e após uma sessão aguda de TF.

Palavras-chave: Treino de Força; Diferentes Configurações; Relação Esforço:Pausa; Pressão Arterial; Controlo Autonômico Cardíaco.

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ACUTE EFFECTS OF DIFFERENT SET CONFIGURATIONS WITH EQUATED WORK-TO-REST RATIO ON HEMODYNAMIC AND AUTONOMIC RESPONSE IN RESISTANCE TRAINING: A SYSTEMATIC REVIEW

Abstract: The study aimed to perform a systematic review about the influence of different set configurations with the equated work-to-rest ratio on hemodynamic and autonomic responses during and after resistance training. **Methods:** The articles were selected from Periodicals Capes Portal, PubMed, Medline, LILACS, Cochrane library, Scopus, and Google Scholar, published between 2012 to 2019. Inclusion criteria were: English-published randomized studies with adult participants (total: 71; Female: 15; Male: 56) (≥18 years old) involving resistance training intervention; detailed work-to-rest (W:R) ratio. **Results:** Five resistance training studies with equated work-to-rest ratios were found. Sets with longer time under tension (TUT) seem to induce more expressive metabolic responses than short TUT. These outcomes may lead to distinct hemodynamic and autonomic responses during RT sessions. **Conclusion:** When the W: R ratio is equated between different set configurations, sets with longer TUT appear to induce greater hemodynamic response and vagal withdrawal during and after an acute session.

Key words: Resistance training; Set configuration; Work-to-rest ratio; Blood pressure; Cardiac autonomic control.

Introduction

Exercise-induced autonomic nervous system modulation, reduced cardiac output, and peripheral vascular resistance (PVR) can induce lower blood pressure (BP) levels after a training session(1,2). In this sense, resistance training (RT) is recommended as a nonpharmacological treatment to reduce after-session BP levels, a therapy for primary prevention, treatment, and disease control(1,3).

Hemodynamic and autonomic responses during and after the RT session depend on the manipulation of training variables (exercise selection, sets per exercise, repetitions per set, rest between sets, training volume, intensity, and movement velocity)(4). One study by Nery et al.(5) demonstrated significantly higher BP levels in 40% 1-repetition maximum (RM) compared to 80% 1-RM when performed until muscle failure. In contrast, Vale et al.(6) compared different intensities (6RM vs. 15RM) and did not show differences in systolic (SBP) and diastolic BP (DBP) values. However, lighter loads (15-RM) induced acute increases in cardiac sympathetic activity after the session, which could be related to more significant cardiovascular stress. Alongside intensity, training volume is another critical RT variable. McCartney et al.(7) demonstrated that higher RT volumes induce higher BP levels. Moreover, Lamotte et al.(8) showed that lower BP values were observed with longer rest intervals (90s and 120s). On the other hand, Figueiredo et al.(9), comparing different volumes, showed that the highest volume (5 sets) promoted significant reduction after RT in BP and parasympathetic activity when compared to lower volumes (1 and 3 sets). Different set configurations may result in distinct hemodynamic and autonomic responses(5-9).

Work-to-rest ratio (W: R) is an approach to analyze the relation between work and rest, leading account intensity, volume, and rest. W: R is obtained by dividing the total work (set x reps x weight) by the total resting time (number of rest intervals x interval duration)(11,12). Thus, Paulo et al.(12) compared different structures of rest intervals and the number of repetitions per set on BP response during protocols among equated and non-equated W: R. The results demonstrated that 9x 5:22s protocol induced a lower increase in BP compared to 3x 15:88s protocol, suggesting that short sets induce lower cardiovascular stress during execution. Furthermore, the protocol 9x 5:22s induced lower SBP values in comparison with 45 45 x1:4s protocol, demonstrating that set duration is not the only factor that promotes influences in cardiovascular responses. Therefore, it is still necessary to understand the influence of different set configurations equalized by the W: R ratio on cardiovascular responses.

Thus, the present systematic review investigated the influence of different set configurations with W: R equated on hemodynamic and autonomic responses during and after acute RT.

MATERIALS AND METHODS

Inclusion criteria: randomized controlled trials; scientific articles published in English between 2012 and 2019; adult participants (≥18 years old); resistance training intervention; detailed work-to-rest ratio description. Bibliographic databases were: Periodicals Capes Portal, PubMed, Medline, LILACS, Cochrane library, Scopus, and Google Scholar. The search keywords were: "work to rest ratio" AND "resistance training" OR "strength training," and papers that included an analysis of BP and heart rate variability (HRV) were selected. The exclusion criteria were: studies with aerobic training or that did not describe the W:R control. Six reviewers individually evaluated the titles and abstracts of retrieved articles (REIS, CBF; PEREIRA, PTVT; ABREU, LP; MELLO, I. A.; and LEITE, TG) to assess their eligibility for review. Any disagreements were resolved by consensus by a sixth reviewer (LEITE, RD). Finally, three authors reviewed the final manuscript (MIRANDA, H.; IGLESIAS-SOLER, E.; and LEITE, RD). To assess the methodological quality of the studies, we used the PEDro scale [13,14].

After reading and selecting the articles, the characteristics of the sample, the country where the study was conducted, a description of the exercise protocols, training status, gender, hemodynamic and autonomic assessment methods, and variables collected were extracted.

RESULTS

Our initial research identified 1.565 studies based on the descriptor "work-to-rest ratio". After the title and summary review, 1.514 studies were excluded, which did not detail the W:R control in RT or investigate high-intensity interval training. After reading 51 full-text papers, 21 were duplicates, and 25 did not detail the W:R or did not analyze BP and/or autonomic nervous system response. Five studies remained for systematic review (Figure 1). The methodological quality of the studies classified by the PEDro scale is presented in Table 1. In addition, Table 2 presents the characteristics of the studies included in the review. The quality of the study's data is described in Table 1.

Figure 1: Flow diagram of the search process

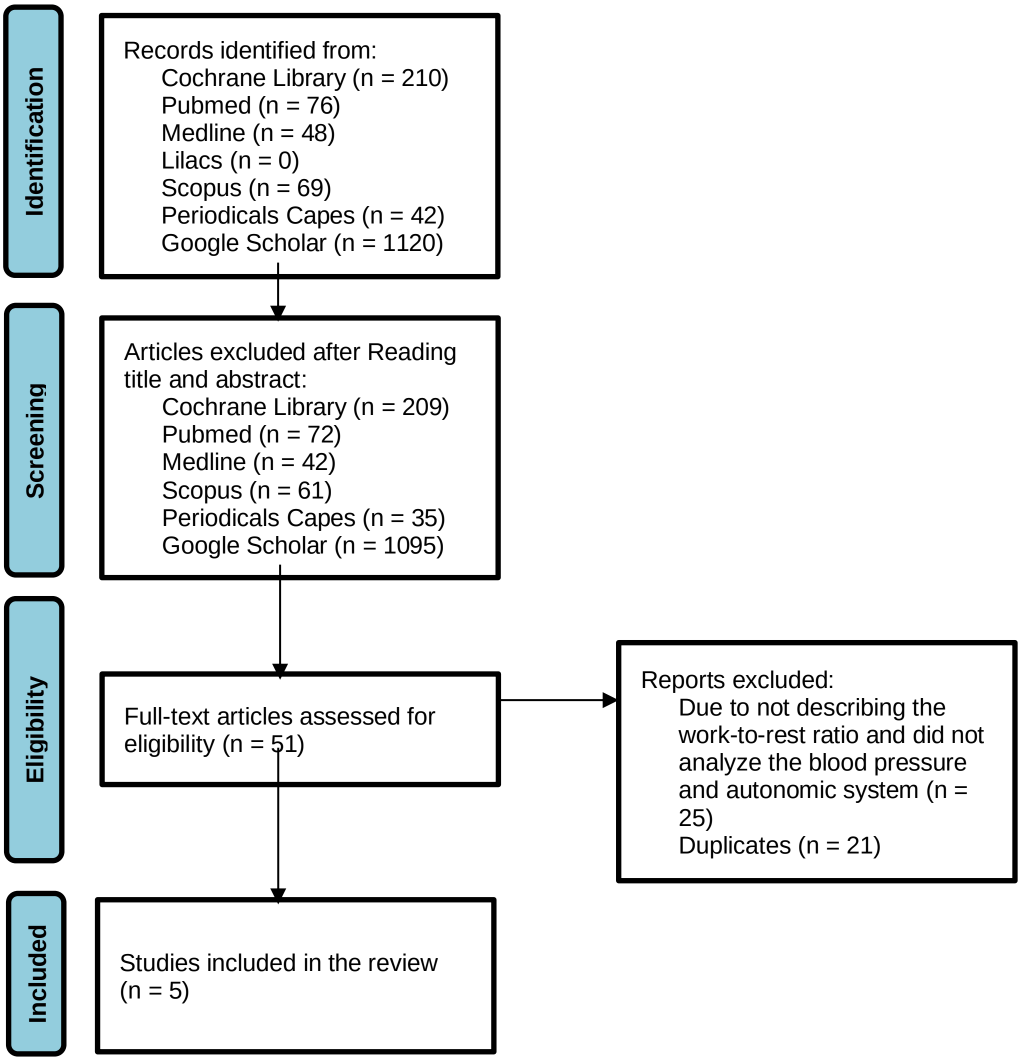

Table 1: PEDro scale item scores and total scores for all included studies

Studies	Item No.											Total Score
	1[a]	2	3	4	5	6	7	8	9	10	11	
Paulo et al.[12]	Specified	1	1	1	1			1	1	1	1	8/10
Rio-Rodriguez et al.[15]	Specified	1	1	1	1			1	1	1	1	8/10
Mayo et al.[16]	Specified	1	1	1				1	1	1	1	7/10
Mayo et al.[17]	Specified	1	1	1	1			1	1	1	1	8/10
Iglesias-Soler et al.[18]	Specified				1			1	1	1	1	5/10

Table 2: Characteristics of included studies

Study and country	Participants and Training status	Resistance training protocol and exercise	Hemodynamic and autonomic evaluation
Paulo et al.[12] (Brazil)	Female (n=10; 24.6±5 years) Male (n=10; 26.3±3 years) Untrained	**High work-to-rest** (non-equated - 45reps:88s) 3 sets x15 reps:44seconds/ Load: 20-RM **Low work-to-rest** (equated - 45reps:176s) Three sets x 15 reps:88 seconds/ Load: 20-RM **Low work to rest** (equated - 45reps:176s) Nine sets x 5 reps:22 seconds/ Load: 20-RM **Low work to rest** (equated - 45reps:176s) 45 sets x 1 reps:4 seconds)/ Load: 20-RM Dynamic Leg Extension	**Finger Photoplethysmography Measure:** • **Pre, during (after each set), and immediately post** **Variables:** • **SBP, DBP, HR, and RPP**
Rio-Rodriguez et al.[15] (Spain)	Male (n=11; 21.0±2 years) Physically active	**Traditional set configuration (TT)** 4 sets of 80% TTF duration:180s/Load: 50% MVC **Intra-set rest configuration (IST)** 16 sets of 20% TTF duration:36s/ Load: 50% MVC Isometric Leg Extension	**Finger Photoplethysmography Measure:** • **Pre, during (continuum), and immediately post** **Variables:** • **SBP, DBP, MAP, HR, and RPP.** • **HRV (iRR; LF; HF, and LF/HF)**
Mayo et al.[16] (Spain)	Male (n=13; 23±3 years) Resistance training experience (at least six months)	**Failure session:** 5 sets x until failure 720s/ load: 10-RM **Inter-repetition rest:** Same number of repetitions (Failure session)/ 720 seconds distributed between each repetition); Load: 10-RM Dynamic Bench Press and Parallel Squat	**Portable cardiac monitor (RS 800 CX polar®) and oscilometric device (Omron® MIT elite plus)** **Measure:** • **Basal and post (until 40 minutes)** **Variables:** • **SBP and DBP** • **HRV (HF; LnHF/iRR)**

Mayo et al.[17] (Spain)	Female (n=5) / Male (n=12; 23±3 years) Resistance training experience (at least six months)	Five sets x 8 reps/ Interval rest: 3 minutes/ load: 10 RM load (40 reps:720s) Ten sets x 4 reps/ Interval rest: 80 seconds/ load: 10 RM load (40 reps:720s) 40 sets x 1rep/ Interval rest: 18.5 seconds/ load: 10 RM load (40 reps:720s) Dynamic diagonal sled-type Leg Press machine	**Finger Photoplethysmography Measure:** • **Basal and post (until 40 minutes).** **Variables:** • **SBP, DBP, and MAP** • **HRV (RMSSD, LnHF, LnLF, LnLF/HF, and LF(nu))**
Iglesias-Soler et al.[18] (Spain)	Male (n=10; 23±4 years) Experienced judo Fighter (at least 18 months of experience in RT)	**Traditional training (TT):** 3 sets x until failure reps/ Interval rest: 3 minutes/ load: 4-RM. **Cluster training (CT):** Same number of repetitions (traditional resistance training)/ 360 seconds distributed between each repetition); load: 4-RM. Dynamic Squat	**Sphygmomanometer and phonendoscope/ memory belt (Suunto ltd.) Measure:** • **Basal, during, and post** **Variables:** • **SBP, HR, and RPP** • **HRV (SDNN, RMSSD, LnLF; HF; LnLF/HF; LF(nu); HF(nu)).**

Reps: repetitions; TTF: time to task failure; MVC: maximal voluntary isometric contraction; SBP: systolic blood pressure; DBP: diastolic blood pressure; MAP: mean arterial pressure; HR: heart rate; RPP: rate pressure product; HRV: heart rate variability; iRR: RR interval; LF: low-frequency; HF: high-frequency; LF/HF: LF/HF ratio; RMSSD: Root mean square of successive RR interval differences; LnLF: natural logarithm LF; LnHF: natural logarithm HF; LnLF/HF: natural logarithm LF/HF; LnHF/iRR: natural logarithm of HF divided by the squared mean R-R interval; SDNN: Standard deviation of NN intervals.

Paulo et al.[12] compared non-equated (High W:R: 45reps:88s) and equated (Low W:R: 45reps:176s) protocols and observed that HIGH$_{W:R}$3X15:44s and LOW$_{W:R}$3X15:88s protocol induced similar SBP and HR increase. The equated protocols analysis demonstrated that LOW$_{W:R}$9X5:22s protocol led to smaller SBP and DBP increases than LOW$_{W:R}$3X15:88s and LOW$_{W:R}$45X1:4s protocols. The LOW$_{W:R}$45X1:4s protocol caused greater SBP and DBP increases than LOW$_{W:R}$9X5:22s.

Rio-Rodriguez et al.[15] observed significant HR and rate pressure product (RPP) increases during exercise. Both protocols, traditional set (TT) (pre: 66±13 bpm; during 108±14 bpm) and intra-set rest configurations (IST) (Pre: 66±14 bpm; During 88±15 bpm), induced HRmean increases compared to baseline values. After protocols, only the IST protocol HRmean returned to baseline values (Pre: 66±14 bpm; Post: 66±13 bpm). In contrast, HRmean did not return to baseline values (Pre: 66±13; Post: 75±12) after the TT protocol. RPP values increased significantly during exercise compared to baseline for TT (Pre: 5.928±1.233 mmHg.bpm; During: 12.425±1.841 mmHg.bpm) and IST (Pre: 5.629±1.411 mmHg.bpm; During: 9.007±1.739 mmHg.bpm) protocols. TT protocol led to significantly higher RPP values compared to IST. In both protocols, there was an increase in SBP, DBP, and MAP values compared to the baseline, but no statistical difference was observed.

The HF index decreased significantly in the TT protocol (Pre: 6.62±1.13; Post: 5.87±0.95) and remained lower after exercise compared to the IST protocol (Pre: 6.48±1.11; Post: 6.79±1.21). On the other hand, there was no statistical difference between TT (Pre: 7.06±0.90; Post: 6.80±0.71) and IST (Pre: 6.91±0.64; Post: 7.28±0.89) protocols for the LF index.

Mayo et al.[16] demonstrated no differences in LnHF baseline values between exercises (Squat and Bench Press). However, lower LnHF values were observed for squat exercise compared to bench press and baseline. Failure protocol caused significantly lower values compared to Pre and Control protocol. In the Inter-repetition rest protocol, squat LnHF values were significantly lower than bench press exercise. When comparing exercises, both Failure and Inter-repetition rest protocols presented lower LnHF values than the control session in the squat exercise. For the bench press, lower LnHF values were observed in the Failure protocol than Control and Inter-repetition rest protocols. In addition, SBP and DBP values decreased significantly in the failure protocol compared to the control up to 40 minutes after the session.

Mayo et al.[17] demonstrated that LnRMSSD values remained significantly lower compared to Pre up to 40 minutes (Pre: 4.18±0.37 *vs.* Post: 3.79±0.55), and control group (post control: 4.16±0.5 vs. 5x8:720s: 3.79±0.55) for 5x8:720s protocol. In addition, the 10x4:720s protocol induced significant reduction up to 25-30 minutes compared to Pre (Pre: 4.1±0.53 *vs.* Post:3.77±0.54) and control (10x4:720s: 3.77±0.54 *vs.* Control: 4.14±0.47). Furthermore, the 10x4:720s protocol significantly decreased post-exercise LnRMSSD compared to the 40x1:720s protocol within 25-30 minutes (10x4:720s protocol: 3.77±0.54 *vs.* 40x1:720s protocol: 3.96±0.52).

LnHF post-exercise values were significantly lower than Pre values for the 5x8:720s (Pre: 7.11±0.73; 30-35min: 6.19± 1.06) and 10x4:720s (Pre: 6.96±1.08; 30-35min: 6.3±1.06) protocols. The 5x8:720s protocol was significantly shorter post-exercise than the control session within 30-35 minutes (5x8:720s: 6.19±1.06; Control: 6.99±1.1). In addition, lower LnHF values for the 10x4:720s protocol were observed compared to control up to 25-30 minutes (10x4:720s: 6.21±1.14; Control: 6.98±0.96) and Pre value (6.96±1.08), remaining up to 30-35 minutes (6.3±1.06).

For LnLF, the 10x4:720s protocol led to lower values compared to control up to 20-25 minutes (10x4:720s: 6.77±0.92; Control: 7.51±0.82) and compared to 40x1:720s protocol up to 25-30 minutes (10x4:720s: 6.75±1.03; 40x1:720s: 7.27±0.82). Ln LF/HF and LF (nu) showed no significant behavior. For SBP, DBP, and MAP, the hypotensive effect was not observed up to 40 minutes in any protocol.

Iglesias-Soler et al.[18] observed a significant increase in SBP, HR, and RPP since set 2 and set 3, with higher values in the traditional training (TT) protocol when compared to the cluster training (CT) protocol. TT and CT protocols caused post-exercise reductions in LnSDNN, LnRMSSD, LnLF, and HF (ms^2).

DISCUSSION

This review aimed to present studies that analyzed the influence of different set configurations with equated W:R on hemodynamic and autonomic responses during and after acute RT. Different exercise prescription configurations (volume, intensity, interval, and contraction velocity) equated in W:R during acute RT sessions may influence distinct hemodynamic and autonomic behaviors.

Our results indicate that extended set configuration (traditional set) protocol can induce a significant increase in hemodynamic and cardiovascular response during exercise when compared to short set configuration both in isotonic[18] and isometric exercise[15] independent of W:R equated. The mechanisms behind hemodynamic and cardiovascular increases during extended set configuration may be related to vasoconstriction, which reduces oxygen (O_2)

bioavailability, causing local hypoxia and ischemia, increasing metabolic stress[19]. Furthermore, as local metabolites increases, sensory organs (chemoreceptors, mechanoreceptors) located in the muscle will promote a significant afferent adjustment for ANS, augmenting peripheral sympathetic activity and reducing parasympathetic (vagal) activity during exercise [19]. In this sense, Rio-Rodriguez et al.[15] and Iglesias-Soler et al.[18] showed that extended set configuration or traditional set protocol induced more significant vagal withdrawal and increased BP [15,18].

The studies demonstrated no hypotensive response after training. Nevertheless, Mayo et al.[16] showed that muscle failure protocols led to significantly lower SBP and DBP values than Inter-repetition rest after RT sessions. However, no significant reduction was observed in comparison to the baseline. A possible explanation for these events is a long time under tension, resulting in higher metabolites and nitric oxide (NO) concentration, leading to greater post-exercise vasodilation and hypotensive response[16]. However, Rúa-Alonso et al.[20] also recently observed no hypotensive effect in different protocols. On the other hand, HR remained higher after long and short-set configuration protocols. However, the values in the extended set configuration (4x 10:120s) were higher than in the short set configuration (8x 5:51s), suggesting a slower parasympathetic reactivation.

In this sense, our brief review studies that analyzed the autonomous control showed that long-set configuration induced greater vagal withdrawal than short-set configuration due to higher participation glycolytic metabolism[12, 13]. Recently, Rúa-Alonso et al.[20] observed the same behavior, where longer sets induce greater vagal withdrawal than shorter sets. In addition, Mayo et al.[16] observed that exercise with a large muscle (squat exercise) induces a significant reduction of cardiac vagal modulation when compared to exercise with a small muscle (bench press exercise). This response may be related to the amount of recruited muscle mass, the glycolytic pathway, and lactate concentration. Furthermore, high lactate concentration can negatively affect ANS recovery[16]. However, this review has some limitations that need to be acknowledged. First, all studies included in the present study evaluated acute responses, which is necessary to investigate chronicle responses. Furthermore, the sample was composed of young people with different training status and without any disease.

CONCLUSIONS

When W:R is equated between different set configurations, sets with longer TUT appear to induce greater hemodynamic response and vagal withdrawal during and after the session. In addition, inserting short rest between repetitions can be an interesting strategy to promote lower cardiovascular stress.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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