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Original Article

EFFECT OF CONTRACTION VELOCITY IN THE ECCENTRIC PHASE ON RATING OF PERCEIVED EXERTION

EFEITO DA VELOCIDADE DE CONTRAÇÃO NA FASE EXCÊNTRICA SOBRE A PERCEPÇÃO SUBJETIVA DE ESFORÇO

Ramon Luciano Silva[1], **Leonardo Carvalho Caldas**[1], **Carlos Brendo Ferreira Reis**[1], **João Francisco de Oliveira Junior**[1], **Richard Diego Leite**[1] and **Lucas Guimarães-Ferreira**[1]

[1]Federal University of Espírito Santo, Vitória-ES, Brazil.

RESUMO

O objetivo do presente estudo foi analisar a influência da velocidade de execução na percepção subjetiva de esforço (PSE) e o volume de repetições em diferentes velocidades. Métodos: A amostra foi composta por 10 voluntários do sexo masculino (23,4 ± 5,4 anos), com no mínimo 6 meses de experiência no treinamento de força. Os participantes realizaram 8 séries de até 8 repetições com intensidade de 60% de 1RM em diferentes velocidades de execução de movimento: cadência lenta (6020), cadência moderada (2020) e cadência livre. Foram avaliadas a PSE (escala OMNI-RES) e o volume de repetição executadas em cada condição. Resultados: O número de repetições executadas nos protocolos de cadência lenta e moderada foi menor quando comparada ao protocolo livre (p < 0,05) a partir da 2ª e 6ª séries, respectivamente. A PSE no protocolo de cadência lenta foi maior quando comparado com as outras cadências (p<0,05). Conclusão: Os protocolos de cadência lenta e moderada reduzem significativamente o número de repetições realizadas e resultam em maior percepção subjetiva de esforço quando comparado com cadência livre.

Palavras-chave: Treinamento de resistência. Contração Muscular. Fadiga Muscular. Esforço Físico.

ABSTRACT

The objective of the present study was to analyze the influence of execution velocity on rating of perceived exertion (RPE) and on volume of repetitions at different velocities. Methods: The sample consisted of 10 male volunteers (23.4 ± 5.4 years old) with at least 6 months of experience in strength training. The participants performed 8 sets of up to 8 repetitions with an intensity of 60% of 1RM at different velocities of movement execution: slow cadence (6020), moderate cadence (2020) and free cadence. RPE (OMNI-RPE scale) and volume of repetitions performed in each condition were assessed. Results: The number of repetitions executed in the slow- and moderate-cadence protocols was smaller compared to that in the free protocol (p <0.05), as of the 2nd and 6th sets, respectively. RPE in the slow-cadence protocol was higher compared to that in the other cadences (p <0.05). Conclusion: The slow- and moderate-cadence protocols significantly reduce the number of repetitions performed and result in a greater rating of perceived exertion in comparison with free cadence.

Keywords: Resistance training. Muscle contraction. Muscle fatigue. Physical Effort.

Introduction

Strength training performed on a regular basis is recognized for increasing muscle mass and strength, as well as for improving body composition and the execution of daily and sports activities[1]. Thus, the manipulation of training variables (exercise order, recovery interval, weekly frequency, volume and intensity) is essential to ensure organic adaptations in the short and long term[1-3]. Intensity manipulation can be determined by load/intensity (kg), time interval between sets and exercises, exercise selection and order, range of motion, and velocity of movement execution (cadence)[4,5].

Controlling the velocity of movement execution can bring about different physiological responses, favoring strength gain and preventing injuries[4,6,7]. Fast movement velocities can boost increases in muscle power[8], while the use of controlled velocities with an emphasis on the eccentric phase induces a longer muscle tension time, increasing the recruitment of contractile and structural proteins. Additionally, a greater energy expenditure and metabolic disorder associated with tissue damage and inflammatory processes may be associated with increased protein turnover and muscle growth[7]. At slower velocities, fatigue, reduced strength production and reduced neural activity are observed[6].

A simple, reliable, safe and validated strategy for controlling intensity during strength training is the OMNI-RPE scale[9,10]. The OMNI rating of perceived exertion (RPE) scale is used as a means to assess perceived exertion during strength training, being correlated with increased lactate concentration, increased load percentage (1RM) and neuromuscular activity[9,10]. Different acute variables of strength training can be manipulated to induce desired adaptations. However, movement cadence, often neglected, has a direct effect on perceived exertion and training volume[4,11,12]. Therefore, it is necessary to investigate how acute responses deriving from different movement cadences affect the volume of repetitions and RPE. Thus, the hypothesis of the present study is that a lower velocity of movement execution will induce a greater RPE compared to moderate and fast velocities. Therefore, the objective of this research was to analyze the influence of execution velocity on RPE and on volume of total repetitions in three protocols with different execution velocities.

Methods

Participants

Ten male volunteers (23.4 ± 5.4 years old, 82.5 ± 37.5 kg, 177.2 ± 19.2 cm) were selected to participate in the study; they had at least 6 months of experience with strength training and no history of joint injury in the shoulder, elbow and wrist. All individuals signed a free and informed consent form. The experimental protocol was approved by the Ethics Committee of the Federal University of Espírito Santo, in compliance with the resolution of the Brazilian National Health Council No 466/12 (CAAE: 5302212.0.0000.55.42).

Maximum Strength Test (1RM)

A specific warm-up was performed during a bench press, which consisted of 2 sets of 10 repetitions, with a 2-minute interval and 50% of the estimated load, from the load mentioned by the participants for 10 repetitions maximum. After the warm-up, a 5-minute break was allowed for the first attempt at the maximum strength test (1RM).

A total of five attempts were used to determine the maximum load (1RM). There was a rest interval of 5 minutes between each attempt. The highest load lifted by the subject in the test was used as a parameter to determine the intensity of the training sessions[14].

Rating of Perceived Exertion Scale

After the 1RM bench press test, a session for familiarization with the OMNI rating of perceived exertion (RPE) scale was performed in order to present the procedures adopted in the experimental sessions to the participants; the exercise was executed at different movement velocities (cadence) between the muscle contraction phases, with the aid of a researcher who tracked the time using a digital stopwatch.

During the experimental sessions, RPE values were collected at the end of each set and 10 minutes after the training session (session RPE). Muscle pain before the start of each session was assessed in order to prevent any eventual muscle pain resulting from the previous experimental session from interfering with the subsequent session. The method consisted of pressing the belly of the pectoralis major and the triceps muscles; afterwards, the individuals reported their level of discomfort, quantified through a scale graduated from 0 to 10, with 0 = "no pain" and 10 = "extreme pain"[15].

Experimental Protocol

The participants were subjected to three protocols randomly distributed, with an interval of 72 hours between them and pre-established movements. The subjects performed three experimental protocols: Protocol A – 8 sets of up to 8 repetitions, with a load referring to 60% of 1RM in the bench press, and movement velocity of 2 seconds in the concentric phase, and 6 seconds in the eccentric phase (6020). Protocol B consisted of 8 sets of up to 8 repetitions, with 60% of 1RM and movement velocity of 2 seconds in the concentric phase, and 2 seconds in the eccentric phase (2020). Protocol C consisted of 8 sets of up to 8 repetitions with 60% of 1RM and free movement velocity (Table 1). Verbal encouragement was applied to help the individuals reach the pre-established repetition. The movement cadence of the protocols was controlled and guided by an experienced researcher using a digital stopwatch, who would give a verbal feedback aloud during the execution of the repetitions in each set and between each phase of concentric and eccentric muscle contraction. The criterion adopted for interrupting the experimental session was when the participant completed the 8 repetitions and/or following a concentric failure. To calculate the volume of repetitions, the number of repetitions in each set was recorded.

Table 1. Experimental Protocols

Protocols	Sets	Repetitions	%RM	Movement Speed (seconds)
A	8	8	60%	2’’ concentric and 6’’ eccentric (6020)
B	8	8	60%	2’’ concentric and 2’’ eccentric (2020)
C	8	8	60%	Free

Source: The authors

Statistical Analysis

Data are presented as mean and standard deviation. The normality of data distribution was assessed using the Kolmogorov-Smirnov test. RPE and number of repetitions per set were analyzed through two-way analysis of variance (ANOVA) for repeated measures – 3 (execution velocity) x 8 (sets). Bonferroni's post hoc was used whenever a main or interaction effect was detected. The number of total repetitions and the mean session RPE were analyzed using one-way ANOVA with Bonferroni's post hoc. The statistical software Graphpad Prism, version 6.0, was used for all analyses. A significance level of $p < 0.05$ was used.

Results

The statistical analysis revealed main effect for cadence ($P < 0.0001$; $F = 31.66$), main effect for set ($P < 0.0001$; $F = 107.1$) and cadence x set interaction effect ($P < 0.0001$; $F = 17.23$), suggesting that the number of repetitions performed is affected by velocity of movement execution (cadence), by number of sets and by the interaction between these factors.

For the group that performed the movements at free velocity, no changes were observed in the number of repetitions during the 8 sets (Figure 1). A significantly lower number of repetitions ($p < 0.0001$) per set was found in the slow-velocity protocol as of the 2nd set, in comparison with the other protocols. The moderate-velocity protocol showed a significantly lower number of repetitions (≤ 0.033), as to number of repetitions per set, compared to the free-velocity group as of the 6th set (Table 2).

Table 2. Number of bench press repetitions after each set as a function of different cadence protocols

Protocols	Bench press repetitions							
	Set 1 Mean (SD)	Set 2 Mean (SD)	Set 3 Mean (SD)	Set 4 Mean (SD)	Set 5 Mean (SD)	Set 6 Mean (SD)	Set 7 Mean (SD)	Set 8 Mean (SD)
Free cadence	8 (0)	8 (0)	8 (0)	8 (0)	8 (0)	8 (0)	8 (0)	8 (0)
2020 cadence	8 (0)	8 (0)	8 (0)	7.9 (0.32)	7.6 (0.97)	7.3 (1.34)†	7.1 (1.45)†	6.8 (1.62) †
6020 cadence	7.9 (0.32)	6.1 (1.52)*	5.1 (1.1)*	4.2 (1.23)*	4.3 (1.25)*	4.1 (0.99)*	3.9 (0.99)*	3.4 (1.17)*

Note: Main effects: Cadence P <0.0001; Sets P <0.0001; Interaction P <0.0001; * = indicates significant difference (P <0.05) for groups 6020 vs 2020 and 6020 vs Free within the same set; + = indicates significant difference (P <0.05) between groups 2020 vs Free within the same set
Source: The authors

The number of total repetitions performed at slow velocity was statistically lower compared to that of the protocol performed at moderate and free velocities (P <0.0001; F = 107.1) (Figure 2).

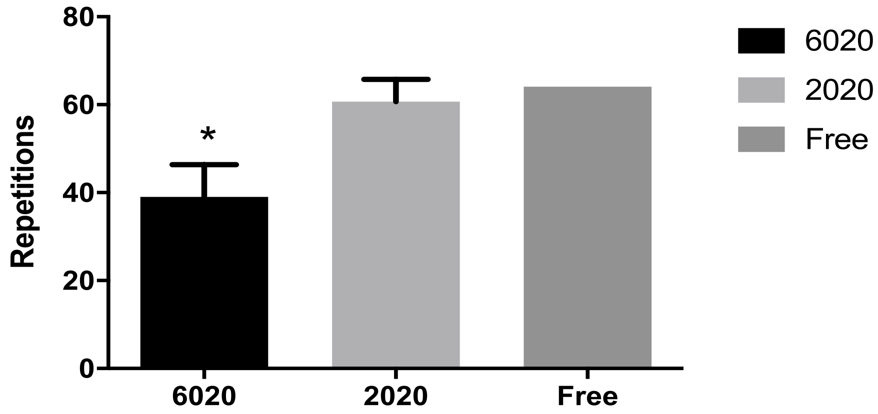

Figure 2. Number of total repetitions at three movement velocities (6020, 2020 and free)
Note: Data expressed as Mean ± SD. * = Indicates significant difference (P <0.05) for groups 6020 vs 2020 and Free
Source: The authors

As for RPE, main effect was found for cadence (P <0.001; F = 60.35), main effect was found for set (P <0.0001; F = 55.35), and interaction effect was found for cadence x set (P <0.0001; F = 5.62), suggesting that RPE assessed through the OMNI-RPE scale is influenced by velocity of movement execution, by number of sets and by the interaction between these factors (Table 3).

The RPE values in the slow-velocity protocol were statistically higher compared to the moderate-velocity (P ≤0.0008) and the free-velocity (P <0.0001; Table 3) protocols. The same result was observed when the moderate-velocity protocol was compared to the free-velocity protocol (P <0.0001; Table 3).

Table 3. Perceived exertion with the OMNI-RPE scale in the bench press after each set as a function of different cadence protocols

Protocols	Bench press repetitions							
	Set 1 Mean (SD)	Set 2 Mean (SD)	Set 3 Mean (SD)	Set 4 Mean (SD)	Set 5 Mean (SD)	Set 6 Mean (SD)	Set 7 Mean (SD)	Set 8 Mean (SD)
Free cadence	1.4 (0.97)	2.1 (0.88)	2.3 (0.95)	2.7 (1.06)	3.1 (1.1)	3.7 (1.34)	4.4 (2.17)	4.4 (2.07)
2020 cadence	3.5 (1.96)†	4.3 (1.95)†	5.3 (2.0)†	6.3 (2.0)†	7.3 (2.0)†	7.9 (1.73)†	8.0 (1.49)†	8.4 (1.58)†
6020 cadence	6.7 (2.06)*	8.7 (1.64)*	9.3 (1.34)*	9.4 (1.07)*	9.6 (0.7)*	9.8 (0.42)*	9.8 (0.42)*	9.8 (0.42)*

Note: Main effects: Cadence P <0.0001; Sets P <0.0001; Interaction P <0.0001; * = indicates significant difference (P <0.05) for groups 6020 vs 2020 and 6020 vs Free within the same set; + = indicates significant difference (P <0.05) between groups 2020 vs Free within the same set
Source: The authors

The training session RPE was significantly higher at slow velocity compared to that at moderate velocity (P = 0.0002) and free velocity (P <0.0001), whereas the values observed in the moderate-velocity protocol were statistically higher compared to those of the free-velocity protocol (P = 0.01) (Figure 3).

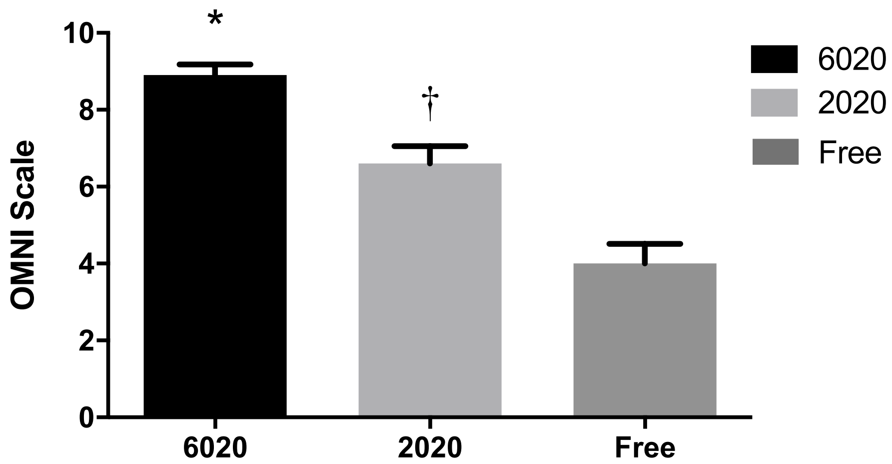

Figure 3. Rating of perceived exertion – training session mean
Note: Data expressed as Mean ± SD. * = Indicates significant difference (P <0.05) for groups 6020 vs 2020 and Free. † = Indicates significant difference (P <0.05) for groups 2020 vs 6020 and Free
Source: The authors

Discussion

The purpose of this study was to analyze the influence of movement execution velocity within three protocols (Slow 6020 x Moderate 2020 x Free) on RPE, during repeated bench press sets, and to identify possible changes in the total number of repetitions performed in each experimental condition. The main findings were a) the 6020 cadence protocol induced a significantly greater rating of perceived exertion compared to the other protocols; and b) the number of total repetitions was influenced throughout the sets, showing a significant reduction in the 6020 protocol.

The study showed that the protocol with the longest total time under tension, due to the slow movement velocity (6020), presented RPE values higher than those of the other protocols (6020 > 2020 > free). Such condition is related to a momentary increase in difficulty of execution and exercise intensity, as well as, possibly, to a physiological increase in lactate, phosphocreatine depletion and decreased blood pH, which can induce a greater RPE during strength exercises[5,11]. As a result of these physiological changes, there may be a reduction in the number of repetitions throughout the sets[16], which was also verified in our study, thus corroborating our initial hypothesis.

Regarding RPE, Lagally et al.[11] reported that the execution of strength exercises at a greater intensity (80% 1RM) resulted in a higher RPE compared to the protocol at 60% 1RM with equalized volume. On the other hand, when bench press was executed until concentric failure at 50% or 70% of 1RM, no difference in RPE was observed, despite the greater total weight lifted in the 50% 1RM condition16. In a study conducted by Silva et al.[16], cadence was free, i.e., not controlled by the researchers. In their turn, while investigating the influence of cadence on RPE, Diniz et al.[12] showed that the participants who performed the experimental protocol at a slow movement velocity (2 seconds of concentric action for 4 seconds of eccentric action) presented a higher RPE, both per set and total, and a lower volume of total repetitions than in the protocol consisting of 2 seconds of concentric action for 2 seconds of eccentric action, and in the free-velocity protocol.

In the present study, the participants who performed the protocols at moderate (2020) and free movement velocities presented a lower RPE throughout the sets, as well as and higher volumes of repetition, corroborating the findings of Day et al.[16], according to which the group that executed the protocol with less intensity performed a greater number of repetitions and presented a lower RPE. RPE is related to the exertion to which one is exposed; the muscles subjected to an overload have an increase in the recruitment of motor units and in the frequency of neural firing, resulting in a perception of greater exertion[16].

Concerning volume of total repetitions, the slow-velocity protocol promoted reductions in the number of repetitions throughout the sets in comparison with the protocols performed at moderate and free velocities (6020 > 2020 > Free). This finding corroborates with Hatfield et al.[4], who subjected healthy men with experience in strength training for at least 1 year to execution at different intensities (60% vs 80% of 1RM), at two different movement velocities (Super slow – 10 seconds in the eccentric phase, and 10 seconds in the concentric phase vs Free). The authors found that, at both intensities, the execution of the movement at a slow velocity resulted in a lower number of total repetitions, with cadence possibly being a determining variable for volume of repetitions between sets and for total repetitions.

The present study indicated that cadence manipulation can be used to stimulate momentary concentric failure. All participants in the free-cadence group were able to perform 8 sets of 8 repetitions without reaching concentric failure. In the moderate-cadence group (2020), one participant, in the 4th set, reached concentric failure before being able to complete the 8 repetitions. In the 8th set, 5 participants in this group were unable to complete the 8 repetitions. In the slow-cadence group (6020), soon in the 1st set, one participant was unable to complete the 8 repetitions and, as of the 3rd set, none of the participants in this group was able to complete the 8 repetitions. Therefore, these results indicate that cadence manipulation can be used to increase the time under muscle tension and induce momentary concentric failure in the first repetitions of each set, and that it may also interfere with adaptations caused by strength training[17].

For instance, in a study carried out by Burd et al.[17], the effect of time under tension on protein synthesis stimulation was assessed. Eight healthy men participated in the study; they underwent two unilateral knee extension exercise protocols, performing 3 sets with loads of 30% of 1RM that consisted of slow movements (6060 cadence) until failure, or fast movements (1010 cadence) with paired volume but without reaching failure. The slow protocol stimulated greater increases in the recruitment of motor units and increases in myofibrillar protein synthesis between 24-30 hours after the exercise was executed. The fast protocol, however, was not able to stimulate increases in myofibrillar protein synthesis. Because changes in muscle mass are correlated with changes in myofibrillar protein synthesis[18], these data suggest that, when strength exercise is performed at low intensities, the cadence of the movement can be determinant for muscle hypertrophy by raising the time under tension and stimulating momentary concentric failure, which seems to be necessary when training is performed at low intensity (<60% 1RM)[19].

Cadence also appears to directly interfere with gains in muscle strength and power. Pareja-Blanco et al.[20] assessed the effect of two strength training programs at different movement velocities. The MaxV group performed a given prescribed number of repetitions at the highest intentional velocity, while the other group performed the same prescribed number of repetitions using half the required movement velocity intentionally. Both training programs were performed 3 times a week for 6 weeks using squats only. All training variables were paired, except for velocity of movement execution in the concentric phase. Both groups showed performance increases with training. However, when compared to each other, the higher-velocity group showed better results on different tests, as evidenced by its larger effect sizes (ES) for counter-movement jumps (ES = 0.63 vs. 0.15), 1RM test (ES = 0.94 vs. 0.54), and mean propulsive velocity with low loads (ES = 1.76 vs. 0.75), high loads (ES = 2.03 vs. 1.64) and all tested loads (ES = 1.76 vs. 0.88).

Recently, a meta-analysis study pointed in the same direction, indicating that, in strength training at moderate intensities (60-79% of 1RM), greater gains in dynamic strength are achieved when the velocity of execution is fast, and that, although slow cadence also stimulates strength gains, they are smaller[21]. Therefore, such research suggests that, when the goal is to develop dynamic strength, using a faster cadence of movement would be more interesting. It also reports that these results are independent of the participants' training status or age.

Thus, as practical applications, movement velocity (cadence) can significantly influence RPE and volume of repetitions between sets during strength training. As a result, cadence is a variable that needs to be adequately controlled, as it has the ability to interfere with volume and momentary difficulty during the exercise. It can be used as a method to raise training intensity without need for additional load increases. However, the choice must take into account the main goal of the training, as manipulating the velocity of movement execution can also affect the type of expected chronic adaptation.

Conclusions

The present study suggests that a slower execution velocity in strength training can significantly reduce the number of total repetitions, as well as progressively increase the rating of perceived exertion, in comparison with moderate and free velocities, influencing on the volume and intensity of training sessions.

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Authors' **ORCID:**
Ramon Luciano Silva: https://orcid.org/0000-0002-1831-8207
Leonardo Carvalho Caldas: https://orcid.org/0000-0001-8936-1061
Carlos Brendo Ferreira Reis: https://orcid.org/0000-0003-4663-3770
João Francisco de Oliveira Junior: https://orcid.org/0000-0002-6809-9970
Richard Diego Leite: http://orcid.org/0000-0001-7937-6972
Lucas Guimarães-Ferreira: https://orcid.org/0000-0002-2970-7355

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Author address: Lucas Guimarães-Ferreira. Av. Fernando Ferrari, 514, Centro de Educação Física e Desportos, Universidade Federal do Espírito Santo, Goiabeiras, Vitória/ES. CEP [Postal code]: 29075-910. E-mail: lucas.ferreira@ufes.br