

# Relationship Between Repetitions and Selected Percentages of One Repetition Maximum

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## Abstract

*Thirty-eight male subjects with no previous muscular strength training experience were tested to determine the number of repetitions they could perform at 40, 60, and 80 percent of one repetition maximum (1 RM) for each of seven specified weight training lifts. The results indicated that there is a significant difference ( $p < .0001$ ) in the number of repetitions performed at the selected percentages of 1 RM, as well as in the number of repetitions performed at these percentages across lifts. The findings also indicate that a given number of repetitions is not always associated with the same percentages of the 1 RM when performing different lifts. The prediction of the 1 RM can not be generalized based on the number of repetitions performed.*

**Key Words:** Maximal strength, strength, repetition maximum, strength testing

## Introduction

Strength gains as a result of weight training are achieved through an increase in the ability of contractile elements in each muscle fiber to contract more strongly, and by the recruitment of a greater proportion of the total available fibers in each contraction (21). The development of these two factors can be accomplished by the use of the overload principle. This principle states that in order for strength improvements to occur, the demands placed on the muscle must be gradually increased over a period of time, and the resistance should be of a magnitude significant enough to cause physiological adaptation in the muscle tissue (7, 9, 13, 23).

Based on the overload principle, various textbooks recommend that an individual should work with a resistance of at least 60 percent of one repetition maximum (1 RM) as the minimum threshold to stimulate strength development (1, 14, 18). Berger (5) indicated that this resistance must be equal to or greater than two thirds of an individual's 1 RM. Other texts/reviews (3, 4, 11, 15, 18) suggest that maximum strength gains are obtained when a muscle is actually stressed maximally at least once during the training session.

Applying the overload principle, researchers have conducted work to find the ideal number of repetitions to elicit adequate strength gains. Most research in this area has shown that fewer than 10 repetitions maximum should be used when trying to increase muscular strength (2, 6, 7,

8, 12, 19, 21). Based on these data, a rule of thumb widely accepted by teachers, coaches, and athletes is that less than 10 maximum repetitions should be used for muscular strength development and more than 10 repetitions for local muscular endurance gains.

Assuming that 60 percent of the 1 RM or that no more than 10 maximum repetitions is the minimum threshold for strength development, it seems imperative that the exact number of repetitions performed at this percentage be established. However, while several authors assume that the 10 repetition maximum are performed somewhere between 60 and 80 percent of the 1 RM (1, 14, 18), limited data are available in the literature to predict the average number of repetitions that an individual could perform at selected percentages of the 1 RM.

Pollock et al. (22) generalized that someone training strictly for health enhancement should be able to perform 12 to 15 repetitions at 75 percent of the 1 RM as compared to 20 to 25 repetitions for the competitive athlete. O'Shea (20) also generalized that at 90 percent of the 1 RM an individual should be able to perform 1 to 3 repetitions, at 80 percent 5 to 6 repetitions, and at 70 percent 8 to 12 repetitions. Similarly, Landers (17) suggested that the 1 RM for any lift could be predicted based on the number of repetitions performed with a given resistance. It was proposed that 2 repetitions can be accomplished at 95 percent of the 1 RM, 4 repetitions at 90 percent of the 1 RM, 6 repetitions at 85 percent of the 1 RM, 8 repetitions at 80 percent of the 1 RM, and 10 repetitions at 75 percent of the 1 RM. A study conducted by Clarke and Irving (10) indicated that 10 repetitions could be performed at 55 percent of the 1 RM on the leg curl exercise.

Because of the lack of scientific data available on the number of repetitions that individuals can perform at selected percentages of their 1 RM, and the controversy about the number of repetitions that individuals can perform at different percentages of the 1 RM this study was initiated. The purposes of the study were: to determine the average number of repetitions that untrained males could perform at 40, 60, and 80 percent of their 1 RM on each of seven selected weight training lifts; and to determine if statistical differences in the number of repetitions performed at the selected percentages of the 1 RM exist among the seven selected lifts.

**Methods**

Thirty-eight male subjects with no previous muscular strength training experience were shown the proper technique used for each of the seven lifts. Informed consent was obtained. The seven lifts and the order of performance were as follows: arm curl, quadriceps lift, bench press, sit-up, leg curl, lateral pulldown, and leg press. This order was chosen to alternate the muscle groups exercised. Physical and performance data on height, weight, age, percent body fat, and 1 RM were collected on day one. Percent body fat using the skinfold thickness technique was calculated using the Siri (24) formula, after calculating body density based on the generalized prediction equations developed for men (16). The physical characteristics of the subjects are presented in Table 1.

The 1 RM was determined through the trial and error method. If an attempt was made with relative ease, 4.54 to 9.07 kgs (10 to 20 pounds) were added to the resistance. If the attempt was performed with difficulty, 2.27 to 4.54 kgs (5 to 10 pounds) were added. A rest interval of two to three minutes was allowed between each attempt. All lifts were performed using constant resistance on a sixteen station Universal Gym apparatus.

Data for the repetitions performed at 40, 60, and 80 percent of the 1 RM were collected on separate days, over a period of time ranging from four to eight weeks, with a minimum one-week interval between sessions. This interval was used to minimize any training effect that might occur if data collection sessions were held too close together. The subjects performed the selected percentages in a random order, with the seven lifts for a given percentage performed in one session. Repetitions for each lift were done in a continual cadence (no pause between repetitions) until the maximum number of repetitions was accomplished. Each subject was allowed a rest interval of 90 to 120 seconds between the different lifts.

The means and standard deviations were calculated using the Statistical Analysis System (SAS) package. A one-way MANOVA using the Wilks criterion--with the seven specified weight training lifts as the independent variables and the number of repetitions performed at the selected percentages of the 1 RM as the dependent variables--was performed. This analysis was conducted to test for significant differences in the number of repetitions that the subjects could perform at selected percentages of the 1 RM among the seven specified lifts. The Duncan Multiple Range Analysis was then performed to identify the significant differences in the number of repetitions among the lifts.

**Results**

The results of the 1 RM, and the average number of repetitions performed by untrained male subjects at the selected percentages of the 1 RM for the seven specified weight training lifts, are presented in Table 2. The greatest amount of weight lifted (1 RM) was observed for the leg press exercise, while the least amount of weight was lifted in the leg curl. The highest number of repetitions performed at 40, 60, and 80 percent of the 1 RM was observed for the leg press, while the lowest number of repetitions was performed on the leg curl.

The one-way MANOVA indicated a significant difference ( $p < .0001$ ) in number of repetitions performed at the selected percentages of the 1 RM, as well as in the number of repetitions performed at these percentages across lifts. The results of the post-hoc analysis are also presented in Table 2. At 40 percent of the 1 RM, the leg press lift ( $x=80.1$  repetitions) was significantly different from all other lifts. The lateral pull down ( $x=41.5$ ) and bench press ( $x=34.9$ ) lifts were significantly different from all other lifts, but not significantly different from each other. The arm curl lift ( $x=24.9$ ), quadriceps lift ( $x=23.4$ ), sit-up lift

**Table 1. Physical characteristics of the subjects**

N		38
Age (yr)	35.10 <sup>a</sup> ± 12.00 <sup>b</sup>	
Height (cm)	179.02 ± 5.66	
Weight (kgs)	78.01 ± 10.66	
Percent Body Fat	12.36 ± 04.66	

<sup>a</sup>=Mean, <sup>b</sup>=Standard Deviation

**Table 2. Mean scores, standard deviations and post-hoc analysis results for the number of repetitions performed at selected percentages of the 1 RM for seven selected weight training lifts.**

LIFT	40%	60%	80%	1 RM***
	X SD	X SD	X SD	X SD
LP*	80.1 ± 47.9 A**	33.9 ± 14.2 A	15.2 ± 6.5 A	137.93 ± 27.17
BP	34.9 ± 08.8 B	19.7 ± 04.9 B	09.8 ± 3.6 B	63.86 ± 15.38
LD	41.5 ± 16.1 B	19.7 ± 06.1 B	09.8 ± 3.9 B	59.87 ± 11.61
QL	23.4 ± 05.1 C	15.4 ± 04.4 C	09.3 ± 3.4 BC	54.93 ± 13.34
SU	21.2 ± 07.5 C	15.0 ± 05.6 C	08.3 ± 4.1 BCD	40.87 ± 12.56
AC	24.3 ± 07.0 C	15.3 ± 04.9 C	07.6 ± 3.5 CD	33.20 ± 5.94
LC	18.6 ± 05.7 C	11.2 ± 02.9 D	06.3 ± 2.7 D	33.02 ± 8.53

\*LP = Leg Press (knees bent at a 100 degree angle for the starting position), BP = Bench Press, LD = Lateral Pull down (resistance pulled behind the head to the base of the neck), QL = Quadriceps Lift (or knee extension), SU = Sit-Up (horizontal board, feet held in place, knees at a 100 degree angle, and resistance held on the chest), AC = Arm Curl (low pulley), LC = Leg Curl (to 90 degree of flexion).

\*\*Letters indicate significantly different grouping, Alpha = .05; same letter = no difference.

\*\*\* 1 RM expressed in kgs

( $x=21.2$ ), and leg curl lift ( $x=18.6$ ), were not found to be significantly different from each other.

### Discussion

This data indicates that the number of repetitions performed at selected percentages of the 1 RM is not the same for all lifts. According to the results of this study, no longer can beginning strength training participants assume that a given number of repetitions is always associated with the same percentage of the 1 RM for all lifts. Neither can the prediction of the 1 RM be generalized based on a number of repetitions performed, at least within the range investigated in this study. For example, when working at 60 percent of the 1 RM, 33.9 repetitions of the leg press were performed on average, while on the arm curl only 15.3 could be performed.

The findings of this study are also of interest because previous research has shown that 10 or fewer maximum repetitions should be used to stimulate muscular strength development (2, 6, 7, 8, 12, 19, 21), and there are few scientific studies available that support the use of 60 percent of the 1 RM as the minimum resistance to produce these gains. In addition our results show that at 60 percent of the 1 RM, all lifts elicited more than 10 repetitions, suggesting that if a person trains at this percentage, local muscular endurance, rather than muscular strength, will be developed. Therefore, the minimum threshold for strength development must be set at a higher percentage of the 1 RM. These data also indicate that in the case of the bench press, the lateral pull down, and the quadricep lifts, all exercises that involve a relatively large amount of muscle mass, the 10 repetition maximums are performed at about 80 percent of the 1 RM. In the case of the leg press exercise, the 10 repetition maximum would be performed at an even higher percent of the 1 RM.

If no more than 10 maximum repetitions should be used for strength gains, the results of this study indicate that the minimum threshold, when expressed as percentage of the 1 RM, may vary from one muscle group or groups of muscles to the next. This may be related to the amount of muscle mass involved with the exercise. Consequently, following the rule of thumb of exercising with a 10 RM or less may be a better guideline to achieve muscular strength development as opposed to working with certain percentages of the 1 RM.

### Practical Applications

For individuals just starting resistance exercise programs, two practical applications can be derived from this study. First, a given number of repetitions is not always associated with similar percentages of 1 RM when performing different weight training exercises. Second, although previous research has shown that 10 or fewer maximum repetitions should be used to stimulate strength development, and while several authors have indicated that 60 percent of the 1 RM is the minimum threshold for strength development to occur, no scientific research had been conducted to determine the number of repetitions performed at this percentage (60) or other percentages of the 1 RM. The findings of this study indicate that if 10 or fewer maximum repetitions should be used to stimulate strength development, a minimum of 80 percent of the 1 RM, and not 60 percent as reported by several authors, might be needed in most lifts to obtain strength gains.

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