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Effects of different rest intervals on isokinetic muscle performance among older adults

Efeitos de diferentes intervalos de recuperação no desempenho muscular isocinético em idosos

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Abstract

Objective: To compare the effects of different rest intervals (RI) between sets of isokinetic contractions on muscle performance in older adults. **Methods:** Twenty older participants (66.9±3.9 years; 76.1±13.4kg; 169±5.2cm) underwent three sessions of unilateral isokinetic training for the knee extensor muscles, with different RI (1 minute, 2 minutes and 3 minutes) at an angular velocity of 60°•s^{-1}. Each session consisted of three sets of 10 repetitions, during which the peak torque (PT), total work (TW) and fatigue index (FI) were evaluated. Factorial ANOVA for repeated measurements, with Bonferroni *post-hoc* analysis, was used to identify possible differences between the RI. The statistical significance level was set at $p<0.05$. **Results:** No differences in muscle performance during the first sets were observed between the different RI ($p>0.05$). Although muscle performance was lower during the third sets with all RI, the greatest decreases in PT, TW and FI occurred with the 1 minute RI ($p<0.05$). **Conclusion:** The results showed that the RI variable has an important influence on isokinetic muscle performance in older adults, particularly from the third sets onwards, which suggests that RI should be increased as successive sets are performed within the same exercise session.
Article registered in the Clinical Trials under the number NDT00673998.

Key words: resistance exercise; muscle strength; isokinetic contraction; older adults.

Resumo

Objetivo: Comparar os efeitos de diferentes intervalos de recuperação (IR) entre séries de contração isocinética no desempenho muscular em idosos. **Métodos:** Vinte idosos voluntários (66,9±3,9 anos, 76,1±13,4kg, 169±5,2cm) foram submetidos a três sessões de exercício resistido isocinético unilateral da musculatura extensora do joelho com diferentes IR (1 minuto, 2 minutos, e 3 minutos) na velocidade de 60°•s^{-1}. Cada sessão consistia em três séries de 10 repetições durante as quais foram avaliados o pico de torque (PT), trabalho total (TT) e índice de fadiga (IF). ANOVA fatorial para medidas repetidas, com a análise de *Post hoc* por Bonferroni, foi utilizada para identificar possíveis diferenças entre os IR. O nível de significância estatístico utilizado foi de $p<0,05$. **Resultados:** Não foram observadas diferenças no desempenho muscular entre as 1as séries nos diferentes IR ($p>0,05$). Apesar de ter sido observado menor desempenho muscular na 3^{a} série em todos os IR, maiores quedas no PT, TT e IF foram observadas quando adotado o IR de 1minuto ($p<0,05$). **Conclusão:** Os resultados mostraram que a variável IR exerce importante influência sobre o desempenho muscular isocinético em idosos, principalmente a partir da 3^{a} série, o que sugere incrementos no IR à medida que séries subsequentes forem executadas durante a mesma sessão de exercícios.
Artigo registrado no Clinical Trials sob o número NDT00673998.

Palavras-chave: exercício resistido; força muscular; contração isocinética; idosos.

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Introduction

The existing literature on the physiology of aging indicates that the human capacity to generate muscle strength diminishes with age, particularly among people over 60[1,2]. This process is attributed to the atrophy of the muscle tissue (sarcopenia) and to the loss of muscle fibers[3,4]. According to some authors, the reduction in muscle strength and power influences the loss of autonomy experienced by older adults in performing their daily activities, such as walking, climbing stairs, sitting down and getting up from a chair[5,6]. Resistance exercise has resulted in effective changes in muscle strength and power, as well as in the maintenance of the functional abilities[7,8]. However, the use of this type of training for older adults has only been accepted in the past two decades, as it was previously considered too aggressive for this population[9].

The use of isokinetic dynamometers was initially proposed for the evaluation of muscle strength in different populations. Nevertheless, studies have detected more rapid strength gains by means of training with the isokinetic rather than traditional methods, due to the greater induction toward maximal strength production during the full range of motion[10]. However, the benefits originating from the prescription of isokinetic contractions must respect several factors such as intensity, frequency, and volume. These factors are the result of a combination of the number of repetitions, sets, loads, sequence, and rest interval (RI) between the sets and the exercises[11-13]. Muscle rehabilitation programs for strength gain apply different RI durations between the sets of exercises without any scientific proof. The choice of a particular RI duration is commonly based on the training goals, although the intervals should be adjusted according to several other criteria.

A factor that may influence the process of muscle strength recovery is age. Bottaro, Russo and Oliveira[14] studied the influence of different RI durations (30, 60, and 90 seconds) in isokinetic contractions, to evaluate the peak torque (PT) in a group of older adults and concluded that 30 seconds would be enough time for the participants to recover the strength before starting a new testing set. This fact was confirmed by Parcell et al.[15] who also studied different RIs (15, 60, 180, and 300 seconds) in young adults, showing that 60 seconds would be needed for the total recovery of the PT evaluation in isokinetic contractions. The work developed by Parcell et al.[15] also reports that other studies use different RI durations, ranging from 30 seconds up to 3 minutes. It should be noted that the protocols followed by Bottaro, Russo and Oliveira[14] and by Parcell et al.[15] aimed at evaluating muscle function and not at rehabilitating muscle strength.

With regard to studies which used muscle strength protocols by means of isokinetic contractions, Bilcheck et al.[16] compared three different RI durations in young women (2.5, 5, and 10 minutes). The authors concluded that 2.5 minutes can be used without compromising muscle strength. In another study, Pincivero, Lephart and Karunakara[17] applied a protocol of four sets of 10 repetitions each in young adults and demonstrated that 40 seconds are not enough for the full recovery of the isokinetic muscle strength evaluated by means of the PT at an angle speed of $90°•s^{-1}$.

Therefore, in spite of the use of isokinetic dynamometers as a tool for the rehabilitation of muscle strength gain in different populations[10,18], there is no study to date that has investigated the effects of the RI on the prescription of isokinetic exercise as a form of muscle rehabilitation among older adults. Thus, the aim of the present study was to compare different RI durations between the isokinetic contraction sets in the muscle performance of older adults.

Methods

Sample

The group who took part in this study consisted of twenty-five older adult males who attended the institution's physical activity project and who had been doing combined aerobic exercises for at least six months, and no more than two years. All participants initially underwent a clinical evaluation by the laboratory cardiologist including an electrocardiogram at rest, blood pressure, cardiovascular risk analysis, and full anamnesis. After the cardiovascular risk analysis, individuals with uncontrolled hypertension were excluded from the study. As the tests were being carried out, two participants were also excluded on medical grounds, and three others did not attend the entirety of the sessions. Twenty participants in all underwent the three test sessions. This study was approved by the Research Ethics Committee of Universidade Católica de Brasília (protocol number 072/2004). Before the tests began, the participants signed a consent form which explained the goal, procedures, likely discomforts, risks, and benefits of the study.

The criteria for inclusion were as follows: 1) age between 60 and 75 years, 2) regular physical exercise (at least 1 hour a day, twice a week) in the past 6 months, at least, and 3) body mass index (BMI) $<30Kg/m^2$. The criteria for exclusion were: 1) uncontrolled hypertension, 2) cardiovascular diseases, 3) history of knee pain that might limit activities of daily life, 4) history of musculoskeletal disorder, 5) neural disease or previous fracture in the lower limbs, or 6) use of pharmaceuticals that could affect the mechanisms of muscle contraction.

Procedures

The sessions were carried out in an air-conditioned institutional laboratory, on three different days, and the interval between sessions was of at least 48 hours and no more than seven days. The specific RI for each session (1 minute, 2 minutes, or 3 minutes) was applied in a counterbalanced order, in three groups chosen at random, at an angle speed of 60°•s^{-1}. Each session consisted of three sets of 10 repetitions. The participants executed all sessions at the same time of the day. They were told not to do any physical activity concomitant with the experiment.

Initial evaluation

After receiving permission from the laboratory cardiologist, the participants were measured for BMI with a digital scale (Toledo©, São Bernardo do Campo, SP, 2001) and height with the use of a stadiometer (Country Technology Inc., Gays Mills, WI, 1999). The body composition was measured with a skin fold caliper (Lange©, Santa Cruz, California, 1999). With these measurements, the body density was calculated by means of the sum of three skin folds for men[19]. The body density was converted into fat percentage by means of the Siri equation[20].

Warm-up

A warm-up session was carried out on a cycle ergometer (Lode, Excalibur model), with a 50W load, for 5 minutes. After the warm-up on the cycle ergometer, a specific warm-up exercise was added, also serving to familiarize the participant with the Biodex System 3 isokinetic dynamometer (Biodex Medical Systems Inc., Shirley, NY, 2002). This warm-up consisted of a set of 10 repetitions at an angle speed of 300°•s^{-1} [14].

Muscle performance evaluation

A Biodex isokinetic dynamometer was used to evaluate the muscle performance of the unilateral concentric extension of the right knee. The lateral femoral epicondyle was adopted as the biological axis, and then aligned with the axis of the dynamometer in the sitting position with the trunk at 80º flexion. The maximum stabilization was applied in order to minimize the cooperation of muscle groups other than the knee extensors[21]. The positioning for the settings and test followed the guidelines put forward by Stumbo et al.[21]. For the evaluation of the fatigue index (FI), the formula suggested by Sforzo e Touey[22] was used.

All the tests were carried out by the same examiner, and before each session the dynamometer was calibrated following the instructions of the manufacturer. The settings for each participant were noted down with the purpose of keeping the same position in all sessions. The weight of the limb to be tested was also calculated in order to correct for gravity.

Statistical treatment

The normality of the data was evaluated by means of the Kolmogorov-Smirnov test. ANOVA 3 X 3 for repeated measures was carried out [RI (1 minute, 2 minutes, and 3 minutes) x set (1st, 2nd, and 3rd)] with the Bonferroni *post hoc* analysis for the variables (PT and TW) by means of the statistical package SPSS for Windows, version 11.5. The level of significance was $p<0.05$. The statistical power calculated for 20 individuals was >0.80.

Results

The 20 participants who completed the study had a mean age of 66.9±4.0 years; mean body mass of 76.7±13.5kg; mean height of 1.69±0.05m; mean BMI of 26.7±4.3Kg/m^2; and mean relative fat mass of 20.6±6.3%.

The PT results for the knee joint muscles at an angular speed of 60°•s^{-1} are displayed in Figure 1. There was no significant difference in the PT between the RIs in the 1st set. When possible differences within the groups were compared, the 1-minute RI showed a significant decrease in the PT of the 3rd set when compared to the 1st and 2nd sets. As for the 2 and 3-minute RIs, there was a significant reduction in the PT of the 3rd set when compared with the 2nd ($p<0.05$). No differences occurred between the 1st and 2nd sets in the 2 and 3-minute RIs. As for possible differences between the sessions, smaller values were observed in the 3rd set of 1-minute RI when compared with the 3rd set of the 2 and 3-minute sessions. Smaller values were also observed in the 2nd set of the 1-minute session when compared with the 3-minute session ($p<0.05$).

The results for total work (TW) are shown in Figure 2. There was significant difference in the TW between the RIs of the 1st set. When comparing possible differences within the groups, there was a significant drop in the TW of the 1-minute session of the 3rd set when compared with the 1st and 2nd sets. The same happened in the 2-minute session, in which no significant reduction of the TW of the 3rd set was detected compared with the 1st and 2nd sets. Furthermore, in the 3-minute session, smaller TW values were observed in the 3rd set when compared separately with the 2nd set. When possible differences between the groups were compared, smaller values were observed in the 2nd and 3rd sets of the 1-minute session, compared with the respective set, both in the 2-minute and 3-minute sessions. Moreover, a smaller value was also recorded in the 3rd set

during the 2-minute RI when compared to the respective set in the 3-minute session ($p<0.05$).

The FI results are shown in Table 1. A higher FI was observed when the 1-minute RI was adopted (FI=13.86%). Thus, the FI was inversely proportional to the RI, and its values were 6.99% and 4.26% for the 2 and 3-minute RIs, respectively.

Table 1. Fatigue index (FI%) and delta peak torque (ΔPT=N.m^{-1}) during different rest intervals (n=20).

Variable	Rest Interval		
	1 min	2 min	3 min
Δ PT (N.m^{-1})	16.98	5.46	3.46
FI (%)	13.86	6.99	4.26

ΔPT=PT delta (1st set – 3rd set); (FI) Fatigue Index ($FI = [(TW_{(1^{st}\ set)} - TW_{(3^{rd}\ set)}) / TW_{(1^{st}\ set)}] \times 100\%$).

Discussion

The aim of the present study was to compare the effects of different RIs on the isokinetic muscle performance of older adults while performing three sets of 10 unilateral repetitions of the right knee extensors at a speed of 60°•s^{-1}. This protocol was applied following the recommendations for resistance exercise to increase muscle strength[12,23]. The results of the research showed that the duration of the RI may influence the isokinetic muscle performance among older adults. However, what stands out is the conclusion that the RI has a greater influence after the second set of exercises, when used for that purpose.

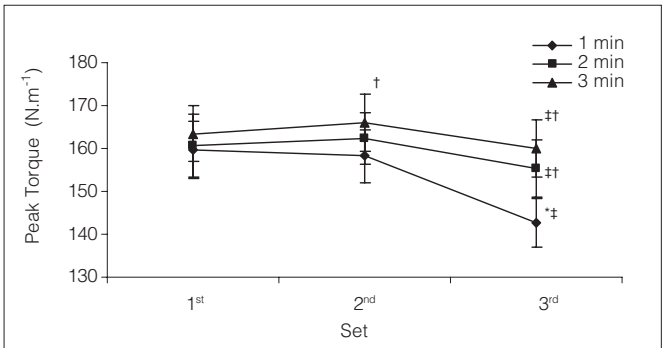

Figure 1. Peak Torque (PT) within and between different rest intervals (1min, 2min and 3min) at 60°•s^{-1} (n=20).

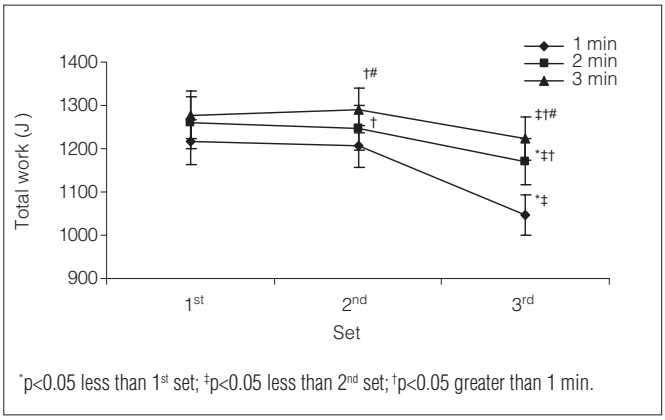

Figure 2. Total work (TW) within and between different rest intervals (1min, 2min and 3min) at 60°•s^{-1} (n=20).

In a meta-analysis, Rhea, Alvar and Burkett[24] concluded that the use of multiple sets is superior to the simple set to enhance strength gain and muscle mass in resistance exercises. This study has been used to justify the fact that the maintenance of the work volume is imperative to the increase in muscle strength. Nonetheless, the superiority of the multiple sets is due to the possibility it has of sustaining a given number of repetitions for innumerable sets[25]. Thus, the RI may be a decisive factor to maintain a volume of training for several sets, as it could provide a sufficient recovery time to the energy sources (i.e. adenosine triphosphate [ATP] and phosphocreatine [PC]). It also allows the elimination of the byproducts of the muscle contraction which lead to fatigue (i.e. H^+ ions) thus reestablishing muscle strength[26].

In the present study, the use of RI of only 1 minute reduced PT and TW values in the 3rd set in comparison with the other sets (1st and 2nd sets), when applying 10 subsequent maximal contractions at an angle speed of 60°•s^{-1}. Moreover, the decrease in PT and TW for 2 or 3-minute RIs only occurred from the 2nd to the 3rd set.

According to Brown and Weir[27], the state of neural preactivation may justify the appearance of greater PT values in the 2nd set for 2 and 3-minute RIs because, according to those authors, a previous neural activation of the movement stimulates the production of muscle strength as it aids the muscles being exercised by preparing them for an optimal muscle performance. In contrast, Gossen and Sale[28] question the efficacy of very short RIs in the action of a possible post-activation potential, which might explain the exception of this pre-activation behavior in the 1-minute RI. Sweeney, Bowman and Stull[29], in turn, claim that the post-activation potentialization results from the phosphorylation of the myosin regulatory light chain, through the myosin light chain kinase, which possibly enhances the interaction between the myosin cross-bridge and the actin filament, making this interaction more sensitive to the calcium released by the sarcoplasmatic reticulum. These facts may partly explain the maintenance of the PT and TW in the 2nd set.

Several studies on isokinetic muscle contraction tried to determine the ideal RI, using the most varied protocols for

resistance exercises. One such study carried out by Bottaro, Russo and Oliveira[14] showed that, in isokinetic contractions of the knee extensor muscles of older adults, only 30 seconds are necessary for the total recovery of the strength levels when a protocol for the evaluation of muscle strength is applied. The difference between the study developed by Bottaro, Russo and Oliveira[14] and the present study may be attributed to the volume of protocols. Bottaro, Russo and Oliveira[14] used two sets of four repetitions each, whereas in the present study the protocol included three sets of 10 repetitions each.

The present data confirm those put forward by Touey, Sforzo and McManis[30] who observed a significant decrease in PT at a speed of 60°•s^{-1}, after the application of 30 and 60-second RI between the sets (3x10) of isokinetic contraction of the knee extensor muscles. Pincivero, Lephart and Karunakara[17] also noted a reduction in the PT values when only 40 seconds of RI were applied in a protocol consisting of four sets of 10 repetitions each, at an angle speed of 90°•s^{-1}. Furthermore, Bilcheck et al.[16] applied three sets of 30 repetitions at 120°•s^{-1} and reported that 2.5 minutes could be used as RI duration without compromising the production of strength in young women. In another study by Pincivero et al.[31], the PT values in young adults were different when comparisons were made between the 40 and 160-second RIs in a protocol of four sets of 20 repetitions.

By using isoinertial exercises (squatting and supine), Willardson and Burkett[32] compared three different RIs (30 seconds, 1 minute, and 2 minutes) in the capacity to maintain the work volume using five sets of 15 maximal repetitions. The study showed that a RI of at least 2 minutes would be needed to maintain the strength levels of this protocol. Ratamess et al.[33] observed the effects of different RIs (30 seconds, 1, 2, 3, and 5 minutes) on the metabolic responses in supine exercise. The sample (n=8) was divided into two groups (G1, n=4; and G2, n=4) which executed a protocol that consisted of two blocks (1st block: five sets of 10 repetitions at 75% 1RM; and 2nd block: five sets of five repetitions at 85% 1RM). The results showed that shorter RIs (30 seconds and 1 minute) would lead to a reduction of 15 to 55% in the work volume. With regard to the 2-minute RI, the results confirmed the maintenance of the performance only in the first two sets, and a decrease ranging from 8 to 29% in the following series. When the 3-minute RI was adopted, the reduction in volume was of approximately 21% in the 4th and 5th sets. Finally, when the 5-minute RI was used, the reduction in muscle performance was only noted in the 5th series. The maintenance of the levels of strength in the first series, as the RI increases, corroborates the results of this study.

Some mechanisms may be extrapolated in relation to the results of the FI put forward in the present research. Muscle contraction leads to the degradation of energy sources and to the accumulation of metabolites which interact with the contractile proteins, making it more difficult to carry out subsequent exercises[34]. This may worsen when the time of contraction is longer, as observed at lower speeds (e.g. 60°•s^{-1}), and subsequent exercises are executed without the due RI, that is, the ratio time of recovery not being suitable to the time of execution. According to Siqueira et al.[35], at low speeds, the recruitment of motor units is greater, which also contributes to a better muscle performance and to a greater accumulation of metabolites. Moreover, the ratio of time under tension to recovery time is a factor that may influence the restoration of the energy pathways. In the present study, this ratio was 1:3, 1:6, and 1:9 for the 1-minute, 2-minute, and 3-minute RIs, respectively.

In this study, the decrease in muscle performance, which was observed especially in the 3rd series when the 1-minute RI was adopted, may be partly explained by the onset of fatigue, defined as the loss of maximal muscle strength production and characterized by a reduced work capacity[34]. Although it was not evaluated, one of the factors that may have contributed to the decrease in muscle performance in the remaining sets is the central fatigue. Another important factor for that reduction is the degradation of the substrata such as phosphocreatine, reduction in muscular and hepatic glycogen, as well as intramuscular acidosis originating from the exercises, particularly those of high intensity, which contributes to the onset of a fatigue condition[36]. The ATP demand on the skeletal muscles during high intensity exercise is initially sustained by the phosphagen and glycolytic systems[37]. The cause for strength loss during the onset of muscle fatigue is attributed to different mechanisms, from the command of movement production via the central organs to local mechanisms such as the interactions between the contractile proteins.

Currently, there is evidence that the mechanisms responsible for the onset of fatigue are multifactorial and specific to the muscle activity being executed[38,39]. According to Maughan, Gleeson and Greenhaff[40], the initial process that leads to the appearance of fatigue results from the reduction in the anaerobic production of ATP or from the increase in the accumulation of adenosine diphosphate (ADP) caused by the absence of PC and by the decrease in the rate of glycogen hydrolysis. The RI between the sets of resistance exercise is a variable that is not studied often although it determines the magnitude of the resynthesis of the phosphagen energy supplies (ATP-PC) and of the anaerobic glycolysis. These metabolic routes are important during high-intensity exercise; hence, muscle performance and metabolic responses can be affected according to the use of the RI[41].

Another relevant point is that the use of the same RI for young adults and older adults must be handled with caution, because young adults have higher proportional values of fast twitch fibers (type II), capable of producing more strength than the slow twitch fibers (type I), although they are not as efficient in terms of resistance[42]. Preliminary studies make it evident that older adults are more resistant to fatigue than young adults when they execute prolonged and intermittent muscle contractions[43-45]. It is believed that this could be related to the greater capacity young adults have to produce strength when compared to older adults. This might favor greater intramuscular pressure, greater occlusion in the blood flow, and a larger accumulation of metabolites[46-48].

Malffati et al.[49] claim that the increasing use of isokinetic dynamometers in orthopedic rehabilitation programs demands some knowledge of the physiological adjustments generated by this type of exercise. Thus, the results of the present study allowed us to conclude that the RI variable has a great influence on the isokinetic muscle performance of older adults. It could also be pointed out that there was some impairment to the isokinetic muscle performance with 1-minute intervals and particularly in the 3rd series of the remaining RIs. These results suggest that, to maintain the work volume during a rehabilitation session of muscle strength in older adults, the RIs should not only last more than 1 minute, but they should also be increased as the subsequent sets are carried out.

The results of the present study are specific to the isokinetic tests and more commonly applied in rehabilitation and research centers. Therefore, professionals who deal with training and rehabilitation must pay special attention to the factors that may influence muscle fatigue, such as age and sex, when they prescribe resistance exercises to different populations. Further studies must be developed comparing the different RIs between different populations, such as older adults *vs* young adults, men *vs* women, children *vs* adolescents. More importantly, longitudinal studies on the effects of RIs on the rehabilitation of the muscle strength need to be developed.

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