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The Effects of Active Versus Passive Interset Rest Intervals in the Bench-Press Exercise in Resistance-Trained Men: A Randomized Crossover Study

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Purpose: Interset rest (ISR) is a variable of resistance training (RT) that has received limited attention and focused mainly on the length of the ISR rather than examining the effects of different stimuli when using the same ISR duration. The aim of this study was to compare the effects of 2-minute passive (PAS) or active ISR (ACT) on intraset velocity loss, blood lactate concentrations, and rating of perceived exertion during bench press in resistance-trained men. ***Methods:*** Fourteen participants (23.64 [2.02] y, 82.79 [10.74] kg, 181.50 [7.02] m, maximal power in bench press 660 [113] W) completed 2 RT sessions of 5 × 8 repetitions at maximal velocity using individual optimal load for maximal power output with 2-minute PAS or ACT ISR. During the ACT, participants completed repetitions of vertical chest press at 5% to 10% 1-repetition maximum at a controlled velocity. The intraset velocity loss was measured using a lineal encoder, and blood lactate concentrations and rating of perceived exertion before and after each set were registered. ***Results:*** Intraset velocity loss was lower in ACT compared with the PAS protocol, without statistically significant differences ($P = .571$). Blood lactate concentrations increased across the session for both ISR protocols, but this increase was diminished in ACT compared with PAS, without statistical meaning ($P > .05$). ***Conclusions:*** Continuing to perform the same activation during rest intervals was well-tolerated and may reduce the loss of performance due to accumulated workload throughout an RT session, suggesting that ACT may trigger a metabolic advantage in exercise performance for consecutive sets during an RT bout.

Keywords: strength, recovery, resistance training

Resistance training (RT) has become an integral part of almost all guidelines for physical activity recommendations of the principal international health and fitness organizations.[1] RT is widely practiced by athletes in various fields of sport and by the general population, and extensive research has been conducted into its many health benefits.[2] Specifically, RT is known to be particularly beneficial in improving skeletal-muscle mass, strength, power, and endurance at all stages of life.[3] However, to achieve the desired objectives from an RT program, each variable should be designed properly.

When designing RT sessions, coaches and fitness trainers must define and adjust key variables, as those proposed by the American College of Sports Medicine's FITT-VP model (ie, frequency, intensity, time, type, volume, and progression), as these determine individual physiological responses to training. A 1988 study by Fleck and Kraemer[4] noted that interset rest (ISR) is an aspect that has received scant attention in research into optimal RT methods.[4] Later on, other authors have called for greater research into ISR[5] given its importance for hormonal and metabolic response and the intensity of output during RT sessions.[6] In addition, most studies in this area have focused on the length of the ISR period[7] rather than the effects of different modes of exercise and/or methods when using the same interval length.

A systematic review by Latella et al[8] of 26 controlled clinical trials investigating different rest strategies between sets in RT concluded that active ISR (ACT; eg, dynamic stretching, aerobic exercise, vibration) can improve acutely strength performance. ISR period should not be viewed as a period of passive rest but as a time of recovery, and then, athletes and coaches should apply activities that maximize recovery between work bouts for a given purpose.[9] In particular, ISR should allow the maximum restoration of phosphagen system (adenosine triphosphate [ATP] and phosphocreatine [PCr], ATP-PCr) to increase strength performance during successive sets in a RT session,[10] and oxygen is required to resynthesize PCr[11]; thus, ACT may improve this metabolic pathway.

In this vein, one of the approaches to the problem when using ACT could be to use the same movement as the evaluated exercise. Valenzuela et al[12] compared the effects of 2 ACT protocols with the same duration (2 min) on performance in several sets of indoor climbing, finding that continuing to climb at a lower intensity during ISR allowed maintaining performance in successive sets of ascents compared with walking during ISR. Scudese et al[13,14] analyzed the effects of ACT and passive ISR (PAS), both 2 minutes, in upper- and lower-body exercises (bench press and squat, respectively), using the same movements in the ACT protocol as those assessed during the RT session, but with low load (arms weight for bench press exercise and body weight when exercising squats). The

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authors found no significant differences between ACT and PAS strategies in the maximal number of repetitions completed to muscle failure, and a greater rate of perceived exertion (RPE) for the ACT protocol.[13,14] However, Berlanga et al[10,15] found that ACT using the same exercise reduces intraset power loss compared with PAS of equal length interval (2 min), without finding significant changes in RPE. However, the heterogeneity of both the training protocols and the measured outcomes makes it difficult to extract practical applications.

Thus, the aim of this study was to compare the acute effects of ACT versus PAS ISR on intraset velocity loss, blood lactate concentrations, and RPE during bench press exercise in resistance-trained males. Thus, we hypothesized that ACT will decrease the loss of performance across the sets when exercising in bench press.

Methods

Subjects

Fourteen advanced resistance-trained males[16] participated in this study (age: 23.64 [2.02] y, body mass: 82.79 [10.74] kg, height: 181.50 [7.02] m, 5.54 [0.32] y of RT experience, 1-repetition maximum [1RM] in bench press: 95.26 [18.77] kg, and maximal power in bench press: 660 [113] W). All volunteers had at least 5 years of RT experience, performing RT sessions at least 3 times per week. Their 1RM in bench press was at least equal to their body mass, and none had any injuries or contraindications to perform physical exertions. All participants were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study, and all procedures were in accordance with the Code of Ethics of the World Medical Association and the Declaration of Helsinki. All data was processed and handled in accordance with the Data Protection Act, and the study was approved by our research ethics committee (UFV42/2018).

Design

A randomized crossover study was developed to compare the effects of ACT versus PAS ISR during bench-press exercise, both lasting the same interval duration (2 min). This ISR interval was selected to avoid that duration on its own could allow the restoring metabolic substrates used during consecutive sets, as has been previously demonstrated.[17] All participants were instructed to maintain their usual lifestyle habits in terms of physical exercise, hydration, and diet. They were, however, instructed to avoid caffeine or any other stimulants or ergogenic aids at least 12 hours before measurements as well as any upper-limb training 72 hours prior to each session in our laboratory.

Methodology

Each volunteer visited our laboratory 3 times. In the first visit, we conducted a mean maximal power (P_{max}) test for bench press on a Smith machine (Evolution Deluxe Smith Machine and Rack, Titanium Strength) following the protocol described in other studies.[15,18] Briefly, incremental P_{max} test included sets of 1×3 at maximal velocity for the concentric phase starting with a load equivalent to the 30% of 1RM estimated by each participant for the bench press exercise (24.23 [4.25] kg), increasing the load by 10% in each of the sets performed until we obtained P_{max} value confirmed with lower power values in, at least, the next 2 sets, with 5-minute passive rest between each set. After the P_{max} test, we measured a 1RM in vertical chest press after 5 minutes of passive rest (Compact C01, Bodytone) to determine the load to be used during the ACT protocol, where all subjects were able to complete between 2 and 6 repetitions until muscle failure; we then calculated 1RM using the Brzycki equation.[19] These evaluations began with a 5-minute warm-up of moderate cardiovascular activity followed by joint mobility exercises for upper limbs and a 5-minute passive rest. As specific warm-up before the P_{max} test, participants completed 1×10 in bench press using the Smith machine without any added load (bar weight was 21 kg) at a 2-second velocity of execution in the concentric phase and 2 seconds in the eccentric, followed by 5-minute passive rest, and 1×3 at 20% of 1RM estimated at maximal velocity for the concentric phase.

The next 2 sessions were held less than 72 hours apart. During each session, the warm-up was the same as the first day. For the PAS protocol, participants completed 5×8 at maximal velocity using the individual optimal load for P_{max} (OptLoad P_{max}, range between 40–60 kg), with a 2-minute passive rest between each set remaining seated on the bench (Figure 1). For ACT, the protocol was the same but with a 2-minute active rest (30 s of transition after each set and before starting the next set and 60 s of exercise), performing 15 repetitions in vertical chest press with 5% to 10% 1RM at a velocity marked by a metronome (2 s for the concentric phase and 2 s for the eccentric phase; Metronome Beats 5.0.1; Figure 1). Eight repetitions for each set was selected to be able to analyze more clearly intraset velocity loss, and 2 minutes between each set was defined following others similar trials.[10,15]

The mean propulsive velocity (MPV) for each repetition was measured using a lineal encoder (Chronojump), with a sampling rate of 1000 Hz, and using data analysis software (Chronojump 1.9.0). This device was previously validated as a tool to measure load displacement velocity on a Smith machine.[20] MPV intraset loss was calculated as the difference between the mean values for the first 2 repetitions and the mean values for the last 2 repetitions in each set.[21] A linear relationship was assumed for the MPV across all repetitions within a set.

Blood lactate concentrations (Lact) were obtained from finger-prick test using a portable analyzer (Lactate Pro 2, Busimedic) before and after each set (Lact Pre- and Lact Postsets 1, 2, 3, 4, and 5, respectively) and 1, 3, and 5 minutes after the last set (Lact Post 1, 3, and 5, respectively).

An OMNI-RES scale from 0 to 10 points was used to register RPE.[22] The RPE was registered at the end of each set (RPE 1–5, respectively) and 1, 3, and 5 minutes after the last set (RPE Post 1, 3, and 5, respectively).

Statistical Analysis

An a priori sample size was calculated with G*Power software (3.1.9.2) using *F* test family for repeated measures considering within-between subjects differences and interaction (5 sets $\times$ 2 ISR protocols).[23] In addition, an alpha error probability of .05, a power ($1-\beta$ error probability) of 0.80, and a large effect size[24] were considered. Thus, a total sample size of 10 participants was necessary, and considering a possible loss in follow-up, a sample size of 14 participants was recruited. Normality was confirmed for each outcome using a Shapiro–Wilk test, and a Levene's test was conducted to verify homoscedasticity. A 2-way analysis of variance for repeated measures and Bonferroni post hoc was used to compare related changes to each ISR protocol (ACT vs PAS) and interaction between sets for MPV, MPV intraset loss, Lact, and RPE. To examine the magnitude of such differences, effects sizes between mean scores with both ISR protocols were calculated. Effects sizes in strength training research proposed by Rhea[25] for

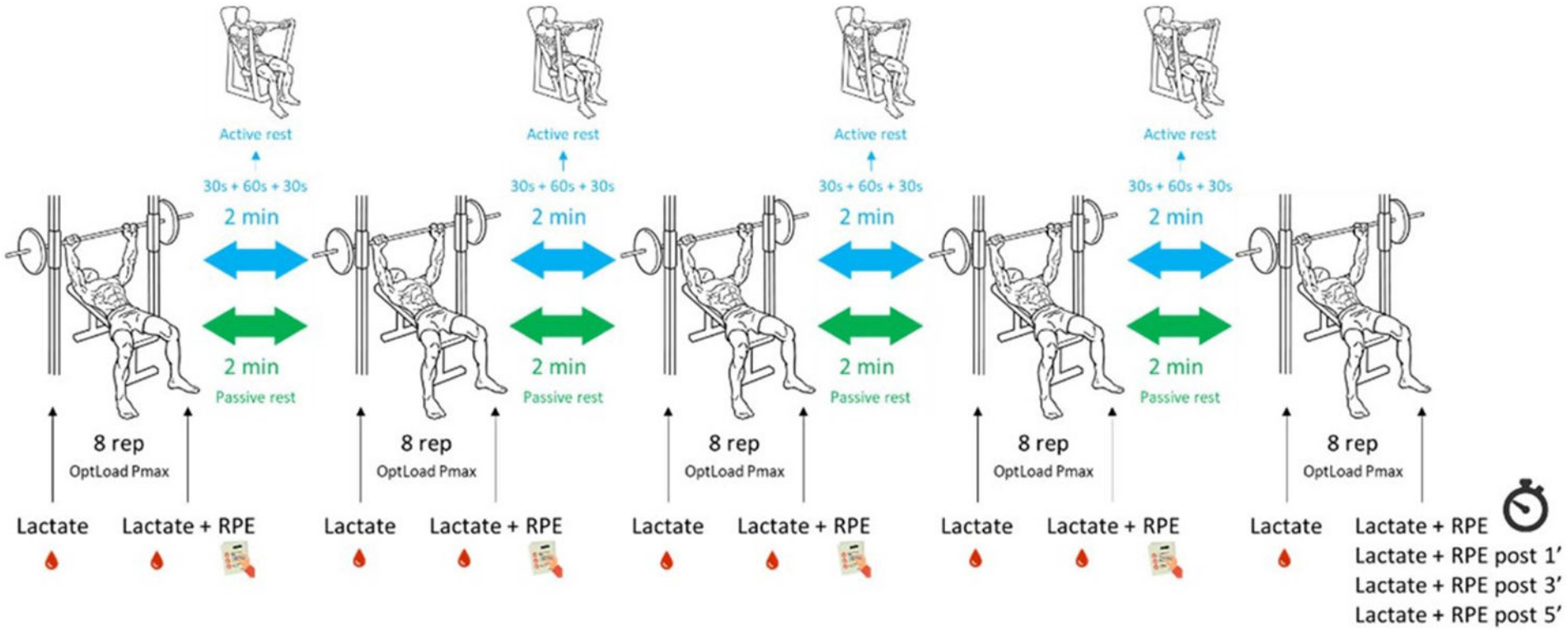

Figure 1 — Experimental design. OptLoad P_{max} indicates optimal for maximal power output; RPE, rating of perceived exertion.

highly trained individuals (training for at least 5 y) were considered: trivial < 0.25, small 0.25–0.50, moderate 0.50–1.00, and large > 1.00. Statically significance was fixed at $P \leq .05$ with a CI of 95%. All data were analyzed using SPSS (version 20), and all values are expressed as mean (SD) in the text, tables, and figures.

Results

ACT protocol showed a higher MPV from the second set onward, with no statistically significant differences between protocols ($P = .511$). In addition, MPV intraset loss was lower in ACT than the PAS protocol without statistically significant differences ($P = .571$; Table 1). A supplementary table (Supplementary Table S1 [available online]) has been included to offer a more detailed perspective on interindividual variability.

The intragroup analysis of blood lactate during ISR, that is, blood lactate concentrations at the end of each set and before starting the subsequent set (ie, Lact Postset 1 vs Lact Preset 2; Lact Postset 2 vs Lact Preset 3; and so on), showed a statistically significant difference for both protocols but always with a lower increase (percentage of change) for ACT protocol compared with PAS, and a larger effect size was also observed for PAS protocol compared with ACT (PAS vs ACT: moderate vs large for ISR 1, large vs small for ISR 2, moderate vs small for ISR 3, and small vs trivial for ISR 4; Table 2).

From the second set onward, all sets began with lower blood lactate concentrations for the ACT protocol compared with PAS. However, there were no statistically significant differences between protocols (Figure 2).

Regarding RPE, comparison between protocols did not show statistically significant differences neither at the end of each set (PAS vs ACT: 3.71 [1.78] vs 3.21 [1.83], 4.14 [1.76] vs 3.93

Table 1 MPV (m/s) and MPV Loss (%) for Each Set in Both Protocols

	MPV, m/s		MPV intraset loss, %	
Set	Passive	Active	Passive	Active
1	1.191 (0.089)	1.181 (0.111)	11.11 (3.96)	14.15 (8.26)
2	1.165 (0.107)	1.189 (0.094)	17.93 (10.25)	11.10 (3.97)
3	1.174 (0.111)	1.180 (0.099)	16.41 (7.10)	13.75 (5.26)
4	1.178 (0.111)	1.187 (0.105)	14.27 (6.18)	13.79 (6.58)
5	1.161 (0.128)	1.191 (0.103)	13.44 (5.36)	12.37 (4.79)

Abbreviation: MPV, mean propulsive velocity.

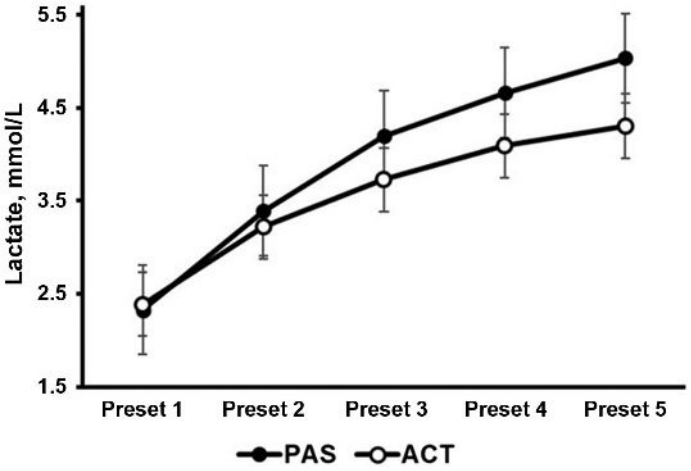

Figure 2 — Blood lactate concentrations before starting each set for both protocols. ACT indicates active; PAS, passive.

Table 2 Comparison of BLa (mmol/L) in Both Protocols

	Passive ISR			Active ISR		
	BLa	Change, %	*d*	BLa	Change, %	*d*
Preset 1	2.329 (0.603)	—	—	2.386 (0.257)	—	—
ISR 1						
Postset 1	2.600 (0.879)	30.50	0.93	2.514 (0.565)	28.12	1.11
Preset 2	3.393 (0.825)*			3.221 (0.707)*		
ISR 2						
Postset 2	3.207 (0.827)	30.96	1.15	3.329 (0.808)	12.02	0.48
Preset 3	4.200 (0.901)*			3.729 (0.848)*		
ISR 3						
Postset 3	3.979 (1.127)	17.23	0.60	3.700 (0.712)	10.62	0.48
Preset 4	4.664 (1.151)*			4.093 (0.933)*		
ISR 4						
Postset 4	4.593 (1.210)	9.64	0.34	4.314 (1.299)	–0.17	–0.01
Preset 5	5.036 (1.378)*			4.307 (0.936)		
Postset 5	4.793 (1.513)	—	—	4.700 (1.508)	—	—
Post 1 min	5.500 (1.590)	—	—	5.343 (1.613)	—	—
Post 3 min	5.286 (1.855)	—	—	4.786 (1.466)	—	—
Post 5 min	4.736 (1.583)	—	—	4.343 (1.151)	—	—

Abbreviations: BLa, blood lactate concentration; ISR, interset rest.
*$P < .05$ (intragroup comparison).

[2.03], 4.59 [1.80] vs 4.61 [2.04], 5.07 [1.81] vs 5.25 [1.81], and 5.68 [1.66] vs 5.57 [2.06]; for sets 1, 2, 3, 4, and 5 respectively; $P = .693$) nor during the recovery period (PAS vs ACT: 4.14 [1.39] vs 3.89 [1.87], 2.54 [1.29] vs 2.50 [1.47], and 1.29 [0.96] vs 1.57 [1.22]; after 1, 3, and 5 min, respectively; $P = .722$).

Discussion

The purpose of this study was to compare the effects of maintaining the same exercise during ISR versus PAS on MPV for each set, MPV intraset loss, blood lactate concentrations, and RPE in advanced resistance-trained males. Our study found that an ACT protocol induced a lower increase in blood lactate concentrations compared with PAS and that within the ACT protocol, participants achieved a moderately greater MPV and a lower MPV intraset loss compared with PAS. However, these differences were not statistically significant.

Previous studies have shown that different ACT strategies during RT exercises may offer greater metabolic and biomechanical advantages in increasing strength performance.[8,12–15,26–32] A systematic review by Latella et al[8] showed that active stimulus during ISR may improve strength performance; however, the authors cautioned that drawing conclusions on the effect of different ISR strategies is difficult given the heterogeneity of the design and methodologies of the studies analyzed.

Other researchers have examined different ACT strategies, including aerobic exercise,[12,26–28] whole-body vibration,[31,32] stretching,[29,30,33] and resistance exercises.[12–15] In our study, participants performed the same activity during ACT as the RT session. This type of experimental approach has not received a great deal of study. Scudese et al[14] analyzed the effects of continuing to perform the same exercise, bench press, during the ISR but using no additional load (arms weight) while training at 4×10RM, and they found that ACT induced more fatigue than PAS with the same duration, but it did not decrease strength endurance performance measured as the maximum number of repetitions performed in the training session. Similar results have been observed in analyzing the effects of ACT during squat exercises and continuing to perform squats with body weight during ISR, finding that active stimulus induced more fatigue but did not decrease strength performance.[13] However, it should be noted, the experimental approaches of both studies differed considerably from our own, as they focused on RT until muscle failure using moderate to high loads (~75% 1RM), and without measuring the velocity of execution during ACT, nor during the exercise session. Furthermore, these studies did not individually quantify the training load corresponding to ACT as we did in the present study, which may entail a different internal load for each participant possibly impairing recovery between sets.

In the same vein, continuing to perform the same exercise, Berlanga et al[10,15] have shown that ACT is effective in increasing MPV of the set and decreasing the percentage of intraset MPV loss in bench press exercise, although the experimental design that these researchers performed (2×8 and the third set until muscle failure) prevents an exhaustive comparison between ACT and PAS since it only presents 2 ISR intervals. In addition, antagonist muscle activation has recently been highlighted as a viable strategy for enhancing acute performance in throwing and other explosive tasks. In line with Pisz et al,[34] exercises targeting antagonist musculature (eg, bent-over row for upper back when the primary action involves the pectoral region) may induce comparable postactivation performance enhancement effects to those observed with agonist-based conditioning. These findings suggest that performing antagonist exercises during active rest intervals may be equally effective as focusing on the agonist thereby alleviating metabolic fatigue while still preserving neuromuscular function.

It has been demonstrated that one of the most important factors in athletic performance is the rate of force development, that is, the ability of the neuromuscular system to increase contractile force as rapidly as possible.[35] From a physiological point of view, maximal power output (P), determined by high values of force (F) and velocity (V; ie, $P = F \times V$), depends primarily on the metabolic pathways in the cell cytoplasm of skeletal muscle, classically known as anaerobic, where we can distinguish the phosphagen system (ATP-PCr) and glycolysis; ATP-PCr being capable of synthesizing ATP most rapidly.[36] Therefore, ISR during RT should allow maximum resynthesis of PCr for greater performance during successive sets. PCr synthesis takes place through aerobic metabolic pathways; thus oxygen is required to restore the phosphagen system during intense physical effort,[11] such as 1 set of RT exercise. Therefore, the use of active rest strategies between sets may facilitate the irrigation of the musculoskeletal tissue, improving the supply of oxygen to muscle cells, leading to the restoration of the phosphagen system and thus enhancing performance in successive sets.[12,26,28,32] Our analysis of blood lactate concentrations suggests that ACT may promote greater PCr resynthesis after each exercise set than passive rest in the same interval time due to lower lactate concentrations found with ACT versus PAS protocol; thus, it may facilitate the use of the faster ATP pathway (phosphagen system vs glycolysis) during RT exercises.

Golas et al[17] compared the effects of different ISR intervals (2, 4, and 6 min) among the maximum number of repetitions performed during 10 sets of the bench press exercise until concentric failure with a load of 60%1RM, demonstrating that 2 minutes reduce volume workload and increase blood lactate concentrations, which may be beneficial to improve strength endurance and glycolytic metabolism. However, this conclusion may not fit with our hypothesis since we were not focused on improving volume workload, but, rather on decreasing intraset loss of velocity. It seems very unlikely that activating the same muscle groups during a short rest interval (ie, 2 min) can enhance neuromuscular performance; nevertheless, we have shown that when using very low load and slow velocity of execution, continuing with the same exercise during ISR may enhance lactate clearance without impairing fatigue as shown by the same values in RPE for both ISR protocols.

Other possible mechanism to decrease intraset MPV loss with an ACT protocol during ISR may be the increase and maintenance of muscle temperature that has been shown to enhance neural transmission and muscle compliance, which may influence on mechanical efficiency during successive sets in a RT exercise; as highlighted by Mohamad et al,[9] who analyzed the effects of 90 seconds of cardiovascular exercise versus PAS to improve force and power during an RT session with different training loads (70% 1RM or 35%1RM), demonstrating that ACT may enhance neuromuscular performance when using high loads (ie, 70%1RM).

There were no significant differences in RPE between protocols, despite the greater blood lactate concentrations for PAS compared with ACT. This is in line with the findings of Hiscock et al,[37] which suggest that RPE may not be related to blood lactate concentrations. However, our findings are contrary to those of Scudese et al[13,14] who reported an increase in levels of fatigue in ACT.

Nowadays, most RT programs include passive rest periods between sets. However, there is solid evidence that corroborates the

benefits of including active stimuli during the ISR. Some of the benefits that have been demonstrated with this type of strategy are greater efficiency in neural transmission and muscle compliance, maintenance of muscle temperature, greater metabolic efficiency for ATP synthesis, and increased energy expenditure during a RT session. However, the heterogeneity of the studies in this vein, and the wide range of possibilities for including active stimuli during ISR (ie, type of exercise, intensity, etc.), make it difficult to extract practical approaches that athletes and coaches can include in their training programs.

While this study provides valuable insights, it is not without certain limitations that should be considered. First of all, it is related to our acute design, which only captures immediate effects of ACT versus PAS intervals, and does not address potential long-term, or chronic adaptations. Furthermore, because muscle temperature was not measured, any influence of this parameter on velocity loss, fatigue, or recovery remains unknown. Lacking these data may limit a more comprehensive understanding of the physiological mechanisms underlying the performance outcomes observed in this research. In addition, since the differences between PAS and ACT were not statistically significant, further research is needed to determine the optimal training load that should be used during ACT ISR to enhance recovery between successive sets in an RT session. Finally, although we have calculated the sample size a priori, future studies may consider investigating the effects of ACT intervals based on the same movement in larger and different samples (ie, women, untrained, etc).

Conclusions

According to our findings, continuing with the same exercise during interset rest intervals in resistance training was feasible and did not elevate perceived fatigue among participants. While active rest showed a slight tendency to reduce velocity loss within each set compared with passive rest, these differences were not statistically significant. These findings imply that a low-intensity active interset-rest protocol can be adopted without compromising overall performance or perceived exertion, although it offers no decisive advantage in mitigating performance decline. Nonetheless, it may help maintain muscle activation and could enable a higher training volume to be achieved when repetitions are prescribed to be completed up to a certain percentage of intraset velocity loss. Coaches could therefore consider including such protocols as an alternative component of resistance-training programs.

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References

1. World Health Organization. *WHO Guidelines on Physical Activity and Sedentary Behaviour*. 2020.
2. Kraemer WJ, Ratamess NA, Flanagan SD, Shurley JP, Todd JS, Todd TC. Understanding the science of resistance training: an evolutionary perspective. *Sports Med*. 2017;47(12):2415–2435. doi:10.1007/s40279-017-0779-y
3. Westcott WL. Resistance training is medicine: effects of strength training on health. *Curr Sports Med Rep*. 2012;11(4):209–216. doi:10.1249/JSR.0b013e31825dabb8
4. Fleck SJ, Kraemer WJ. Resistance training: basic principles (part 1 of 4). *Phys Sportsmed*. 1988;16(3):160–171. doi:10.1080/00913847.1988.11709461
5. de Salles BF, Simão R, Miranda F, da Silva Novaes J, Lemos A, Willardson JM. Rest interval between sets in strength training. *Sports Med*. 2009;39(9):765–777. doi:10.2165/11315230-000000000-00000
6. Bird SP, Tarpenning KM, Marino FE. Designing resistance training programmes to enhance muscular fitness: a review of the acute programme variables. *Sports Med*. 2005;35(10):841–851. doi:10.2165/00007256-200535100-00002
7. Senna GW, Willardson JM, Scudese E, et al. Effect of different interset rest intervals on performance of single and multijoint exercises with near-maximal loads. *J Strength Cond Res*. 2016;30(3):710–716. doi:10.1519/JSC.0000000000001142
8. Latella C, Grgic J, Van Der Westhuizen D. Effect of interset strategies on acute resistance training performance and physiological responses: a systematic review. *J Strength Cond Res*. 2019;33(1):S180–S193. doi:10.1519/JSC.0000000000003120
9. Mohamad NI, Cronin JB, Nosaka KK. The effect of aerobic exercise during the interset rest periods on kinematics, kinetics, and lactate clearance of two resistance loading schemes. *J Strength Cond Res*. 2012;26(1):73–79. doi:10.1519/JSC.0b013e31821bf1f5
10. Berlanga LA, Matos-Duarte M, López-Chicharro J. Effects of active vs. passive interset rest among physiological and perceptual outcomes in bench press exercise. *Sci Sports*. 2023;38(3):302–309. doi:10.1016/j.scispo.2022.03.010
11. Harris RC, Edwards RHT, Hultman E, Nordesj LO, Nylind B, Sahlin K. The time course of phosphorylcreatine resynthesis during recovery of the quadriceps muscle in man. *Pflugers Arch*. 1976;367(2):137–142. doi:10.1007/BF00585149
12. Valenzuela PL, de la Villa P, Ferragut C. Effect of two types of active recovery on fatigue and climbing performance. *J Sports Sci Med*. 2015;14(4):769–775. PubMed ID: 26664273
13. Scudese E, Brandão PB, Senna GW, et al. Active vs. passive inter-set recovery in lower limbs strength performance. *J Exerc Physiol Online*. 2018;21(5):39–48.
14. Scudese E, Senna GW, Scartoni FR, Simão RF. A influência de diferentes recuperações entre as séries no treinamento de força. *Rev Bras Ciênc Mov*. 2011;19(2):70–77.
15. Berlanga LA, Matos-Duarte M, López-Chicharro J. Efectos de la recuperación activa versus pasiva en press de banca. *Apunts*. 2021;10(145):17–24. doi:10.5672/apunts.2014-0983.es.(2021/3).145.03
16. Santos Junior ERT, De Salles BF, Dias I, Ribeiro AS, Simão R, Willardson JM. Classification and determination model of resistance training status. *Strength Cond J*. 2021;43(5):77–86. doi:10.1519/SSC.0000000000000627
17. Golas A, Stronska K, Krzysztofik M, Maszczyk A, Stastny P, Zajac A. The influence of rest interval on total training load during 10 sets of the bench press exercise performed to concentric failure. *Med Sport*. 2019;72(2):3445. doi:10.23736/S0025-7826.19.03445-8
18. da Silva BVC, de Moura Simim MA, Marocolo M, Franchini E, da Mota GR. Optimal load for the peak power and maximal strength of the upper body in Brazilian Jiu-Jitsu athletes. *J Strength Cond Res*. 2015;29(6):1616–1621. doi:10.1519/JSC.0000000000000799
19. Brzycki M. Strength testing—predicting a one-rep max from reps-to-fatigue. *J Phys Educ Recreat Dance*. 1993;64(1):88–90. doi:10.1080/07303084.1993.10606684
20. Pérez-Castilla A, Piepoli A, Delgado-García G, Garrido-Blanca G, García-Ramos A. Reliability and concurrent validity of seven commercially available devices for the assessment of movement velocity at different intensities during the bench press. *J Strength Cond Res*. 2019;33(5):1258–1265. doi:10.1519/JSC.0000000000003118

21. Rial-Vázquez J, Mayo X, Tufano JJ, Fariñas J, Rúa-Alonso M, Iglesias-Soler E. Cluster vs. traditional training programmes: changes in the force–velocity relationship. *Sports Biomech*. 2022;21(1):85–103. doi:10.1080/14763141.2020.1718197
22. Lagally KM, Robertson RJ. Construct validity of the OMNI resistance exercise scale. *J Strength Cond Res*. 2006;20(2):252–256. doi:10.1519/R-17224.1
23. Faul F, Erdfelder E, Lang AG, Buchner A. G*Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods*. 2007;39(2):175–191. doi:10.3758/BF03193146
24. Cohen J. A power primer. *Psychol Bullet*. 1992;112(1):155–159. doi:10.1037/0033-2909.112.1.155
25. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. *J Strength Cond Res*. 2004;18(4):918–920. doi:10.1519/14403.1
26. Corder KP, Potteiger JA, Nau KL, Figoni SE, Hershberger SL. Effects of active and passive recovery conditions on blood lactate, rating of perceived exertion, and performance during resistance exercise. *J Strength Cond Res*. 2000;14(2):151–156. doi:10.1519/00124278-200005000-00006
27. Hannie PQ, Hunter GR, Kekes-Szabo T, Nicholson C, Harrison PC. The effects of recovery on force production, blood lactate, and work performed during bench press exercise. *J Strength Cond Res*. 1995;9(1):8–12.
28. Lopes FAS, Panissa VLG, Julio UF, Menegon EM, Franchini E. The effect of active recovery on power performance during the bench press exercise. *J Hum Kinet*. 2014;40(1):161–169. doi:10.2478/hukin-2014-0018
29. Miranda H, Maia MF, Paz GA, Costa PB. Acute effects of antagonist static stretching in the inter-set rest period on repetition performance and muscle activation. *Res Sports Med*. 2015;23(1):37–50. doi:10.1080/15438627.2014.975812
30. Nasiri R, Damirchi R, Mirzai B. The effect of duration and type of rest interval between sets with low and moderate intensities on the volume of bench press in untrained men. *Res Sport Sci Q*. 2011;2(2):25–33.
31. Rhea MR, Kenn JG. The effect of acute applications of whole-body vibration on the itonic platform on subsequent lower-body power output during the back squat. *J Strength Cond Res*. 2009;23(1):58–61. doi:10.1519/JSC.0b013e3181875045
32. Timon R, Collado-Mateo D, Olcina G, Gusi N. Effects of interset whole-body vibration on bench press resistance training in trained and untrained individuals. *J Sports Med Phys Fitness*. 2016;56(3):232–240. PubMed ID: 25583231
33. Paz G, Maia M, Whinchester J, Miranda H. Strength performance parameters and muscle activation adopting two antagonist stretching methods before and between sets. *Sci Sports*. 2016;31(6):e173–e180. doi:10.1016/j.scispo.2016.01.011
34. Pisz A, Blazek D, Jebavy R, et al. Antagonist activation exercises elicit similar post-activation performance enhancement as agonist activities on throwing performance. *BMC Sports Sci Med Rehabil*. 2023;15(1):44. doi:10.1186/s13102-023-00657-9
35. Rodríguez-Rosell D, Pareja-Blanco F, Aagaard P, González-Badillo JJ. Physiological and methodological aspects of rate of force development assessment in human skeletal muscle. *Clin Physiol Funct Imaging*. 2018;38(5):743–762. doi:10.1111/cpf.12495
36. Hargreaves M, Spriet LL. Skeletal muscle energy metabolism during exercise. *Nat Metab*. 2020;2(9):817–828. doi:10.1038/s42255-020-0251-4
37. Hiscock DJ, Dawson B, Donnelly CJ, Peeling P. Muscle activation, blood lactate, and perceived exertion responses to changing resistance training programming variables. *Eur J Sport Sci*. 2016;16(5):536–544. doi:10.1080/17461391.2015.1071880