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Original Article

ACUTE EFFECT OF DIFFERENT EXERCISES ORDERS IN THE MAXIMUM NUMBER OF REPETITIONS IN PROTOCOLS REALIZED WITH DIFFERENT REPETITION DURATION

EFEITO AGUDO DE DIFERENTES ORDENS DE EXECUÇÃO DOS EXERCÍCIOS NO NÚMERO MÁXIMO DE REPETIÇÕES EM PROTOCOLOS REALIZADOS COM DIFERENTES DURAÇÕES DAS REPETIÇÕES

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RESUMO

O objetivo do presente estudo foi investigar o efeito no número máximo de repetições (NMR), da ordem de execução de dois exercícios que envolvem a participação de musculatura em comum, o agachamento guiado e o flexor de joelhos, em duas durações das repetições. Participaram do estudo 16 voluntários do sexo masculino e treinados na musculação. Os protocolos foram realizados em duas ordens dos exercícios e durações das repetições (livre e 4s) no qual os voluntários realizaram o NMR em cada exercício em duas séries, intensidade de 60% de 1RM, pausa de 90 segundos entre séries e 180 segundos entre exercícios. Foram realizadas duas ANOVAs *two-way* com medidas repetidas para comparação do somatório do NMR e quando necessário aplicado o *post hoc* de *Bonferroni*. Na duração da repetição livre, ambos os exercícios apresentaram um NMR maior quando realizados como primeiro exercício do que quando foram realizados como segundo. Porém, com a duração da repetição de 4s não houve interação nem efeito principal dos fatores analisados. Portanto conclui-se que a duração da repetição é uma variável capaz de modificar os resultados encontrados pelas diferentes ordens de execução dos exercícios.
Palavras-chave: Treinamento de força. Número máximo de repetições. Ordem dos exercícios. Duração da repetição.

ABSTRACT

The objective of this study was to investigate the effect of exercise order of two exercises involving the participation of common musculature (smith machine back squat and leg curl, on the NMR, in two repetition durations. Sixteen trained male volunteers participated in this study. The protocols were performed in two exercise orders and repetition durations (self paced and 4s) in which volunteers realized their NMR in each exercise over two sets, at an intensity of 60% of 1RM, with 90 seconds between sets and 180 seconds between exercises. The ANOVA whit repeated measures were performed for comparison of the NMR and *Bonferroni* post hoc was applied when necessary. Regarding the self paced repetition duration, both exercises presented a higher NMR when performed as the first exercise than when performed as second. However, there was neither interaction nor main effect of the factors analyzed for the repetition duration of 4s. Therefore, it is concluded that the repetition duration is a variable capable of modifying the results found by the different orders.
Keywords: Resistance training. Maximum number of repetitions. Exercise order. Repetition duration.

Introduction

Studies has been investigated the exercise order in resistance training programs[1-4]. However, there still are divergences as to exercise configuration within one same training session. The American College of Sports Medicine[5] recommends that multi-joint exercises should be performed before single-joint exercises, as they are dependent on a more complex neuromuscular control and allow individuals to exercise with heavier weights[4]. Nevertheless, Sforzo and Touey[2] and Monteiro *et al*.[1] found that, regardless of number of joints and size of muscle groups involved, executing an exercise first in a sequence allows reaching a maximum number of repetitions (MNR) that is higher than when it is executed later. However, other situations must be considered, such as use of exercises for different or similar muscle groups, as well as manipulation of other variables such as repetition duration. Some examples are exercises such as smith machine back squat (BS, multi-joint) and leg curl (LC, single-joint), as both demand the hamstring, but in different joint movements – hip extension in the first,

and knee flexion in the second exercise. Although the hamstring has reduced activation during squatting compared to knee flexor exercises and stiff[6], Schoenfeld[7] reports that this muscle, in multi-joint exercises, acts both as antagonist to the quadriceps in knee extension, and agonist in hip extension. Considering, thus, this distinctive participation of the hamstring in single- and multi-joint exercises, it has not yet been duly clarified in the literature how executing these two types of exercises in different orders may impact performance, that is, whether the demand for this muscle in an exercise could interfere with performance in another exercise.

Additionally, repetition duration has been investigated in different protocols[8-10] with values between 2 and 7s[11-13], directly influencing MNR[10], which is a parameter for quantifying training volume[14], as well as a measurement of performance in the exercise. However, the literature provides no information about the effects of manipulating exercise order on MNR in different repetition durations. Self-paced repetition duration may allow the practitioner to adjust accelerations at joint angles of greater mechanical disadvantage in order to maintain performance, which is a common prescription for the training of non-athlete and athletes from different modalities. On the other hand, a fixed duration may hinder these adjustments, since speed would tend to stay close to a constant value throughout the range of motion (ROM). These conditions could interfere with performance in different ways, according to the characteristics of each exercise, such as single- or multi-joint ones, also influencing performance, verified by maximum number of repetitions, mediated by execution order.

Thus, the aim of the present study was to investigate the effect of different execution orders on performance (measured by MNR) in BS and LC exercises, using protocols with "self-paced" and "4s" repetition durations. It is expected that BS and LC, when performed as first exercises, present a higher MNR compared to when they are performed as second exercises with self-paced repetition duration. With 4s as repetition duration, the hypothesis is that there will be a smaller difference in the performance of the exercises in different orders.

Methods

Sample

This study had the participation of 16 male adult volunteers (age: 21.9 ± 3.3 years old; body mass 79.7 ± 9.4 kg; height: 179 ± 10 cm; 1 repetition maximum (1RM) performance in BS: 115.1 ± 11.7; 1RM performance in LC: 94.9 ± 17.9), who had been doing resistance training for at least six months[5], and had no history of musculotendinous injuries in the spine, hips, knees and ankles, or history of use of anabolic steroids. The individuals received information about aim and methods. In sequence, signed an informed consent form. The study was approved by local Research Ethics Committee (legal opinion No 199249).

Procedures

The study employed a block design with repeated measures, in which the volunteers participated in all experimental situations. Collections took place in the Weight Training Laboratory, where each volunteer showed up on seven days separated by a minimum period of 48 and maximum of 72 hours.

The sessions were performed always at a same time of the day for each volunteer, and standardizations referring to position and ROM used in the tests were determined individually and maintained in all sessions.

1RM Test

On the first session, after signing the free and informed consent form, the volunteers were positioned on the equipment and executed procedures for familiarization with the 1RM

tests in each exercise; the execution order was randomly determined. On the second and third days, they performed the 1RM tests in the exercises, maintaining the positions standardized at the first session. Right after each 1RM test, there was a familiarization with the different durations, just as done by Diniz *et al*.[8]. The 1RM test and experimental sessions were carried out on the smith machine (Master®). The weights used had their masses checked on a scale with precision of 100 g (Filizolla®), calibrated beforehand. The leg curl exercise was performed on an equipment where the individual stayed in a sitting position. The 1RM tests were run with a maximum number of six attempts and intervals of three to five minutes[8], and weight was progressively raised until the volunteer was not able to finish a concentric action. Thus, the 1RM value corresponded to the weight lifted in the previous attempt.

Smith Machine Back Squat

The displacement range of the bar and the position of the feet were determined individually after the volunteer found a position that was as similar as possible to his training routine. The upper limit of bar displacement was determined until the full extension of the knees, and the reference for the lower limit was a rubber tape attached to the equipment for when the volunteer reached a knee flexion range close to 90 degrees. This range was determined by means of a goniometer with the axis aligned with the lateral epicondyle of the femur, and the rods with the greater trochanter of the femur and the lateral malleolus. Familiarization and the 1RM test were carried out with two evaluators placing the bar on the volunteer's back, who was standing with his knees extended. At the volunteer's sign, the bar was released, and an eccentric action was performed descending the bar until the lower limit, followed by a concentric action until full knee extension.

Leg curl

The position was determined after the volunteer found a position that was as similar as possible to his training routine for this exercise. A bench fixing strap was wrapped around the pelvic region to minimize accessory pelvic movements. The familiarization procedures and the 1RM test started with the knees fully extended, and flexion was determined until the support mechanical arm of the equipment touched the lower limit of the machine[15].

Training Sessions

During sessions 4 through 7, the volunteers should execute the exercises similarly to the 1RM test, reaching the MNR in each exercise, with two sets, and 90s rest period between sets, 180 seconds between exercises, and intensity of 60% 1RM. The volunteers were allocated in the sessions according to the same criteria as the 1RM test. Therefore, two sessions were executed with self-paced duration and two sessions with duration of 4 seconds – 2s for each muscle action (concentric and eccentric). Duration was controlled from the metronome. Two sessions were performed with the smith machine back squat exercise followed by leg curl, and the other two sessions employed the inverse order.

Statistical Analysis

The data normality was verified using the Shapiro-Wilk test. To compare the MNR performance between experimental situations, 2 two-way Anova with repeated measures were conducted, composed of factors order and exercise, for both different repetition durations (self-paced and 4s). When necessary, a post hoc Bonferroni significant difference test was used to identify the differences reported in the ANOVAs. Statistical analysis was performed with the software SPSS 20.0. Probability was set at $p \leq 0.05$ for statistical significance for all tests.

Results

With self-paced repetition duration, interaction was found between factors order and exercise (F = 14.230, p = 0.002, power = 0.941). The Bonferroni post-hoc evidenced that the BS and LC exercises had a higher MNR when performed as the first exercises, compared to being performed as the second one (order 1: BS = 29.62 ± 8.82; LC = 32.12 ± 8.84; order 2: LC = 38.31 ± 10.61; BS = 25.62 ± 7.72). For order 1 (BS 1st – LC 2nd), there was no difference in performance between exercises, but for order 2 (LC 1st – BS 2nd), the volunteers executed a higher MNR in the LC exercise. Nevertheless, for the 4s duration, no interaction was found between factors order and exercise (F = 10.085; p = 0.006; power = 0.843), neither main effect, that is, the execution order did not interfere with performance in the exercises, and there was no difference in MNR between both exercises, regardless of the order executed (order 1: BS = 22.62 ± 4.87; LC = 18.75 ± 7.62; order 2: LC = 21.87 ± 9.02; BS = 19.81 ± 4.43). The results found in the post hoc can be viewed in figures 1 and 2:

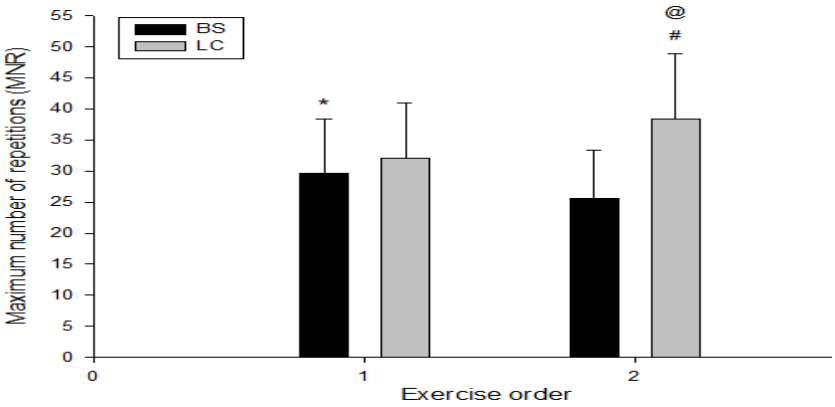

Figure 1. Mean and standard deviation for sum of maximum number of repetitions (MNR) referring to the smith machine back squat (BS) and leg curl (LC) exercises, self-paced repetition duration, both orders. Order 1 (BS 1st – LC 2nd); order 2 (LC 1st – BS 2nd)

Legend: *higher MNR in the exercises when performed first in the sequence; @ LC > BS in order 2 (interaction effect)
Source: The authors

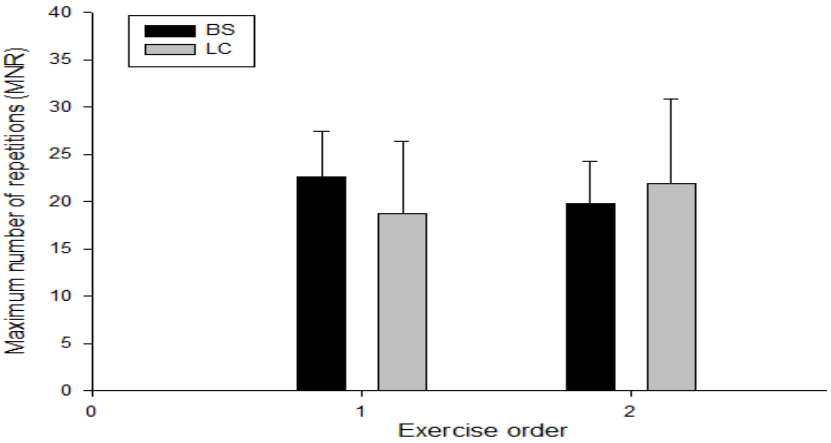

Figure 2. Mean and standard deviation for sum of maximum number of repetitions (MNR) referring to the smith machine back squat (BS) and leg curl (LC) exercises, 4s repetition duration, both orders

Source: The authors

Discussion

Results showed that, with the self-paced repetition duration, exercise order influenced MNR. This finding did not depend on muscle group size and number of joints, because when an exercise was performed first in the order, performance was better than when it was executed as the second one, corroborating with results found in the literature[1-4]. The fact that the hamstring is recruited in both exercises, but in different joint movements, may have affected performance in the second exercise, since this muscle group was requested in the first exercise. Thus, both leg curl (single-joint) and squat (multi-joint) as the first exercise demanded the hamstring, which interfered with performance in the second exercise. Gil *et al*.[16], analyzing number of repetitions in two execution orders, and using leg curl and leg press (multi-joint), also reported a higher number of repetitions for leg curl executed first compared to being executed after leg press, and suggested the occurrence of some prior level of fatigue on the hamstring during leg press. In the present study, however, this result was found only when duration was self-paced.

Moreover, results showed that when BS was performed first, there was no difference in MNR between exercises, but when LC was executed first, it showed an MNR higher than BS. This result was somewhat unexpected because, in addition to being done as the first exercise, BS involves more joints and muscle groups[7], leading to a higher number of motor units being recruited and alternating during the task, which would allow a higher MNR[17]. This finding may be perhaps explained by a difference in the 1RM test. In the BS exercise, the test starts with eccentric action followed by a concentric action; in this case, there was participation of the stretch-shortening cycle (SSC). The effect of using the SSC on muscle strength performance was reported by Wilson *et al*.[18]; these authors analyzed, in bench press exercise, performance in the 1RM test starting with concentric and with eccentric action. In this study it was verified better performance in the second situation, with values up to 18% higher for impulse produced in the first 0.37s of concentric action. This may be explained by the fact that, during an eccentric action, elastic components stretch in the musculoskeletal system, generating an accumulation of elastic potential energy that will be used in the beginning of the concentric action; this enables higher motion speeds in the beginning of the concentric action and generates greater strength responses compared to isolated concentric action[19,20]. Thus, the weight corresponding to 60% of 1RM was determined in this condition. On the other hand, the same test in the LC exercise started with concentric action and, contrarily to squat, the result had no influence of the SSC. Therefore, the results for the tests in these exercises do not reflect one same execution condition. Executing the test in LC starting with eccentric action, just as in BS, would produce a higher absolute value of lifted weight and, as a result, for one same relative intensity of 60% of 1RM, the absolute lifted weight would be heavier, which could reduce MNR compared to the protocol adopted in the present study for leg curl. Additionally, although the 1RM test for leg curl starts with concentric action without SSC participation, in sets performed at 60% there was SSC participation during repetitions, allowing the individual to execute a higher MNR. Therefore, these factors altogether may contribute to understanding the higher MNR in LC compared to BS, contrary to expectations.

However, the effect of order on MNR only manifested with the self-paced repetition duration. With the 4s duration, no differences were found, that is, execution order and the particularities of the 1RM tests were not determinant factors for performance. Therefore, repetition duration presented itself as another mediating variable for results. In self-paced durations, there may be changes in speed and acceleration as a way to optimize performance at different ROMs – for instance, the end of eccentric action in squat, and the second half of concentric action in leg curl; in the first case, to reduce the transition time and optimize the

SSC utilization, and, in the second case, to overcome the ROM in which the sticking point manifests[20]. These changes in acceleration may also happen in moments of greater fatigue with the aim of not interrupting the task. On the other hand, maintaining a pre-determined duration of 2s for each muscle action may hinder changes to the equipment acceleration, since repetitions may be executed at a more stable speed. Although it is possible to expect some changes in acceleration in this situation, voluntary control of duration by the individual could lessen the differences presented before, when reaching the sticking point, for instance.

Studies comparing effects of different execution orders on performance of exercises involving common muscle groups have been neglecting the manipulation of repetition duration[1-4]. The results found in the present research show an interference of this variable, and this should be considered, since training prescriptions suggest manipulations in repetition duration. Thus, definitive recommendations about exercise order prescription[5] should be taken with caution, as the variables of a training program are interdependent and may influence performance in different directions, according to their combinations. Exercise order should not be prescribed isolated from other variables, such as repetition duration, for instance. However, future studies involving a combined manipulation of these variables are still necessary for better understanding how repetition duration can affect responses found in different orders and situations with a higher number of exercises, especially those that require similar muscles.

Conclusions

These results show that, in exercises involving one same muscle group, but in different joint movements, such as BS and LC, the order of the exercises influences MNR, regardless of muscle group size or number of joints involved. However, order is not the only factor that may mediate performance in exercises, since, with the repetition duration of 4s, the order of the exercises did not affect performance. Thus, as a suggestion, the variables that structure a resistance training program should be analyzed in an integrated way, avoiding prescriptions based on isolated analyses. It should be considered that these results may be different when using exercises other than BS and LC, as well as manipulation of other variables besides repetition duration. Furthermore, keeping a record of the self-paced repetition duration may provide more accurate information about how its variability across sets could impact results.

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