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Effect of Movement Range in Maximum Number of Repetitions in Weight Training Exercises

João Elias Dias Nunes*, José Vitor Oliveira Marson

Avenida Benjamin Constant, 1286, District Aparecida, Uberlândia-Minas Gerais.

Corresponding Author:** ***João Elias Dias Nunes, *Avenida Benjamin Constant, 1286, District Aparecida, Uberlândia-Minas Gerais*

Abstract: *Volume in resistance training can be estimated by the sum of the number of repetitions or number of series performed. To evaluate the effect of movement amplitude on maximum number of repetitions in exercises on preacher curl, squat bench press and verifying if the use of the metronome is adequate to control speed of execution in these exercises. Tests consisted of four visits by volunteers to the laboratory, on different dates, with an interval of at least 48 hours without training. One-repetition Maximum (1-RM) and maximum repetitions test (MRT) were performed, with 70% of 1-RM. Amplitudes and speed of movements were controlled by means of a visual feedback device and aid of a metronome. By analyzing data significant differences were obtained in maximum number of repetitions in different motion amplitudes with same relative percentage of 1-RM in all exercises proposed by study. Squat exercises with total amplitude and exercises on the preacher curl with partial amplitude, presented a variation of -8.58 and 16.66%, respectively, in relation to time target established for performing movements. It can be concluded that movement amplitude interferes in the number of repetitions performed, where larger amplitudes cause reductions in the number of repetitions.*

Keywords: *Volume; movement amplitude; preacher curl; squat; bench press; velocity of execution.*

Abbreviations: *1-RM: One-repetition Maximum; MRT: Maximum Repetitions Test; PC: Preacher Curl; BP: Bench Press.*

1. INTRODUCTION

Resistance training has become very popular in recent decades. Presently it is considered an important component for training in most sports, as well as for rehabilitation and injury prevention [1].

As with all physical training, in resistance training, correct instructions and an adequate quantification of the dose-response relationship are necessary in order to achieve relevant results[2].

The application of the "dose" is carried out by the manipulation of training variables, also called acute variables. Among them, volume is one of the most relevant. Volume can be measured by the amount of work (joules) in a given period of time, or it can be estimated by the sum of the number of repetitions of each series performed [2, 3].

The *American College of Sports Medicine* orientates a number of different repetitions (volume) to be performed in resistance exercises in order to achieve different goals, such as strength, hypertrophy, resistance or power, in the same way as it does for different levels of subjects (beginners, intermediate or advanced) [5, 6], which indicates the importance of manipulating this variable in order to achieve different objectives with resistance training.

By the fact that the number of repetitions is an important variable for the prescription of resistance training, several studies have tried to identify factors that influence same. Order, intensity, execution speed, interval between series and sport specialty, are some of these factors [7, 8, 9, 10]

LIMA et al. (2012) aimed at analyzing the maximum number of repetitions in exercise of free bench press, in different amplitudes of movement, both partial and complete [11]. The results indicated that performing the movement with partial amplitude leads to a greater number of repetitions for same relative intensity. However, in this study the duration of repetition was not controlled, which may have

caused a change in execution speed between partial and complete amplitudes for same volunteer, and it is not possible to verify whether amplitudes, partial and complete, were really accomplished, since no resource was used to record the amplitude of each repetition. Therefore, it is necessary to investigate the effect of amplitude of movement on maximum number of repetitions with tools which are more precise.

Furthermore, studies that investigated factors involved in number of repetitions, made use of the metronome to control duration of repetition. As no equipment was used to attest and record whether the repetitions were even being performed at established rhythm, doubt remains as to whether small changes in rhythm could influence results.

In this manner the objectives of this study were to evaluate the effect of movement amplitude on the maximum number of repetitions on the preacher curl, squat, and bench press exercises, as well as verifying whether the use of the metronome is reliable to control speed of execution in these exercises.

2. Materials and Methods

2.1. Sample

For this study 14 volunteers were recruited. The following inclusion criteria were adopted: a) to declare oneself as healthy; b) to have at least 6 months experience consistent with resistance training; c) to be available to interrupt any type of physical training during the period of this study; d) to be male; e) to be between 18 and 25 years of age.

Table1. *Characterization of sample.*

	Average ± Standard Deviation
Age (years)	22,0± 1,79
Body Mass (kg)	81,02±14,85
Height (m)	1,76±0,07
Body Mass Index (kg.m^2)	26,07± 5,00

2.2. Experimental Design

Tests were made up of four visits of approximately 40 minutes, by volunteers to the Motor Performance Research Laboratory (LAPDEM), at the Faculty of Physical Education and Physical Therapy (FAEFI), Federal University of Uberlândia (UFU), on different dates, with an interval of at least 48 hours without training. Movement amplitudes to be performed were determined by way of a draw, as well as the order of performing the exercises.

Day 1: Anthropometric evaluation and judgment of whether the volunteer would fit the inclusion criteria. One-repetition maximum (1-RM) on exercise curl of preacher curl(PC) with full or partial amplitude; 1-RM test in squat exercise with full or partial amplitude and 1-RM test on bench press (BP) with full or partial amplitude.

Day 2. 1-RM PC test (amplitude not drawn on Day 1); 1-RM squat test (amplitude not drawn on Day 1) and 1-RM bench press test (amplitude not drawn on Day 1).

Day 3. Maximum repetitions test with 70% of 1-RM (MRT) PC with full or partial amplitude; MRTsquat with full or partial amplitude and MRTBP with full or partial amplitude.

Day 4: MRTPC (amplitude not drawn on Day 3); MRTsquat (amplitude not drawn on Day 3) and MRTBP (amplitude not drawn on Day 3).

Os testes realizados, a amplitude de movimento, bem como, a ordem de execução dos exercícios Tests carried out, range of movement as well as order of execution of exercises were defined by drawing lots on each of the days of the survey. A ten (10) minute interval was given between each test.

2.3. Anthropometric Evaluation

The anthropometric evaluation consisted in measuring body mass of volunteers, using a digital scale (Fiziola, Brazil), as well as measuring height by using a wall stadiometer (Sanny, Brazil).

2.4. Description of Exercises

For bench press exercise (bench press, Axcess Fitness Equipament, Brazil), total amplitude was defined as movement from 180º to 75º of elbow flexion, and partial amplitude from 180º to 127.5º of elbow flexion, for initial and final positions, respectively. The volunteers were instructed to lie down in a dorsal decubitus position on the straight bench, with their feet supported on the ground. The positioning of hands was set from the smallest angulation performed during exercise.

In exercise preacher curl(Scott bech, Axcess Fitness Equipament, Brazil) the total amplitude was set from 90º to 180º of elbow joint, and partial amplitude from 90º to 135º of elbow joint, for initial and final position, respectively. Volunteers were positioned on bench so that upper front region of trunk was completely supported, positioning arms in front from a small shoulder flexion.

In squat the total amplitude (Smith Machine, Axcess Fitness Equipament, Brazil) was defined as 180º to 90º of knee joint, and partial amplitude from 180º to 135º of knee joint, for initial and final position, respectively. Volunteers were instructed to support equipment bar on trapezium, with feet slightly in front of hip, positioned parallel to width of shoulders.

Angulations were measured and determined with a manual plastic goniometer (Carci, Brazil). For bench press and squat exercises, an electrical circuit was used, connected to a bar which generates a luminous stimulus when reaching the pre-established angulation, in order to limit movement. In the preacher curl exercise, movement extension was delimited to ensure that the desired angulations were respected. An apparatus adapted from a Mirage TT3395 tripod with height adjustment together with a cardboard rolled horizontally on top was used.

Adjustments of each equipment were properly positioned and recorded for each volunteer, being maintained in all tests.

2.5. One-Repetition Maximum Test (1-RM)

Before starting the 1-RM test the volunteer was submitted to a sequence of preparatory exercises, consisting in: 1º) 15 dynamic repetitions with bar weight; 2º) 7 dynamic repetitions with 50% of subjective load; 3º) 3 dynamic repetitions with 70% of subjective load, indicated by volunteer. A sixty (60) second interval was granted of given between preparatory exercises.

Volunteers had 5 attempts to determine maximum repetition, with two minutes rest between each attempt. All movements began with eccentric phase.

2.6. Maximum Repetitions Test (MRT)

From day three, in which MRT was started, we coupled a kinematic variables meter (Peak Power Model, Cefise, Brazil) to the side of equipment bar in order to precisely obtain displacement speed and amplitude of movement performed. This equipment consists of an electronic system interfaced with software that measures displacement speed of any body in an amplitude of up to 2.5 meters. Speed is measured by a precision stopwatch connected to a wire that can be attached to dumbbell or to weight column of devices or to any other point defined by user.

To begin the MRT, it was necessary to have a draw for execution order of exercises and their respective amplitudes, and then to perform a warm-up protocol similar to 1-RM test, a procedure that used the proposed rhythm for repetitions in order to promote familiarization.

Target execution rhythm of exercises was controlled from a metronome positioned at 30 beats per minute (BPM) for amplitudes considered as total, being 2 seconds for eccentric phase and 2 seconds for concentric phase, and 60 BPM for amplitudes considered as partial, with 1 second for eccentric phase and 1 second for concentric phase.

Two minutes after preparatory exercise protocol the volunteer had an attempt to perform the MRT, until concentric failure.

2.7. Statistical Analysis

Statistic a software version 10 was used for statistical analysis. The Shapiro-Wilk test was used to check data normality. *Student's t* hypothesis test was carried out for data that presented a normal distribution, but when distribution was abnormal, the Wilcoxon non-parametric hypothesis test was used. The significance level adopted was $\alpha \leq 0.05$.

3. Results and Discussion

The data below demonstrate relative and absolute intensities used, as well as 1-RM obtained.

Table2. *Maximum force and resistances used in MRT.*

	1-RM (kg)	Absolute Resistance (kg)	Relative Resistance Relativa(%)
BPPartial Amplitude	103,85 ±26,05	72,14 ±18,35	69,42 ± 0,49
BPTotal Amplitude	77,71 ± 26,65	54,00 ±18,49	69,51 ± 0,78
Squat Partial Amplitude	186,42 ± 50,32	130,00 ± 35,52	69,64 ± 0,34
SquatTotal Amplitude	111,71 ± 36,72	77,85 ± 25,94	69,55 ± 0,62
PCPartial Amplitude	49,07 ± 14,01	34,00 ± 9,86	69,23 ± 1,22
PCTotal Amplitude	34,28 ± 8,83	23,57 ±6,08	68,74 ± 2,23

Note: *1-RM = one-repetition maximum; BP = bench press; PC = preacher curl. Data presented as mean ± standard deviation.*

Table3. *Number of repetitions, range of motion and velocity on bench press, squat and preacher curl for partial and total amplitude.*

	Repetitions (n)	**ROM (mm)**	**Velocity (m/s)**
Bench Press			
Partial Amplitude	13,2 ± 3,5*	336,4 ± 113,4*	0,34 ± 0,12
Total Amplitude	9,9 ± 2,3	731,2 ± 98,3	0,40 ± 0,06
Squat			
Partial Amplitude	18,2 ± 2,5*	360,2 ± 110,5*	0,39 ± 0,09*
Total Amplitude	13,1 ± 4,0	795,0 ± 124,7	0,46 ±0,07
Preacher Curl			
Partial Amplitude	16,2 ± 4,0*	445,4 ± 67,8*	0,39±0,06
Total Amplitude	13,7 ± 3,1	781,7 ± 74,0	0,41±0,04

Note: *ROM = range of motion. Data presented as mean ± standard deviation. * $p < 0,05$ in comparation with total amplitude.*

The maximum number of repetitions was significantly lower when movement with total amplitude was performed compared to partial amplitude for squat ($p = 0.004$), preacher curl ($p = 0.019$) and bench press ($p = 0.020$) exercises.

Total range of motion was significantly greater ($p < 0.05$) when movement with total amplitude was performed compared to partial amplitude for squat, preacher curl and bench press exercises.

Velocity of movement was significantly higher when movement with total amplitude was performed compared to partial amplitude for squat exercise, however, there were no significant differences in preacher curland bench press ($p < 0.05$) exercises.

Table4. *Represents mean time per repetition and distance to target established and controlled by metronome.*

	Average Time/Repetition (s)	Average Difference to Targer (%)
BPTotal Amplitude	3,84 ± 0,48*	-4,07 ± 12,00
BPPartial Amplitude	2,08 ± 0,38	3,97 ± 19,00
SquatTotal Amplitude	3,66 ± 0,53*	-8,58 ± 13,25
SquatPartial Amplitude	1,91 ± 0,22	-4,33 ± 11,00
PCTotal Amplitude	3,98 ± 0,22*	-0,48 ± 5,50
PCParcial Amplitude	2,33 ± 0,28	16,66 ± 14,00

Note: *1-RM = one-repetition maximum; BP = bench press; PC = preacher curl. Data presented as mean ± standard deviation. Target consisted of 2s per repetition in exercises with partial amplitude and 4s per repetition in exercises with total amplitude.* * $p < 0,05$ in comparation with partial amplitude.*

Time per repetition was significantly greater ($p < 0.05$) when movement with total amplitude was performed compared to partial amplitude for squat, preacher curl and bench press exercises.

The main objective of this study was to evaluate the influence of motion amplitude on maximum number of repetitions in BP, squat and PC exercises. For this purpose, we sought to equalize intensity

and speed of movement between amplitudes, to ensure that results were explained only as a function of amplitude difference. For all exercises more repetitions were obtained ($p<0.05$) when movements were performed in partial amplitude than in total amplitude, indicating that increase in amplitude reduces maximum resistance for these exercises. (Table 3).

Even speed of movement in squat having been significantly higher for total amplitude (Table 3), which could be a complicating factor in conclusion obtained, the effect of amplitude of movement is not invalid, because this greater observed speed would tend to produce a greater number of repetitions for total amplitude, amplifying differences between the two conditions. According to PEREIRA et al. (2007) a greater speed of intentional movement allows for a greater number of repetitions in fixed load exercises, because once the inertia is overcome, momentum of load is greater and, consequently, force to move it can be reduced [7].

In this way, even performing squat in full amplitude, with higher speed, and therefore obtaining a greater number of repetitions, the squat in partial amplitude presented a higher number of maximum repetitions, and therefore not eliminating the effect of resistance drop caused by higher amplitude.

This result is in accordance with the study of LIMA et al. (2012), which when analyzing BP exercise, found a greater number of repetitions when using partial amplitude [10].

Some studies [11, 12, 13] reveal the existence of a point or region, called "sticking-region", of mechanical disadvantage when performing free weight exercises with complete amplitudes, such as those performed in this study (BP, squat, PC). In this region speed of movement decreases as a function of intermuscular and intramuscular coordination, resulting in a reduction of sustained force [14].

Studies indicate that for BP this region occurs at a distance of approximately 23.77 cm from the chest, or at an angle of 120° of elbow joint [15, 16]. In other words, at an amplitude subsequent to the point of greatest range of motion. The partial amplitude for BP, used in this study, did not reach the "sticking-region" for this movement, which could explain greater number of repetitions observed at this amplitude.

On the other hand [17], when analyzing knee extension exercise isometrically identified that there are joint angles that have a greater ability to perform force, which leads us to the understanding that there are favorable angles for application of force and angles that promote mechanical disadvantages throughout execution.

This evidence is in line with findings of this study, since in the squat exercise, a smaller number of repetitions were found when using full amplitude, suggesting that same has angles at a mechanical disadvantage.

Another factor that has been used to explain why partial amplitude exercises result in more repetitions is muscle damage. BARONI et al. (2016) affirm that as well as intensity, volume and speed of movement, amplitude of movement is one of the causes of muscle damage. When analyzing the PC exercise, he found that, despite having a lower load, the exercise performed with total amplitude caused greater muscle damage [18].

MORGAN and PROSKE (2004) propose that the damage caused in the eccentric phase of exercise depends on length of sarcomeres. A greater elongation increases sarcomere length by spacing between Z lines, causing rupture of structures and consequent reduction in strength level. In this manner, it is assumed that the greater muscular damage caused by exercises with total amplitude, may be a possible factor causing a lesser number of maximum repetitions at greater amplitudes [19].

In PC and BP exercises it is noticeable that control of movement speed did not present significant differences between total and partial conditions, a variable that directly influences the maximum number of repetitions [7]. However, exercise squat presented a lower execution speed for partial amplitude.

According to SÁNCHEZ-MEDINA& GONZÁLEZ-BADILLO (2011) [20], with muscle fatigue development, the execution speed of exercise tends to decrease. The difficulty in controlling speed may have been caused by high resistances used, which may have accelerated fatigue for this exercise and required a longer time for volunteer to move bar to pre-established amplitude.

The second objective addressed in this study was to verify if the use of the metronome is an adequate tool in controlling execution speed. It has been verified, with the analysis of average difference for target, that the use of the metronome was effective for BP exercises in both amplitudes, GA with partial amplitude and PC with total amplitude. However, a high variance was observed in exercises GA with total amplitude and PC with total amplitude.

According to BARBOSA et al. (2015) [8], the speed control method used, which releases an auditory stimulus, can lead to decreased performance, since the volunteer tends to concentrate on the rhythm applied by the metronome, which generates physical and cognitive efforts. When evaluating using the kinematic variables meter we identified that the control performed by the metronome was not effective for some movements, which leads us to think that more familiarization sessions may be necessary for good speed control with the use of this tool. Therefore, more studies are needed to analyze the effectiveness of this method as a tool for speed control execution.

4. CONCLUSION

Based on the data presented, it can be concluded that amplitude of movement interferes with the number of maximum repetitions performed in exercises of bench press, squat and preacher curl, for same relative intensity. Larger amplitudes provoke reductions in number of maximum repetitions. More studies are needed to evaluate the effectiveness of the metronome as a tool to control the speed of execution in weight training exercises.

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