

Original article

Number of repetition after different rest intervals between static stretching and resistance training



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ABSTRACT

Objective: The purpose of this study was to investigate the effects of different intervals between static stretching for hip adductor, quadriceps and hamstring muscles and resistance training in repetition performance.

Method: Twenty-two trained men were submitted to the 10 repetition maximum test and retest for leg extension, leg curl and hip adduction exercises. Three protocols were conducted in a randomized design – PWI: resistance training immediately after static stretching; P15: fifteen-minute rest interval between static stretching and resistance training; P30: thirty-minute rest interval between static stretching and resistance training.

Results: The total number of repetition [(sets * repetitions) + exercises] performed under P30 (84.55 ± 1.68) was significantly higher than P15 (79.73 ± 1.89) and PWI (68.09 ± 2.03), respectively. Significant differences were also found between P15 and P30.

Conclusions: Therefore, 30-minute interval between static stretching and resistance exercises was needed to achieve greater repetition performance. Thus, static stretching for lower limbs may be avoided before a resistance training session.

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Número de repeticiones tras diferentes secuencias de descanso entre estiramiento estático y entrenamiento de fuerza

RESUMEN

Objetivo: El objetivo de ese estudio fue investigar los efectos de distintas secuencias de estiramiento estático, en los músculos aductores de la cadera, cuádriceps e isquiotibiales y el entrenamiento de resistencia, en el rendimiento en repeticiones.

Método: Veintidós hombres entrenados fueron sometidos a la prueba de 10 repeticiones máximas para ejercicios de extensión de piernas, flexión de piernas y aducción de cadera. Tres protocolos fueron realizados utilizando un diseño aleatorio: PSI: entrenamiento de resistencia realizado inmediatamente después del estiramiento estático; P15: intervalo de descanso de 15 minutos entre estiramiento estático y entrenamiento de resistencia; P30: intervalo de descanso de 30 minutos entre estiramiento estático y entrenamiento de resistencia.

Resultados: El número total de repeticiones [(sets * repetición) + ejercicio], realizadas en P30 (84.55 ± 1.68) fue significativamente mayor que P15 (79.73 ± 1.89) y PSI (68.09 ± 2.03), respectivamente. También se observaron grandes diferencias entre P15 y P30.

Palabras clave:

Estiramiento estático

Entrenamiento de resistencia

Rendimiento de fuerza

Intervalo de recuperación

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Conclusiones: Por lo tanto, se necesitó un intervalo de 30 minutos entre el estiramiento estático y los ejercicios de resistencia para lograr un mayor rendimiento en repeticiones. En este sentido, el estiramiento estático para miembros inferiores puede ser evitado antes de una sesión de entrenamiento de resistencia.

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Número de repetição após diferentes intervalos de recuperação entre alongamento estático e treinamento resistido

R E S U M O

Palavras-chave:

Alongamento estático
Treinamento resistido
Desempenho de força
Intervalo de recuperação

Objetivo: O objetivo deste estudo foi investigar os efeitos de diferentes intervalos entre alongamento estático para os músculos adutores do quadril, quadríceps e isquiotibiais e o treinamento resistido no desempenho de repetições.

Método: Vinte e dois homens treinados foram submetidos ao teste de 10 repetições máximas e reteste para os exercícios de extensão, e flexão de joelhos, e de adução do quadril. Três protocolos foram conduzidos em um desenho randomizado: PWI – treinamento resistido imediatamente após o alongamento estático; P15 – intervalo de descanso de 15 minutos entre alongamento estático e o treinamento resistido; P30 – intervalo de descanso de 30 minutos entre alongamento estático e o treinamento resistido.

Resultados: O número total de repetição ([séries * repetições] + exercícios) realizada em P30 (84.55 ± 1.68) foi significativamente maior do que o P15 (79.73 ± 1.89) e PWI (68.09 ± 2.03), respectivamente. Diferenças significativas também foram encontradas entre P15 e P30.

Conclusões: O intervalo de 30 minutos entre o alongamento estático e o exercício resistido foi necessário para alcançar maior desempenho no número de repetição. Assim, os alongamentos estáticos para membros inferiores podem ser evitados antes de uma sessão treinamento resistido.

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Introduction

Flexibility training is a key component in exercise programs with the goal to develop quality of life and health.^{1,2} Static stretching (SS) is one of the methods often adopted to improve the range of motion temporarily.³ However, several studies have shown that pre-exercise stretching induces significant reductions on force production when compared to resistance exercises performed isolated.^{4–7} This phenomenon has been named the stretching-induced force deficit.⁸

Adequate biomechanical performance of lower-body resistance exercises in health and/or sport conditioning programs requires a high level of range of motion.⁹ Appropriate joint flexibility not only permits proper form, but also allows the trainee the ability to work against resistance through a full range of motion.¹⁰ However, SS adopted prior to resistance training (RT) can induce significant decreases on muscle endurance,^{2,4} torque^{10,11} and power performance.⁷ Two primary hypotheses have been proposed to explain the stretching-induced force deficit. The first hypothesis is associated to a neural factor, causing a decrease in muscle activation and reflex sensitivity.¹² The second hypothesis involves a mechanical factor, promoting a decrease in stiffness of the muscle-tendon unit (MTU) that may affect the muscle's length-tension relationship.¹³ On the other hand, there are limited evidences about the time course of the stretching-induced force deficit between SS and resistance exercises.

Fowles et al.¹⁴ observed decreases of 28% on maximal voluntary isometric contraction (MVIC) of triceps surae after SS, and they also found a reduction of 9% after 1 h. McBride et al.¹⁵ observed significant reduction in MVIC, 1, 2, 8 and 16 min after SS. This data indicated that negative effect induced by SS on strength performance has a time course relationship, and it is probably associated to the volume (duration and number of sets) of stretching and the target muscle group. On the other hand, there is a lack of evidences about the effect of different intervals between SS and resistance exercises on repetition performance.

Furthermore, previous evidences suggested that pre-exercise stretching may not prevent injuries or improve athletic and/or stretching performance.^{10,16} However, coaches and practitioners usually adopted stretching exercises before RT with the goal optimize the training sessions durations. For this reason, evidences about exercise models which SS and resistance exercises could be applied in the same exercise session, may be positive and also helps conditioning professionals and practitioners to improve the outcomes without compromising the strength performance.

Therefore, the purpose of this study was to investigate the effect of different intervals between passive SS for hip adductors, quadriceps and hamstring muscles and the repetition performance of resistance exercises for lower body muscles over multiples sets.

Method

Subjects

The study subjects consisted of twenty-two recreationally trained men (25 ± 7 years, 74 ± 30 kg and 175 ± 20 cm). They indicated they were not currently using medical drugs, dietary supplements, or anabolic steroids, and were without joint, muscular or cardiovascular diseases. The experimental conditions were conducted in accordance with the norms of the Brazilian National Health Council, under Resolution No. 466/2012, referring to scientific research on human subjects and Helsinki Declaration. The study was submitted and approved by the Ethics Committee of Federal University of Rio de Janeiro.

Experimental design

The participants initially performed the 10 repetition maximum (RM) test (10-RM) for leg extension (LE), leg curl (LC) and hip adduction (HA).¹⁷ 10-RM retest were applied after a 48-hour to evaluate the test-retest reliability. The testing was carried out until the

subject performer 10 repetitions with the highest load. Three attempts were allowed to find 10-RM loads, and 5-minutes rest intervals were adopted between each trial. Ten minutes of rest interval were adopted between the exercises evaluated. The 10-RM retest was conducted after 48–72 h, starting with the maximum load obtained at the initial test and repeating the same procedure. To minimize the margin of errors the procedures proposed by Miranda et al.¹⁸ were adopted: (a) all the subjects received standard instructions on the general routine of data assessment and the exercise technique of each exercise before testing, (b) the exercise technique of the subjects during all testing sessions was monitored and corrected whenever appropriate, and (c) all the subjects were given verbal encouragement during the test. The subjects were not allowed to practice any exercises during the interval between the testing sessions.

The 10-RM workloads were choosing considering that percentage of 1-RM loads allows greater differences on repetition performance for different muscle groups.¹⁹ The higher 10-RM workload assessed between the two testing sessions was adopted for the exercise sessions. The exercises LE, LC and HA were performed using Technogym equipments (New Jersey, USA). The following positions were adopting to perform the exercises: LE: seated with the back resting on machine support, hip flexed at 90° and knee flexed at 110°. During the exercise, the subject should fully extend both knees, and control the movement to the initial position. LC: seated with the back resting on machine support, hip flexed at 90° and knee fully extended. During the exercise, the subject performs a knee flexion approximately to 110°, and control the movement to the initial position. HA: seated with the back resting on machine support, hip in abduction and flexed at 90° and knee flexed. During the exercise, the subject performs a hip adduction. The participants were instructed to perform the exercise controlling the pace without pause between concentric and eccentric phases. Each set was performed until concentric failure in which the participant was unable to maintain the exercise technique.

In the following test sessions, three exercise sequences were conducted during three non-consecutive days (48–72 h apart) in a randomized crossover design. Protocol without interval (PWI) – the LE, LC and HA were performed immediately after SS exercises for quadriceps, hamstrings and hip adductor muscles, respectively; P15 – fifteen-minute of interval between SS exercises and the performance of LE, LC and HA; P30 – thirty-minute rest interval between SS exercises and LE, LC and HA. RT session consisted of three sets repetition to failure with 10-RM loads for LE, LC and HA exercises adopting 1-minute rest interval between sets and exercises. The number of repetitions completed in each set and exercise was recorded.

A sequence of six stretches (right quadriceps stretching, left quadriceps stretching, right hamstring stretching, left hamstring stretching, right hip adductor stretching, left hip adductor stretching) was repeated for three sets. The researcher demonstrated the proper technique prior to each stretching routine and monitored the subjects' movements throughout stretching to ensure that each stretch was performed correctly. Subjects were informed that the holding point of the stretch was established at the point "just before discomfort".²⁰ Each stretch was held for 30 s followed by a 10-second relaxation period for a total stretching period of 540 s (90 s per muscle). This duration is similar to that typically used by athletes and general population during RT programs.^{9,21} A counterbalance procedure was used to determine the order of stretches.

The positions adopted for the stretching exercise were described below: (a) Leg extensors – the participant was set in the prone position, while the researcher conducting a passive unilateral knee flexion to the point of discomfort displayed by the participant. (b)

Elbow extensors – the participants were placed standing, while the researcher performed passive shoulder abduction with the elbow flexed to the point of discomfort. (c) Leg adductors – the participants were positioned supine while the researcher promoted the horizontal hip abduction with the knee in flexed.

Statistical analysis

Descriptive analyses were presented as the means and standard deviations. The statistical analysis was initially done by the Shapiro–Wilk normality test and by the homocedasticity test (Bartlett criterion). All variables presented normal distribution and homocedasticity. The 10-RM test–retest reliability was calculated through the intraclass correlation coefficient ($ICC = [MS_b - MS_w] / [MS_b + \{k - 1\} * MS_w]$), where MS_b = mean-square between, MS_w = mean-square within, and k = average group size. Two-way ANOVA (protocol × sets) with repeated measures was used to test differences for repetition performance and total work (repetitions × sets) for each protocol and exercise. A one-way ANOVA with repeated measures was computed to compare the total training volume (exercise × repetitions × sets). Significant main effects were subsequently evaluated using Bonferroni's post hoc. A probability value of $p < 0.05$ was used to establish the significance of all comparisons. The statistical analysis was conducted using the software SPSS 20.0 for Windows.

Results

Excellent day-to-day 10-RM workload reliability for each exercise was shown by this protocol. The intra-class correlation coefficients (ICC) for the group were LA (ICC=0.91), LE (ICC=0.93) and LC (ICC=0.94). The paired t test did not show any difference between tests and retest loads for each resistance exercise ($p < 0.05$).

Total training volume (repetitions × sets × exercises) was calculated for LE, LC and HA for each experimental protocols. Significant differences were observed between exercises and sequences ($p = 0.0001$) for total training volume. Training volume under P30 (84.55 ± 1.68) was significantly higher than P15 (79.73 ± 1.89 ; $p = 0.001$) and PWI (68.09 ± 2.03 ; $p = 0.0001$), respectively. Significant differences were also noted under P15 compared to PWI ($p = 0.03$). Significant interactions were noted between repetitions and sets for total work ($p = 0.002$). Total work (repetitions × sets) was higher for LE exercise, under P30 compared to P15 ($p = 0.0001$) and PWI ($p = 0.002$), respectively (Fig. 1). This was also true for LC and HA exercises which showed higher total work under P30

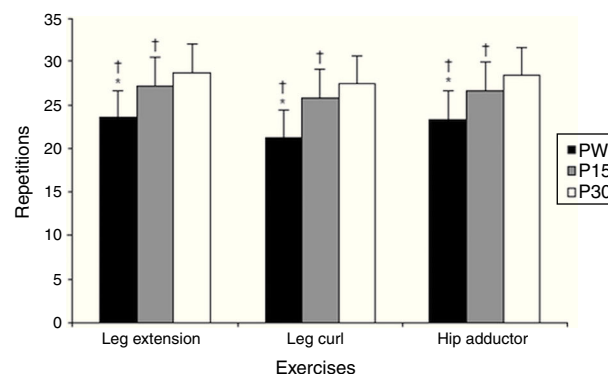


Fig. 1. Total work (repetitions × sets) of each exercise in PWI, P15 and P30 protocols. *: Significant difference for P15; †: significant difference for P30; PWI: RT session performed immediately after SS exercises; P15: fifteen minute interval between SS and RT; P30: thirty minute interval between SS and RT. SS: static stretching; RT: resistance training.

Table 1
Number of repetitions of each set in PWI, P15 and P30.

	Leg extension		
	Set 1	Set 2	Set 3
PWI	8.00 ± 1.32 ^{*,†}	7.00 ± 2.10 ^{*,†}	6.00 ± 2.30 ^{*,†}
P15	9.00 ± 1.02	8.00 ± 2.31	7.00 ± 1.21 [†]
P30	10.00 ± 0.00	8.00 ± 2.32	6.00 ± 1.33
	Leg curl		
	Set 1	Set 2	Set 3
PWI	9.00 ± 1.21	7.00 ± 1.33 ^{*,†}	6.00 ± 1.22 ^{*,†}
P15	9.00 ± 0.31	8.00 ± 1.13	7.00 ± 0.21
P30	9.00 ± 0.92	8.00 ± 0.42	7.00 ± 0.32
	Hip adduction		
	Set 1	Set 2	Set 3
PWI	8.00 ± 1.32 [†]	7.00 ± 0.22	6.00 ± 1.32 ^{*,†}
P15	8.00 ± 0.32	7.00 ± 1.23	6.00 ± 2.34
P30	8.00 ± 1.33	8.00 ± 1.51	8.00 ± 0.33

* Significant difference compared to P15.

† Significant difference compared to P30; PWI: RT session performed immediately after PSS exercises; P15: Fifteen minute rest interval between SS and RT; P30: thirty minute rest interval between SS and RT. SS: passive static stretching; RT: resistance training.

compared to P15 ($p=0.0001$; $p=0.002$) and PSI ($p=0.0001$; $p=0.0001$), respectively. Significant differences were also observed between P15 and P30 for LE ($p=0.031$), LC ($p=0.002$) and HA ($p=0.0001$).

The numbers of repetitions performed per set for each exercise over the experimental protocols are presented as mean and standard deviation in Table 1. A lower number of repetitions performed over the three sets were noted for LE, LC and HA exercises, under PWI compared to P15, except for set 1 of LC, and set 1 and 2 of HA. Similar results were found for all sets when compared to P30, except for the set 2 and 3 of HA. No differences were found between P15 and P30 conditions.

Discussion

The purpose of this study was to clarify the time course of a stretching-induced decrease in repetition performance of lower body exercises. The main finding of the present investigation were the lower number of repetitions performed over the three sets immediately after SS exercises (PWI) when compared to the protocols which were adopted 15 (P15) and 30 min (P30) intervals between SS and RT sessions for LE, LC and HA exercises, respectively. These findings are in agreement with previous studies which observed significant decreases on force production immediately after SS.^{2,4,10,22}

Marek et al.²⁰ also found a decrease in muscle activation, peak torque and isokinetic strength during LE performed immediately after four SS exercises and proprioceptive neuromuscular facilitation exercises for quadriceps muscles. Cramer et al.¹¹ also observed a significant reduction in peak torque during LE exercise at fast and slow speeds after four SS exercises for the quadriceps muscles. However, in the current study, there were significant increases in total training volume performed per set adopting 15-minute (16.1%) or 30-minute (24.2%) interval between SS and resistance exercises compared to the protocol without interval (PWI). These results suggested that progressive intervals between SS and RT exercises may avoid the negative effects induced by stretching exercises on repetition performance for lower body exercises.

Fowles et al.¹⁴ investigated the MVIC of ankle extensors after 30 min of SS and found significant reduction of 28% that persisted

for approximately 60 min after the stretching. Similar results were found by McBride et al.¹⁵ who observed significant reduction in MVIC even after 1, 2, 8 and 16 min of rest interval after three sets with 30 s of SS on quadriceps muscles. However, the authors observed that 30 min after the protocols the MVIC levels returned to control values. Power et al.⁷ also observed a significant reduction in peak torque and MVIC of the knee extensors 60, 90 and 120 min after performed six SS exercises for quadriceps, hamstrings and ankle extensors. However, in the current study, intervals between 15 and 30 min after SS avoided significant decreases in repetition performance during LE, LC and HA exercises compared to PWI. Some peripheral mechanisms have been proposed to explain the reduced muscle activation after stretching as follows: (a) autogenic inhibition of the Golgi tendon reflex,¹² (b) mechanoreceptors and nociceptors,⁴ (c) fatigue-induced inhibition,²¹ (d) joint pressure feedback inhibition because of excessive ranges of motion during stretching,²³ and (e) stretch reflex inhibition originating from the muscle spindles.¹⁰

However, previous studies found opposite results to those observed in the current study associated to PWI. Behm et al.²⁴ found that 135 s of SS exercises for quadriceps and hamstring did not cause significant changes on strength performance. Gomes et al.⁴ found that three sets with 30 s of SS on pectoralis major and quadriceps muscles promoted no significant difference in the number of repetitions completed in the bench press and LE exercises with 40, 60 and 80% 1RM. Ogura et al.⁵ also adopted 30 s of SS and observed no reduction in MVIC during LE and LC. According to Franco et al.² the volume (duration) of the SS is one of the factors that may be responsible for the deleterious effect on the force production. These evidences leaving in doubts the influence of the SS duration on subsequent RT exercise performance.

Furthermore, in the present study, intervals between 15 and 30-minutes showed a higher number of repetitions performed when compared to the protocol without rest intervals between SS and RT. These data indicated that longer intervals between the SS and RT may be an important variable when flexibility and RT are performed in the same training session. The major contributor of the stretching-induced force deficit is unclear (i.e., either a neural factor or mechanical factor). McHugh and Cosgrave²⁵ considered that it may be easier to initiate a neural affect than a viscoelastic effect. These hypotheses may justify the significantly lower repetition performance observed in the current study during PWI. In contrast, several previous studies have indicated that neural effects are more transient⁸ or play a smaller²³ in the stretching-induced force deficit.^{3,9,10,26,27} Therefore, the potential mechanisms underlying the stretching-induced force deficit are not completely understood, and further study has been encouraged to clarify.

Nevertheless, others factors might be responsible for the acute response of stretching on muscle contractibility. Fowles et al.¹⁴ concluded in their study that the decrease on force production was associated with a reduction in motor unit recruitment and activation of Golgi tendon organs. McBride et al.,¹⁵ the prolonged stretching of the fibers determines accommodation in order to compromise the transmission of motor recruitment, inducing muscle strain in plastic components and reducing the muscle tension. It is noteworthy that in the aforementioned studies was not specified if individuals performed flexibility training frequently. Decreased amplitude of surface EMG during MVCs after static stretching provides evidence that the stretching-induced force deficit is attributable to a neural effect.^{13,28}

A secondary finding of the current study in the significant reductions in the number of repetitions noted set per set for all exercises and protocols. These data suggested that 1-minute of rest interval was inadequate to maintain the total work over the three experimental protocols. This is also in agreement with previously

findings reported such as, the study of Miranda et al.²⁹ who found a significant reduction in the number of repetitions per sets using 1-minute compared to 3-minutes rest intervals three sets with 8RM loads for upper and lower body exercises. These data indicated that the rest interval adopted in the current research did not allow a complete level of physiological recovery (i.e., resynthesis of intramuscular phosphocreatine and adenosine triphosphate and removal of detrimental metabolites) adequate to maintain the strength performance.³⁰

One of the limitations of the current study was associated to the SS protocol adopted that was carried out through one exercise for quadriceps, hamstrings and hip adductor, whereas, in previous studies multiples stretching exercises were applied for the same muscle group.^{4,8,9,28} However, the results of the current study may help coaches and RT practitioners, considering that flexibility and RT are usually performed in the same training session.

In conclusion, significant greater repetition performance was noted adopting 30-minute rest interval between SS and RT, when compared to 15-minute and RT performed immediately after stretching. Similar results were observed between P15 and PWI for lower body exercises. Therefore, SS may promote reduction in repetition performance which can last after 15-minute post stretching. Thus, SS may be avoided prior to RT session for lower limb exercises.

Ethical disclosures

Protection of human and animal subjects. The authors declare that no experiments were performed on humans or animals for this study.

Confidentiality of data. The authors declare that they have followed the protocols of their work center on the publication of patient data.

Right to privacy and informed consent. The authors have obtained the written informed consent of the patients or subjects mentioned in the article. The corresponding author is in possession of this document.

Conflict of interest

The authors report no conflicts of interest.

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