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Effect of recovery interval between sets of isokinetic knee extensions among untrained young men

Efeito do intervalo de recuperação entre séries de extensões isocinéticas de joelho em homens jovens destreinados

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Abstract

Objective: To assess the effect of two recovery intervals (RIs) between sets of isokinetic knee extension exercises on peak torque (PT) and total work (TW), among untrained young men. **Methods:** Eighteen men (24.22±2.58 years; 80.42±11.41 kg) performed three sets of ten isokinetic extensions of the right knee, at 60° and 180°/s. The RIs between the sets were one and two minutes long, spread over two test days separated by a minimum of 48 hours. The work-to-recovery ratio was 1:3 and 1:6 for 60°/s, and 1:6 and 1:12 for 180°/s. The subjects had not participated in any resistance training programs within the last six months. The statistical analysis consisted of 2 x 3 repeated-measures ANOVA [RI (one or two minutes) x set (1st, 2nd or 3rd)]. The significance level was $\alpha < 0.05$. **Results:** Neither one minute nor two minutes RIs maintained the PT and TW throughout the three sets ($p < 0.05$). However, at 60°/s, two minutes RIs enabled better PT and TW in the second and third sets than one minute RIs ($p < 0.05$). At 180°/s, two minutes RIs were only better ($p < 0.05$) than one minute RIs for TW in the third set. **Conclusion:** This study indicated that, during an isokinetic training protocol, young men require more than two minutes of RI for full PT recovery at 60°/s and full TW recovery at 60°/s and 180°/s. However, better PT recovery can be attained with a 1:12 work-to-recovery ratio at 180°/s.

Article registered in the Clinical Trials.gov under the number NDT00673998.

Key words: torque; muscle fatigue; quadriceps muscle; knee extension.

Resumo

Objetivo: Avaliar o efeito de dois diferentes Intervalos de Recuperação (IR) entre séries de extensões isocinéticas de joelho no Pico de Torque (PT) e no Trabalho Total (TT) em jovens destreinados. **Métodos:** Dezoito homens (24,22±2,58 anos; 80,42±11,41 kg) realizaram três séries de 10 extensões isocinéticas com o joelho direito a 60° e 180°/s. O IR entre as séries foram de 1 e 2 minutos, contrabalanceados entre os dois dias de teste, separados por, no mínimo, 48 horas. A taxa de trabalho-recuperação foi de 1:3 e 1:6 para 60°/s e 1:6 e 1:12 para 180°/s. Os voluntários não participavam de programas de treinamento resistido há pelo menos 6 meses. A análise estatística foi a ANOVA de medidas repetidas 2 x 3 [IR (1 e 2 minutos) x série (1^a, 2^a e 3^a)]. O nível de significância foi $\alpha < 0,05$. **Resultados:** Tanto 1 como 2 minutos não conseguiram manter o PT e o TT ao longo das três séries ($p < 0,05$). Porém, a 60°/s, 2 minutos de IR possibilitaram um melhor PT e TT na segunda e na terceira série que 1 minuto ($p < 0,05$). Já a 180°/s, 2 minutos só foi superior ($p < 0,05$) a 1 minuto na terceira série para o TT. **Conclusão:** O estudo indicou que durante um protocolo de treinamento isocinético, homens jovens necessitam mais de 2 minutos para recuperar totalmente o PT a 60°/s, e totalmente o TT a 60° e 180°/s. Entretanto, uma melhor recuperação do PT pode ser alcançada com uma taxa de trabalho-recuperação de 1:12 a 180°/s.

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Palavras-chave: torque; fadiga muscular; músculo quadríceps; extensão de joelho.

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Introduction

Muscle strength is recognized in the scientific community as a necessary physical ability for the maintenance of health, functional ability and quality of life¹. Strength training, also known as weight training, resistance training or resistance exercise (RE), has become one of the most popular forms of exercise. RE has been often used in rehabilitation^{2,3} and in the improvement of muscle strength and physical abilities of children, adults and older adults⁴⁻⁶.

To maximize strength and muscle mass gains, the use of multiple sets during a session of RE has shown better results than the use of a single set⁷. However, the superiority of multiple sets is due to the possibility of maintaining a certain work volume for several sets⁸. Therefore, the recovery interval (RI) between the sets can be a decisive factor in maintaining the volume of training sessions or rehabilitation².

Traditionally, the American College of Sports and Medicine (ACSM)¹ recommends a training program with multiple sets and a RI of one to two minutes for beginners and intermediate individuals in the RE. However, there is no consensus in the literature that a 1min or 2min RI is adequate for maintaining volume during multiple sets in individuals with little or no experience with RE. In opposition to ACSM recommendations¹, Rahimi⁹ and Willardson and Burkett¹⁰ observed the superiority of 5min RIs compared to 1min in maintaining volume during sets of squats with trained individuals. Kraemer¹¹ demonstrated that 3min RIs enabled the maintenance of the volume of training in the leg press exercise in subjects with RE experience. In the three studies previously mentioned, the use of 1min RIs did not maintain the volume of training in any of the considered exercises.

Willardson² points out that the choice of RI depends not only on the training objectives but also on other variables, such as: type of muscle action (i.e. isotonic, isometric or isokinetic), muscle fiber composition, loads, number of repetitions and personal experience. Accordingly, some studies have used the isokinetic dynamometer to evaluate the effect of RI in muscle function, however most of these studies used a muscle strength evaluation protocol (i.e. two sets of three or four repetitions)^{12,13}. Few studies have considered the effect of RI on a training protocol with the use of the isokinetic dynamometer in RE inexperienced individuals^{14,15}. Therefore, the aim of the present study was to investigate the effect of two RIs between sets of isokinetic, lower-limb exercise on peak torque (PT) and total work (TW), among untrained young men.

Methods

Sample

Eighteen men (24.22±2.58 yrs old; 175.6±5.12 cm; 80.42 ±11.41 kg) who had not participated, in the six months previous to the study, in any resistance training took part in the current study. The exclusion criteria were chronic disease (diabetes, cardiovascular disease and hypertension), changes in neuromuscular parameters (e.g. muscle injuries) which could affect the result of the study, and the use of medication that could affect muscle function. All participants signed the informed consent form, and the present study project was submitted to and approved by the Research Ethics Committee of the School of Health Sciences - FS of Universidade de Brasília - UnB (protocol 148/2007).

Isokinetic evaluation

The PT and TW were measured by the Biodex System 3 Isokinetic Dynamometer (Biodex Medical, Inc., Shirley, NY). Because some studies have shown that strength gain is velocity specific, the movement velocity was adjusted to 60°/s and 180°/s^{16,17}. The participants were positioned comfortably on the dynamometer seat with safety belts fastened on the trunk, pelvis and thigh to minimize extra body movements which could affect the PT values¹⁸. The lateral epicondyle of the femur was used as a marker to align the knee rotation axis and the instrument rotation axis, allowing free and comfortable knee flexion and extension from 90° flexion to full extension. With the participants positioned on the seat, the following measures were recorded: seat height, backrest inclination, dynamometer height and lever arm length. These measures were recorded to standardize the test position of each participant individually. Gravity correction was obtained by measuring the torque exerted by the lever arm and the participant's leg at full extension and relaxed. The values of the isokinetic variables were automatically adjusted for gravity with the software Biodex Advantage.

The calibration of the Biodex dynamometer was carried out according to the specifications contained in the instruction manual. To reduce the effect of limb deceleration on the following repetition, the lever arm movement at the end of the range of motion was set to the lowest level "Hard" during the test procedure¹⁹. For the test, the participants were asked to cross the arms across the chest²⁰. They received verbal encouragement and visual feedback through the dynamometer's computer monitor to reach the maximum effort level²¹⁻²³. The test procedure was carried out by the same examiner for all participants.

Experimental procedure

The participants performed three sets of 10 repetitions at 60°/s and 180°/s after doing 2-3 submaximum repetitions and 2-3 maximum repetitions with the right limb as preparation for the test. The tests were carried out in increasing order according to velocity, and there was a 10min interval between tests at different velocities. The right limb was used to standardize the test as previous studies did not find differences between dominant and non-dominant lower limbs for isokinetic variables²⁴. The minimum interval between the test days of the different RIs was 48 hours. In accordance with ACSM recommendations¹ for strength and power training, we used 1 and 2min RIs and the velocities of 60°/s and 180°/s. Therefore, the work-to-recovery rate generated was 1:3 and 1:6 for 60°/s and 1:6 and 1:12 for 180°/s. In order to counterbalance the order of the experimental protocols, the participants were randomly divided into two groups. After the group division, group 1 carried out the 1min RI in the first evaluation and the 2min RI in the second evaluation. Group 2 carried out the RIs in reverse order.

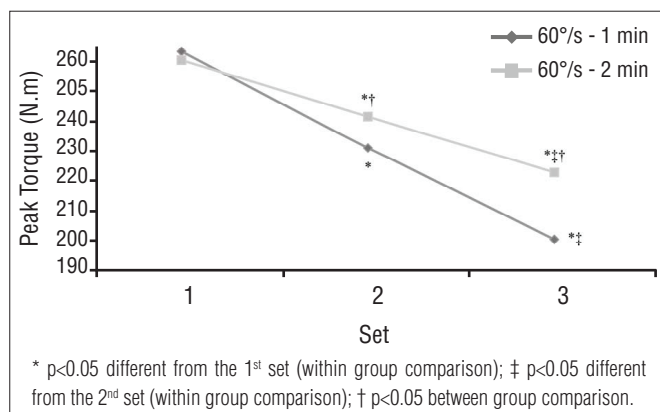


Figure 1. Peak Torque (PT) at 60°/s.

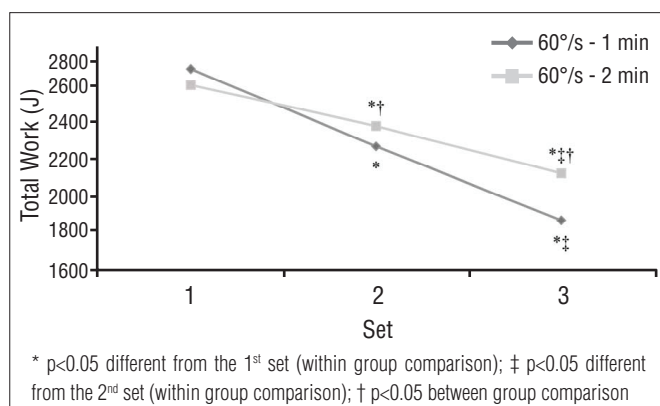


Figure 2. Total Work (TW) at 60°/s.

Statistical analysis

Means and standard deviations were calculated. The Smirnov-Kolmogorov normality test was used to verify data normality. The statistical power (retrospective power) of the present study was set at 0.8 ($\beta=0.2$) both for PT and TW. After calculating the effect size, it was observed that a minimum of 12 individuals would be necessary to avoid the type 2 error for the PT and 14 individuals, for the TW. To evaluate the recovery time for the isokinetic dependent variables, we used a 2 x 3 repeated measures analyses of variance (ANOVA) [recovery interval (1 and 2 minutes) X set (1st, 2nd and 3rd)]. As a post hoc process, we used the multiple comparisons with correction of the confidence interval by the Least-significant difference (LSD) method. The data were analyzed in a personal computer with the statistical software Statistical Package for Social the Sciences - SPSS (version 13.0). The α level was set at 0.05 for all the analyses.

Results

At the velocity of 60°/s, there was a significant reduction in the PT values (Figure 1) over the three sets, regardless of the RI. However, when the RIs were compared, the PT value in the second ($p=0.025$) and third ($p=0.000$) sets of the 2min protocol was higher than those of the sets of the 1min protocol.

The same decrease occurred with the TW at the velocity of 60°/s over the three sets, regardless of the RI (Figure 2). The 2min RI allowed a higher TW value at the second and the third sets when compared with the 1min RI ($p=0.004$ and $p=0.000$, respectively).

At the velocity of 180°/s, there was a decrease in the PT values over the three sets (Figure 3). However, a significant difference ($p=0.002$) was only observed between the first and the third sets with 2min RIs. In contrast, with the 1min RI, a significant decrease in the PT value was observed between the first and second sets, between the first and third sets and between the second and third sets ($p=0.019$, $p=0.001$ and $p=0.025$, respectively). However, there were no significant differences ($p\leq 0.05$) between the PT values in these respective sets when comparing the 1min RI with the 1min RI.

The behavior of the TW at 180°/s was similar to the one at 60°/s (i.e., significant decrease ($p\leq 0.05$) over the three sets) (Figure 4). However, a significant difference ($p=0.014$) was only observed between the third sets when the RIs were compared (1min and 2min).

Regardless of the variable (PT or TW), the 2min RI allowed a better maintenance of these variables over the three sets than the 1min RI (Table 1).

Discussion

The aim of the present study was to compare the effect of two RIs (1min and 2min) during lower limb exercise on PT and TW in untrained men. The choice of exercise protocol (i.e., number of sets, number of repetitions and RI) is in accordance with the recommendations of the ACSM¹ for beginners. The main results were that the 2min RI is better than the 1min RI because it allows a better maintenance of the PT and TW over the three sets of 10 isokinetic knee contractions in untrained men. However, it is important to point out that both 1min and 2min RIs did not provide a complete recovery of the variables over the three sets.

According to Willardson², the RI must allow sufficient replenishing of the energy sources (adenosine triphosphate [ATP] and phosphocreatine [PC]), enable the elimination of by-products of muscle contraction which lead to fatigue (i.e. H⁺ ions) and reestablish muscle strength. Usually a very short RI, such as the one used in the present study, is accompanied by considerable muscle discomfort due to the occlusion of blood flow, lactate production, depletion of the energy sources and decrease in strength production during exercise²⁵. The RIs are important because the performance in subsequent sets is directly related to the recovery time between the sets²⁶. The RI must be controlled not only to allow muscle recovery, but also to enable specific adaptations. Larson and Potteiger²⁵ and Woods et al.²⁷ reported that a short recovery time between the sets leads to a decrease in strength production, and it is used more often to develop hypertrophy because it does not allow a complete recovery of muscle strength between the sets. In contrast, a long recovery time between the sets allows a greater replenishing of the energy pathways, and it is more indicated for muscle strength development. These findings corroborate those of the present study; because the longer RI (2min) allowed better muscle strength recovery than the 1min RI.

Rhea, Alvar and Burkett⁷ point out that the use of multiple sets is better than the simple set because it can maximize strength and muscle mass gains by allowing a greater volume of training. However, a greater volume is only possible if the RI between the sets is sufficient to restore muscle strength. As demonstrated in the present study, more work is only possible with a longer RI. Nevertheless, experimental studies that manipulated the RI between sets to observe the chronic adaptations in the muscle strength gains showed controversial results. Some studies found that a longer RI enabled a greater volume and consequently a greater muscle strength gain^{8,14,28}. In contrast, Garcia-Lopez et al.²⁹ observed that a 4min RI enabled 30% more volume of training than the volume obtained with a 1min RI, but there was no

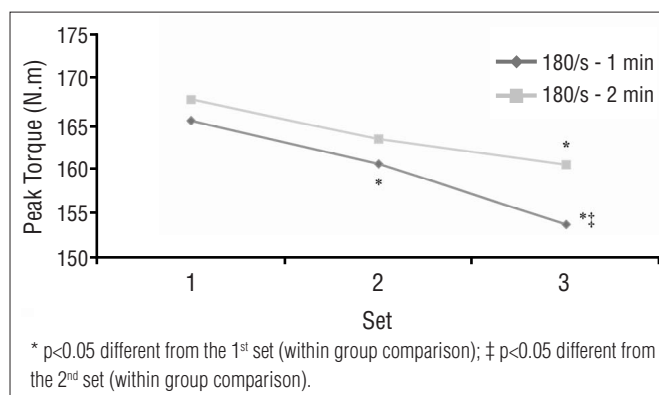


Figure 3. Peak Torque (PT) at 180°/s.

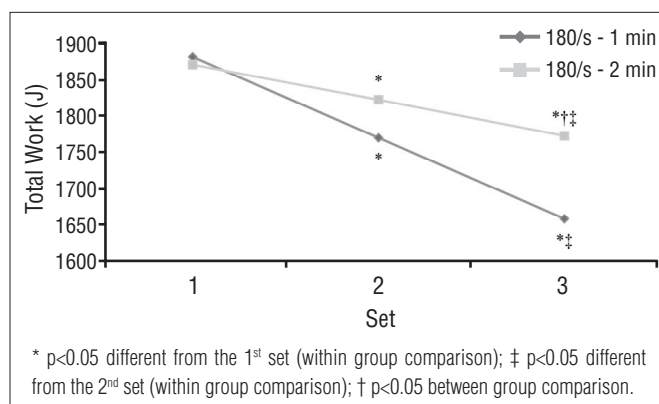


Figure 4. Total Work (TW) at 180°/s.

Table 1. Percentage difference in PT and TW between the 3rd and 1st sets.

	PT		TW	
	1min	2min	1min	2min
60°/s	-24.9%	-14.4%	-30.8%	-18.6%
180°/s	-7.3%	-4%	-12%	-5.3%

PT=Peak Torque; TW=Total Work.

significant difference in muscle strength gain between the two RIs. In a recent study, the authors concluded that great increases in lower limbs muscle strength can be obtained with, at least, a 2min RI, and that a small additional gain can be obtained with a 4min RI between sets³⁰.

In an attempt to better understand the effects of the RI on muscle strength recovery, Pincivero, Lephart and Karunakara¹⁵ demonstrated a significant reduction in the PT and TW when a 40sec RI was used between four sets of 10 concentric repetitions of the quadriceps and hamstring muscles at 90°/s in 15 untrained young people (8 men and 7 women). However, when a 160sec RI was used, the authors did not find a significant reduction in the variables. Thus, the authors concluded that a 160sec RI at 90°/s, i.e. a work and recovery rate of 1:8, is enough to allow muscle strength recovery, regardless of velocity. However, this result

contradicts the present study, as a higher work and recovery rate (1:12 - 2min RI at 180°/s) did not allow the maintenance of muscle strength during the three sets of 10 repetitions.

The different results may have occurred because Pincivero, Lephart and Karunakara¹⁵ used two independent groups with a heterogeneous sample of men and women in the same group. This can be observed in the difference between the initial means of the quadriceps PT among the groups 1 (~180 Nm) and 2 (~157 Nm) of the Pincivero, Lephart and Karunakara's study¹⁵. In addition, several studies have demonstrated that the female gender is more resistant to fatigue than the male gender^{31,32}. Moreover, the PT and TW means generated by the participants of the Pincivero, Lephart and Karunakara's study¹⁵ (~180 Nm and ~1580 J, respectively) were lower than the PT and TW means of the present study (~260 Nm and ~2.600 J, respectively). Studies have shown that individuals who have a greater capacity to produce muscle strength can develop higher levels of fatigue. This can be explained by the fact that stronger men produce greater intramuscular pressure, greater vascular occlusion, greater metabolite accumulation, a decrease in oxygen supply to the muscles and premature failure during prolonged contraction tasks^{31,32}.

Touey, Sforzo and McManis³³ also evaluated the effect of four RIs (30, 60, 120 and 240sec) during four sets of 10 isokinetic quadriceps and hamstring contractions on PT and TW at 60°/s and 180°/s in 28 men (mean age of 20.3yrs). At 60°/s, the results demonstrated that the PT and TW were lower during 30 and 60sec than during 120 and 240sec RIs. However, the TW value at 60°/s was higher with a 60sec

RI than with the 30sec RI in sets 3 and 4, and the TW decreased approximately 34% between the first and the fourth sets with the 30sec RI. At 180°/s, there are no data about the quadriceps PT and TW. However, with regard to the hamstrings, the PT and TW values were lower with the 30sec RI than with the 120 and 240sec RIs. However, the performance with the 60sec RI was equivalent to the 120sec RI, but lower than the 240sec RI. The authors concluded that a 2min RI (120 seconds) is sufficient to optimize muscle performance. These results corroborate those of the present study, which found that a 2min RI was better than a 1min RI at maintaining PT and TW.

The present study demonstrated the importance of the RI to avoid excessive muscle fatigue during RE. The greater the production of muscle strength, the greater the fatigue will be. Based on that, the use of longer RIs (i.e. more than 2 minutes) is necessary to avoid excessive fatigue. This result can also be applied to traditional (isotonic and isometric) exercise to allow the intervention of physical therapists and physical educators who prescribe RE or use it in muscle strength rehabilitation.

Conclusions

According to the results, a 2min RI allows better PT and TW recovery than the 1min RI. However, it appears that full muscle strength recovery is not reached with a 2min RI in protocols and in populations similar to that of the present study.

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