# Acute effect of stretching performed before a resistance exercise session using different intervals on maximum repetitions performance in recreationally trained adults
# Efecto agudo del estiramiento realizado antes de una sesión de ejercicio de resistencia utilizando diferentes intervalos sobre el rendimiento de repeticiones máximas en adultos entrenados recreativamente

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**Abstract.** The present study proposed to compare the acute effect of stretching (SE) before resistance exercise (RE) sessions using different intervals (30 vs. 60 vs. 120 seconds) on maximal repetition performance of recreationally trained adults. Twenty men (age: 29.5 ± 7.05 years; height: 82.92 ± 8.47 kg; weight: 1.78 ± 0.07 cm; body mass index: 26.03 ± 1.55 $m^2kg^{-1}$) recreationally trained in RE ($\geq$ 6 months) completed 4 interventions: 1) RE with 60-second intervals (RE60"), 2) SE plus RE with 30-second intervals (SE+RE30"), 3) SE plus RE with 60-second intervals (SE+RE60"), and 4) SE plus RE with 120-second intervals (SE+RE120"). The RE consisted of three sets until muscle failure of the following exercises: bench press, bench press 35°, decline bench press, biceps curl, and biceps curl 45° at 80% of 10RM. The SE involved two sets of 30-second static SE for chest and biceps separated by a 40-second passive interval. The maximum number of repetitions performed until muscle failure was counted at the end of each set. The results of this study show a progressive reduction in maximum repetitions performance between sets and exercises in tested protocols with and without SE. Significant reductions were presented for the SE+RE30" protocol compared to the RE60" and SE+RE120" protocols. The present study suggests that 60" intervals between sets are necessary to avoid a significant reduction in maximum repetitions performance.
**Keywords:** Neuromuscular performance, strength, strength training

**Resumen.** El presente estudio propuso comparar el efecto agudo del estiramiento (ES) antes de las sesiones de ejercicio de resistencia (ER) usando diferentes intervalos (30 vs. 60 vs. 120 segundos) sobre el rendimiento máximo de repeticiones de adultos entrenados recreativamente. Veinte hombres (edad: 29,5 ± 7,05 años; altura: 82,92 ± 8,47 kg; peso: 1,78 ± 0,07 cm; índice de masa corporal: 26,03 ± 1,55 $m^2kg^{-1}$) entrenados recreativamente en ER ($\geq$ 6 meses) completaron 4 intervenciones:1) ER con intervalos de 60 segundos (ER60"), 2) ES más ER con intervalos de 30 segundos (ES+ER30"), 3) ES más ER con intervalos de 60 segundos (ES+ER60") y 4) ES más ER con intervalos de 120 segundos (ES+ER120").El ER consistió en tres series hasta el fallo muscular de los siguientes ejercicios: press de banca, press de banca 35°, press de banca declinado, curl de bíceps y curl de bíceps 45° al 80% de 10RM. El ES involucró dos series de ES estático de 30 segundos para pecho y bíceps separados por un intervalo pasivo de 40 segundos. El número máximo de repeticiones realizadas hasta el fallo muscular se contó al final de cada serie. Los resultados de este estudio muestran una reducción progresiva en el rendimiento de repeticiones máximas entre series y ejercicios en protocolos probados con y sin ES. Se presentaron reducciones significativas para el protocolo ES+ER30" en comparación con los protocolos ER60" y ES+ER120". El presente estudio sugiere que los intervalos de 60" entre series son necesarios para evitar una reducción significativa en el rendimiento de las repeticiones máximas.
**Palabras clave:** rendimiento neuromuscular, fuerza, entrenamiento de fuerza

## Introduction

The physical fitness components involve body composition, aerobic profile, as well as neuromotor and neuromuscular conditioning (GARBER et al., 2011). Strength and flexibility training, when performed in conjunction, highlight researchers' interest in neuromuscular performance (FIGUEIREDO et al., 2016; GOMES et al., 2011; PAZ et al., 2012; RIBEIRO et al., 2014; SÁ et al., 2015) and cardiovascular effects (ARAUJO et al., 2019; COSTA e SILVA et al., 2019; da SILVA et al., 2019; SANTOS et al., 2014). Stretching exercises (SE) have been widely performed before physical and sports activities by both physical exercise practitioners and athletes. The different combinations between resistance (RE) and SE exercises in the same session are unclear throughout previous literature, thus highlighting an important gap that must be investigated.

SE are commonly used in a training routine during warm-up to reduce joint stiffness and increase local range-of-motion (BEHM & CHAOUACHI, 2011; CHAABENE et al., 2019; GARBER et al., 2011; RUBINI et al., 2007). Previous research has investigated the acute effect of SE followed by RE during training sessions of maximum repetition performance (GOMES et al., 2011; RIBEIRO et al., 2014; RUBINI et al., 2007; SÁ et al., 2015). In this context, Gomes et al. (2011) compared the effect of different static SE techniques and proprioceptive neuromuscular facilitation (PNF) on maximum repetition performance with 40%, 60%, and 80% of 1 repetition maximum load. The Authors identified significant reductions in the number of

repetitions for the PNF condition across all tested intensities. In contrast, Ribeiro et al. (2014) submitted 15 participants in the bench press to four sets until muscle failure at 80% of 1 repetition maximum. This investigation did not find significant reductions in repetitions performance throughout four sets (with static SE: 21.3±0.7% vs. without static SE: 20.5± 0.7%).

The results from Miranda et al. (2015), found the performed SE between agonist-antagonist paired RE sets observed higher latissimus dorsi (p=0.002) and biceps brachii (p=0.001) electromyographic activity and in the repetitions performance during seated row RE performed post chest SE (p=0.010). In contrast Sá et al. (2015)submitted nine participants to a passive SE and PNF protocol and investigated the muscle architecture response of biceps femoris, vastus lateralis, and the maximum repetition performance. Authors observed that the PNF method presented negative results in maximum repetition performance (p = 0.020) compared to passive SE. The current literature does not present the behavior of the maximum repetition performance in an RE session combined with SE performed along the different intervals between sets and exercises. Therefore, the present study aimed to compare the acute effect of SE performed before different RE rest intervals (30-s, 60-s, and 120-s) on maximum repetitions performance in recreationally RE-trained men. The initial hypothesis of this study is that fractionate SE sets (2x30s) would not decrease maximum repetition performance.

## Methodology

### Approaching the study problem

A counter-balanced (randomized), cross-over and within-subject experimental design was used to compare the maximum repetition performance during and after SE performed during different RE rest intervals (30", 60", and 120") (Figure 1). Subjects visited the laboratory for seven sessions during a nineteen-day period with at least forty-eight-hours between visits. At the first visit, informed and written consent was obtained, and subsequently, the Physical Activity Readiness Questionnaire (SHEPHARD, 1988) and anthropometric measures. Over two visits, participants completed the 10-repetition maximum test and retest (10RM), bench press (BP), bench press 35° (BP35°), biceps curl (BC), and biceps curl 45° (BC45°) exercises with 48-hours rest interval between visits. Throughout the following visits (third to seventh), participants performed four experimental interventions, assigned in a randomized order:1) RE with 60 seconds rest intervals between sets (RE60"),2) SE followed by RE with 30 seconds rest intervals between sets (SE+RE30"),3) SE + followed by RE with 60 seconds rest intervals between sets (SE+RE60"), 4) SE followed by RE with 120 seconds rest intervals between sets (SE+RE120"). All procedures were performed at the same time of day (morning) for a given participant to minimize any potential circadian effects. Subjects were suggested not to consume any caffeine or alcohol drinks and to

maintain their eating habits throughout the visits. The number of maximum repetitions was record at the end of each set, of which all were conducted until concentric muscle failure (Figure1).
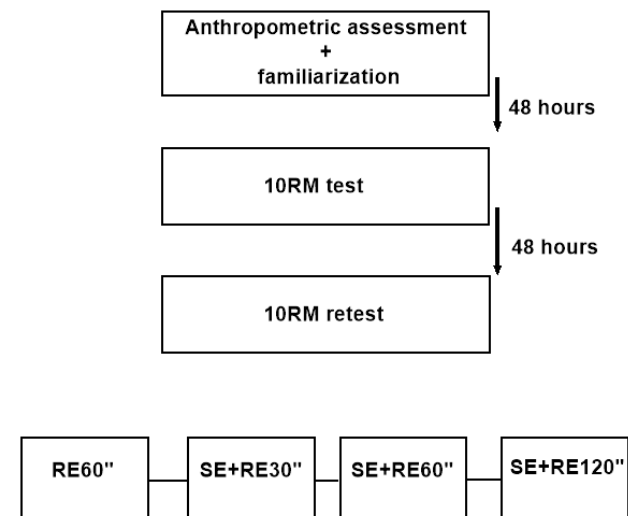


Figure 1. Experimental design. RE60" = RE with 60 seconds rest intervals between sets; SE+RE30" = SE followed by RE with 30 seconds rest intervals between sets; SE+RE60" = SE followed by RE with 60 seconds rest intervals between set; SE+RE120" = SE followed by RE with 120 seconds rest intervals between sets.

### Subjects

Twenty recreationally trained (RE≥ 6 months) men (age: 29.5 ± 7.05 years; height: 82.92 ± 8.47 kg; weight: 1.78 ± 0.07 cm; body mass index: 26.03 ± 1.55 m²kg⁻¹) participated in this study. The sample size was calculated using G*Power 3.1 software (FAUL et al., 2007). Based on an a priori analysis, an n of 16 subjects was calculated after adopting a power of 0.80, $\alpha$ = 0.05, a correlation coefficient of 0.5, the Nonsphericity correction of 1, and an effect size of 0.60. From these values, it was calculated a minimum number of 16 volunteers. The sample size was calculated based on the suggested procedure (BECK, 2013). The statistical analysis initially aimed to reduce the probability of type II error and determine the minimum number of participants needed for this research. The sample size was sufficient to promote a statistical power of > 80%.

All subjects answered negatively to all questions on the Physical Activity Readiness Questionnaire. Recreationally RE-trained men who did not have any functional limitations or medical conditions that could compromise their health were included in the present study. Inclusion criteria included involvement in a structured RE program for at least one year prior to the study and, performed SE during routine training. RE training program had to average at least 50-minute per RE session and consist of at least three sessions per week, using loads of 8-12 RM and rest intervals of 1- to 3-min between sets and exercises. The exclusion criteria included smokers, use of any supplement containing creatine, use of anabolic steroids, use of thermogenic or nitric oxide. During the nineteen-day period of data collection, the participants were instructed not to engage in any

non-study RE, SE, or other strenuous physical activity.

Prior to the study, all participants were provided verbal and written explanations of all study procedures, following which they provided written informed consent. The procedures of the present study were carried out in accordance with Resolution No. 466/12 of the National Health Council. The study and all procedures were approved by the ethics committee of Barra Mansa University Center (53898516.8.0000.5236/2017) and were conducted in accordance with the Declaration of Helsinki.

### Ten repetition maximum (10RM) test

The exercises performed in the 10RM test were BP, BP35°, DBP, BC, and BC45°. All tests were performed using resistance machines (Life Fitness, Liguna Niguel). The following strategies were adopted to reduce the margin of error in the 10RM test (MONTEIRO et al., 2019):(a) standardized instructions were given and previous volunteer test familiarization was performed to ensure that all volunteers assessed would be aware of the entire routine involved in the data collection; (b) the volunteers were instructed about the technique to perform all exercises and attention was paid to the equipment setting adopted by the volunteer when performing the measurement, to avoid small variations in the position of the joints involved in the movement activating other muscles, leading to misinterpretations of the scores assessed;(c) verbal cues were used to maintain a high level of motivation, and the additional weights used were previously calibrated with a precision scale; and (d) the angle performed for each exercise was established and visually checked. The evaluators were attentive in maintaining the same pattern of movement in the same volunteer between tests and training sessions (de SALLES et al., 2010).

The 10-RM test protocol recommendation proposed by Garber et al. (2011) was used: specific warm-up, in which 5 to 10 repetitions were performed, with loads of 40% to 60% of the maximum perceived before the first exercise. After a 1-minute interval, a load between 60 and 80% of their maximum perceived was prepared, and the subjects were instructed to perform 6 repetitions. After another one-minute interval, a small increase in load was made, and the subject was instructed to perform 10-RM. 48 hours after the first day, the re-test was applied to verify the reproducibility of the maximum load (10RM).

### Resistance exercise (RE)

RE protocol consisted of three sets of maximum repetitions (until concentric failure) of BP, BP35°, DBP, BC, and BC45°; always in this same sequence for all experimental conditions. The intensity was adjusted to 80% of the 10RM value for all exercises and 30-s-, 60-s, and 120-s rest intervals between sets and exercises were given according to the protocol performed (RE60, SE+RE30, SE+RE60, and SE+RE120"). The number of maximum repetitions performed was recorded at the end of each set.

### Stretching exercise (SE)

SE were performed for the pectoral and biceps (Figure 2). For all SE exercises, two sets were performed, the position was held for 30-s in each set, and the movement was held when the slight discomfort point was reached (GARBER et al., 2011) always passively applied by one of the evaluators; on the 0-10 scale of discomfort perception proposed by (McCULLY, 2010). A 40sec passive interval was adopted between the sets of SE that were performed only before performing the first bench press exercise.

### Statistical analysis

Normality was tested and not rejected by the Shapiro-Wilk test. Results are presented as mean ± standard deviation. Two-way ANOVA (3 conditions x 1 times) with repeated measures and Tukey's post-hoc test was used to test interactions and compare the maximum repetitions performance means. Additionally, effect sizes (ES) were calculated using the standardized mean difference to determine the magnitude of the treatment effects (ES = [Mean Post − Mean Pre] / SD of the resting or pre-value]). The magnitude of the ES was interpreted using the scale proposed by Rhea (2004) for recreationally trained subjects, which < 0.35; 0.35-0.80; 0.80-1. 5; and > 1.5 represented trivial, small, moderate, and large effects, respectively. Reproducibility between 10RM test sessions were analyzed using the intraclass correlation coefficient (ICC) (MONTEIRO et al., 2019). All analyses were performed in GraphPad software (Prism 6.0, San Diego, CA, USA), and α value at 5% was considered.

### Results

A high ICC was demonstrated between test-retest for BP (0.99), BP35° (0.98), DBP (0.99), BC (0.94), and BC45 (0.90) exercises. Table 1 shows the mean values ± standard deviation and ES for each set throughout all experimental conditions.

All tested variables showed normal distribution (p>0.05). Significant differences were found in BP exercise between sets ($F_{(6, 228)}$ = 711.8; p <0.0001) with significant increases in SET2 between SE+RE120" vs RE60" (p=0.0044; 15.75 vs 14.00 reps), SE+RE60" vs SE+RE30" (p<0.0008; 15.05 vs 13.05 reps), and SE+RE120" vs SE+RE30" (p<0.0001; 15.75 vs 13.05 reps). Similarly, significant increases were found in SET3 between SE+RE60" vs SE+RE30" (p= 0.0084; 10.90 vs 9.25 reps) and SE+RE120" vs SE+RE30" (p <0.0001; 11.55 vs 9.25 reps) (Figure 2).

Significant differences were found in BP35 exercise between sets ($F_{(2, 228)}$ = 251.4; p <0.0001) with significant increases in SET1 betweenRE60" vs. SE+RE30" (p<0.0003; 15.70 vs. 13.60 reps) and RE60" vs. SE+RE60" (p=0.0036; 15.70 vs. 13.95 reps). Still, significant increases were shown in SET2 between RE60" vs. SE+RE30" conditions (p=0.0070; 11.65 vs. 10 reps) (Figure 3).

Significant differences were found in BC exercise

between sets ($F_{(2, 228)}$ = 644.0; p <0.0001)with significant differences in SET1 between SE+RE30" vs. RE60" (p= 0.0207; 18.95 vs. 17.60 reps), SE+RE60" vs. RE60" (p = 0.0008; 19.40 vs. 17.60 reps), and SE+RE120" vs. RE60" (p=0.0003; 19.50 vs. 17.60 reps) (Figure 5).

Table 1.
Maximum repetitions performance.

| Protocol | | RE60" | SE+RE30" | SE+RE60" | SE+RE120" |
|---|---|---|---|---|---|
| BP (reps) | SET1 | 20.6 ± 1.42 | 19.45 ± 1.31 | 20.1 ± 1.11 | 20.45 ± 1.43 |
| | SET2 | 14.00 ± 2.29 | 13.05 ± 1.35 | 15.05 ± 1.7 | 15.75 ± 1.8 |
| | | -4.61 | -4.85 | -4.51 | -3.28 |
| | | High | High | High | High |
| | | p < 0.0001* | p < 0.0001* | p < 0.0001* | p < 0.0001* |
| | SET3 | 10.25 ± 2.17 | 9.25 ± 1.40 | 10.9 ± 1.55 | 11.55±1.53 |
| | | -7.24 | -7.74 | -8.22 | -6.21 |
| | | High | High | High | High |
| | | p < 0.0001* | p < 0.0001* | p < 0.0001* | p < 0.0001* |
| | | p < 0.0001** | p < 0.0001** | p < 0.0001** | p < 0.0001** |
| BP35° (reps) | SET1 | 15.7 ± 2.02 | 13.06 ± 1.84 | 13.95 ± 1.60 | 14.40 ± 1.56 |
| | SET2 | 11.65 ± 1.98 | 10.00 ± 1.29 | 10.90 ± 1.48 | 11.05 ± 1.27 |
| | | -1.99 | -1.94 | -1.90 | -2.13 |
| | | High | High | High | High |
| | | p < 0.0001* | p < 0.0001* | p < 0.0001* | p < 0.0001* |
| | SET3 | 9.15 ± 1.63 | 7.85 ± 1.47 | 9.05 ± 1.27 | 9.05 ± 1.5 |
| | | -3.22 | -3.05 | -3.05 | -3.4 |
| | | High | High | High | High |
| | | p < 0.0001* | p < 0.0001* | p < 0.0001* | p < 0.0001* |
| | | p < 0.0001** | p = 0.0002** | p =0.0009** | p < 0.0003** |
| DBP (reps) | SET1 | 14.00 ± 1.97 | 12.25 ± 1.80 | 12.30 ± 2.12 | 14.15 ± 2.20 |
| | SET2 | 11.10 ± 1.65 | 10.15 ± 1.13 | 9.95 ± 1.14 | 12.35 ± 1.66 |
| | | -1.46 | -1.16 | -1.10 | -0.81 |
| | | Moderate | Moderate | Moderate | Moderate |
| | | p < 0.0001* | p = 0.0003* | p < 0.0001* | p = 0.0025* |
| | SET3 | 8.90 ± 1.65 | 8.75±1.74 | 8.55 ± 1.09 | 10.1 ± 1.61 |
| | | -2.58 | -1.94 | -1.22 | -1.83 |
| | | High | High | Moderate | High |
| | | p < 0.0001* | p<0.0001* | p < 0.0001* | p < 0.0001* |
| | | p = 0.0002** | p = 0.0253** | p = 0.0253* | p = 0.0001** |
| BC (reps) | SET1 | 17.6±2.28 | 18.95±1.23 | 19.4±0,99 | 19.50 ± 1.84 |
| | SET2 | 13.85±1.63 | 14.65±1.46 | 14.2±0,95 | 14.95 ± 1.64 |
| | | -1.64 | -3.48 | -5.22 | -2.45 |
| | | High | High | High | High |
| | | p < 0.0001* | p < 0.0001* | p < 0.0001* | p < 0.0001* |
| | SET3 | 10,4±1.69 | 10,01±0,91 | 10,45±1.09 | 11.20 ± 1.43 |
| | | -3.15 | -7.16 | -3.94 | -4.48 |
| | | High | High | High | High |
| | | p < 0.0001* | p < 0.0001* | p < 0.0001* | p < 0.0001* |
| | | p < 0.0001** | p < 0.0001** | p < 0.0001** | p < 0.0001** |
| BC45 (reps) | SET1 | 13.70 ± 1.94 | 13.15 ± 1.53 | 14.30 ± 1.30 | 15.25 ± 1.77 |
| | SET2 | 10.50 ± 1.60 | 10.45 ± 1.05 | 11.05 ± 1.19 | 12.35 ± 2.15 |
| | | -1.64 | -1.76 | -2.49 | -1.63 |
| | | High | High | High | High |
| | | p < 0.0001* | p < 0.0001* | p < 0.0001* | p < 0.0001 |
| | SET3 | 8.55 ± 1.63 | 9.40 ± 0.99 | 9.45 ± 1.09 | 10.6 ± 1.78 |
| | | -2.64 | -2.44 | -1.34 | -2.62 |
| | | High | High | Moderate | High |
| | | p < 0.0001* | p < 0.0001* | p < 0.0001* | p < 0.0001* |
| | | p < 0.0001** | p < 0.0001** | p < 0.0001** | p < 0.0001** |

RE = resistance exercises with 60 seconds rest intervals between sets; SE+RE30" = SE followed by RE with 30 seconds rest intervals between sets; SE+RE60" = SE followed by RE with 60 seconds rest intervals between sets; SE+RE120" = SE followed by RE with 120 seconds rest intervals between sets. BP = bench press; BP35° = bench press 35°; DBP = decline bench press; BC = biceps curl; BC45 = biceps curl 45°; reps = repetitions; *significant difference in comparison to SET1; **significant difference in comparison to SET2.
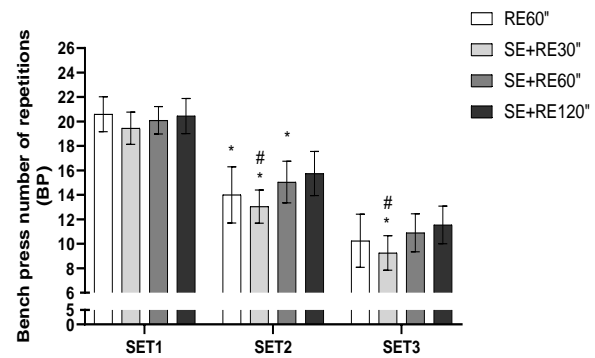


Figure 2. Maximum repetition performance between conditions in bench press (BP). RE = resistance exercises with 60 seconds rest intervals between sets; SE+RE30" = SE followed by RE with 30 seconds rest intervals between sets; SE+RE60" = SE followed by RE with 60 seconds rest intervals between sets; SE+RE120" = SE followed by RE with 120 seconds rest intervals between sets. BP = bench press; *Significant difference for SE+RE120protocol; #Significant difference between SE+ER60" protocol.
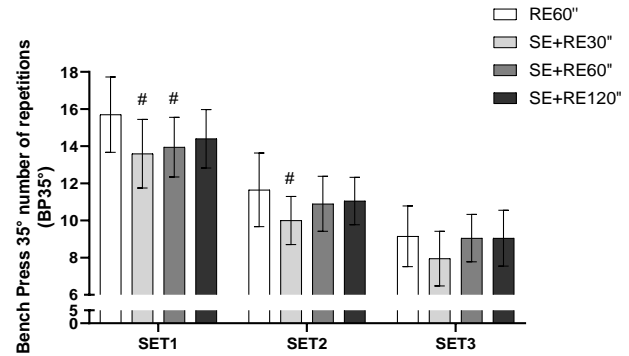


Figure 3. Maximum repetition performance between conditions in bench press 35°. RE = resistance exercises with 60 seconds rest intervals between sets; SE+RE30" = SE followed by RE with 30 seconds rest intervals between sets; SE+RE60" = SE followed by RE with 60 seconds rest intervals between sets; SE+RE120" = SE followed by RE with 120 seconds rest intervals between sets. BP35° = bench press 35°. #Significant difference compared to the RE60.

Significant differences were found in DBP exercise between sets ($F_{(2, 228)}$ = 118.3; p <0.0001) with significant increases in SET1 between RE60" vs. SE+RE30" (p= 0.0066; 14.00 vs. 12.25 reps), RE60" vs. SE+RE60" (p= 0.0090; 14.00 vs. 12.30 reps), SE+RE120" vs. SE+RE30" (p= 0.0026; 14.15 vs. 12.25 reps), and SE+RE120" vs. SE+RE60" (p= 0.0035; 14.15 vs. 12.30 reps). Similarly, significant increases were presented in SET2 between SE+RE120" vs. SE+RE30" (p= 0.0003; 12.35 vs. 10.15 reps) and SE+RE120" vs. SE+RE60" (p<0.0001; 12.35 vs. 9.95 reps). In SET3 significant increases were found between SE+RE120" vs. SE+RE60" (p=0.0211; 10.10 vs. 8.55 reps) (Figure 4).
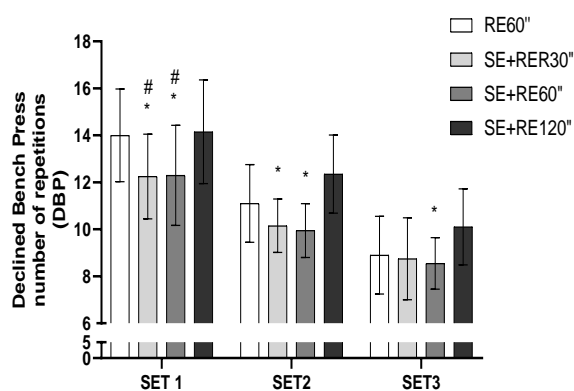
Figure 4. Maximum repetition performance between conditions in declined bench press. RE = resistance exercises with 60 seconds rest intervals between sets; SE+RE30" = SE followed by RE with 30 seconds rest intervals between sets; SE+RE60" = SE followed by RE with 60 seconds rest intervals between sets; SE+RE120" = SE followed by RE with 120 seconds rest intervals between sets. DBP = decline bench press. *Significant difference compared to SE+RE120; #Significant difference compared to RE60.
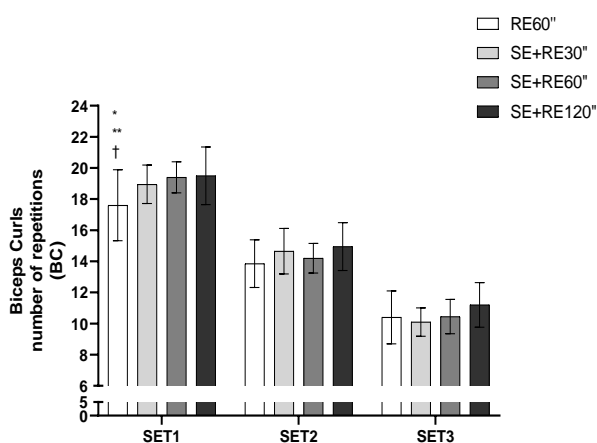


Figure 5. Maximum repetition performance between conditions in biceps curls. RE = resistance exercises with 60 seconds rest intervals between sets; SE+RE30" = SE followed by RE with 30 seconds rest intervals between sets; SE+RE60" = SE followed by RE with 60 seconds rest intervals between sets; SE+RE120" = SE followed by RE with 120 seconds rest intervals between sets. BC = biceps curl. **Significant difference compared to SE+RE60; †Significant difference compared to SE+RE30.

Significant differences were found in BC45° exercise between sets ($F_{(2, 228)}$ = 181.8; p<0.0001) and between protocols ($F_{(3, 228)}$ = 17.53; p <0.0001). Significant increases were found in SET1 between SE+RE120" vs. RE60" (p= 0.0096; 15.25 vs. 13.70 reps) and SE+RE120" vs. SE+RE30" (p=0.0002; 15.25 vs. 13.15 reps). Significant increases were found in SET2 between SE+RE120" vs. RE60" (p=0.0012; 12.35 vs. 10.50 reps), SE+RE120" vs. SE+RE30" (p= 0.0008; 12.35 vs. 10.45 reps), and SE+RE120" vs. SE+RE60" (p=0.0422; 12.35 vs. 11.05 reps). Significant increases were found in SET3 between SE+RE120" vs. RE60" (p<0.0002; 10.60 vs 8.55 reps). (Figure 6).
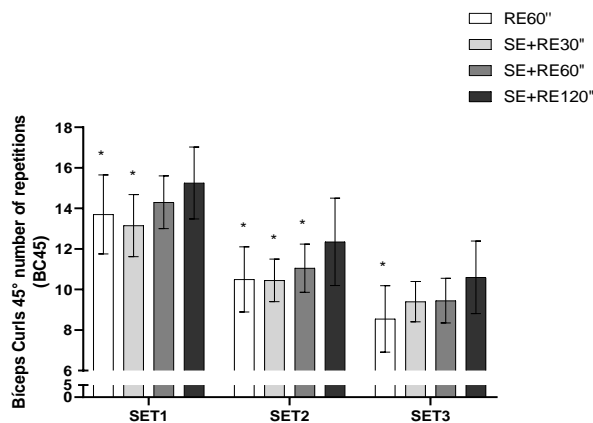


Figure 6. Maximum repetition performance between conditions in biceps curls 45°. RE = resistance exercises with 60 seconds rest intervals between sets; SE+RE30" = SE followed by RE with 30 seconds rest intervals between sets; SE+RE60" = SE followed by RE with 60 seconds rest intervals between sets; SE+RE120" = SE followed by RE with 120 seconds rest intervals between sets. BC45 = biceps curl 45°. *Significant difference compared to SE+RE120" protocol.

## Discussion

The present study aimed to compare the acute effect of SE performed before different RE rest intervals (30-s, 60-s, and 120-s) on maximum repetitions performance in recreationally RE-trained men. The novel findings of the study included: a) the maximum repetitions performance showed significant reductions throughout all sets, regardless of whether or not SE was performed before RE session; b) SE performed before RE did not significantly reduce repetitions performance in exercise BC in the first set; c) the SE+RE120" protocol he was significantly increased to repetitions performance in exercise BC45°. The results founded in the present study agree with our initial hypothesis, which indicated that the SE performed in 2x30" before the RE session does not decrease in maximum repetition performance.

The previous studies demonstrating a progressive reduction in the effects of SE on the neuromuscular system performance (AVELA et al., 2004; FJERSTAD et al., 2018; FOWLES et al., 2000; RIBEIRO et al., 2014; SÁ et al., 2015) demonstrated that after 5and 10 minutes, restoration of 80 and 87%, respectively, of the force that was reduced by SE occurs. In our study, we identified a large magnitude significant decrease in performance for the BP (p <0.05; ES = High) and between SET 2 and SET3 for BP35° (p < 0.05; ES = Moderate to High) exercises regardless of protocol. A moderate magnitude decrease was found in all BP35° protocols, with and without stretching in the third exercise (p = p < 0.05; ES = Moderate). The studies by Fowles, Sale, and MacDougall (2000) corroborates in parts with our findings. The BP35° was the third exercise in the pectoral sequence, this may influence neuromuscular performance due to fatigue accumulation.

That is, until the BP35° performance, 6-min and 12-min elapsed for the conditions SE+RE60 and SE+RE120, respectively. This information is noteworthy as it agrees with the previous literature on the manipulation of the order (ARAUJO et al., 2019) and rest intervals (MONTEIRO et al., 2019) of RE exercises.

Our results are in agreement with some studies that found no negative result of SE performed before the RE session (FJERSTAD et al., 2018; LOPES et al., 2019; RIBEIRO et al., 2014; SÁ et al., 2015). Fjerstad et al. (2018) did not identify significant differences in the level of muscle strength after a SE session performed on the hip adductor muscles for 60 seconds actively and passively. Lopes et al. (2019) submitted a group of volunteers to 5 sets of BP. The authors demonstrated reductions of small to moderate magnitude in the first 2 sets, with no significant change for the following sets. Ribeiro et al. (2014) did not find significant differences after performing SE for chest and triceps brachii in the performance of maximum repetitions in 4 sets in the BP. Both studies differ from ours, in that they presented the execution of only one exercise (BP) for the chest muscles, which may have diluted the deleterious effect of SE after approximately 25 minutes. In our study, we performed 3 different exercises for the chest muscles (BP, BP35°, and DBP) and two exercises for the biceps muscles (BC and BC45°), which may have presented divergent results due to the performance of the exercises in different angulations.

According to Chaabene et al. (2019) when SE are inserted into a short-term warm-up routine (≤ 60 seconds) it can even contribute to reducing the risk of sustaining musculotendinous injuries. During short-term SE, muscle-tendon activation and stiffness are not affected compared to long-term SE (MATSUO et al., 2013; PALMER et al., 2019). Among other factors, this may be due to an elevated muscle temperature induced by a dynamic warm-up program. More specifically, high muscle temperature leads to an increase in the conduction speed of muscle fibers and providing better connection of muscle fibers by enhancing the action between actin and myosin (CHAABENE et al., 2019).

There are some limitations when interpreting the results of this study. It was not assessed the level of flexibility, muscle thickness, or body composition (% fat) of the volunteers. Further studies are needed to evaluate the performance responses in strength, level of muscle damage, and muscle mass development in different volumes of SE and RE assessed through both acute and chronic responses. To our knowledge, this is the first study to investigate the acute effect of SE performed before the RE session at different intervals on maximal repetition performance. In conclusion, SE performed before the RE session at 60- and 120-second intervals do not show significant reductions when compared to the 60-second interval RE protocol. Performing 2x30 seconds of stretching before the RE session with 60- or 120-second intervals does not affect the repetitions performance negatively, when compared to the protocol that did not perform SE.

## Practical applications

SE should be taken into consideration during RE-exercises. This study suggests that 60-s (2x30-s) of SE combined with RE (60-s or 90-s) performed on the upper limbs (chest and biceps) have no significant deleterious effects in maximum repetitions performance when compared to protocols without SE (e.g., RE). This may have impact in prescription and implementation, in both athletic and rehabilitation subjects, and may help to influence decision making by practitioners who want to adopt the latest resources throughout RE training without losing neuromuscular performance (e.g., maximum repetitions).

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