# THE RELATION BETWEEN THE NUMBER OF REPETITIONS AND THE RELATIVE LOAD IN STRENGTH TRAINING

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It was the aim of this study to determine the relationship between the number of repetitions that can be lifted at a range of percentages of the 1RM load in leg curl and bench press. Comparisons were made between males and females, and between long distance runners and sprinters. Findings suggest that this relationship is different between the two types of exercise. No differences were found between males and females. When working with highly trained athletes in bench press it is recommended that different regression equations are employed when studying sprint trained or endurance trained athletes.

**KEY WORDS:** strength training, repetition maximum, bench press, leg curl

**INTRODUCTION:** To develop maximal muscle strength the demands placed on the muscle must be greater than those to which the muscle is accustomed. This 'overload principle' causes the muscle to increase its capacity to do work. Several studies indicate that a load for which the maximum number of repetitions is 8-12 should be used for muscular strength development, while more than 15 repetitions are necessary for local muscular endurance gains (Fleck & Kraemer, 1997). Other authors indicate that the minimum threshold to stimulate strength development is a resistance of at least 60% of one repetition maximum (1RM) (MacDonagh & Davies, 1984). It is crucial to determine the 1RM of the individual, or to determine the number of repetitions that one can perform with a selected load. Working with a 1RM load has some major disadvantages. If it takes too many repetitions to determine 1RM, the subject may be too tired to achieve a real maximum. A 1RM load can also cause injuries if the exercise is not properly executed. Determining 1RM can be health threatening in certain populations: elderly, hypertensive persons, individuals with a history of orthopaedic injury. In these conditions it is recommended to determine the 1RM indirectly by counting the number of repetitions that can be performed with a submaximal load. This latter method can only predict the maximal strength of a person if the relation between the number of repetitions and the load, expressed as a percentage of 1RM, has been determined. Unfortunately only a limited number of studies have analyzed this relationship. Landers (1985) suggested that the 1RM for any lift could be predicted by means of a linear regression based on the number of repetitions performed with a given resistance. He indicated that a two repetitions can be accomplished at 95%, four at 90%, six at 85%, eight at 80% and ten at 75%. Hoeger *et al*. (1987) analysed this relationship in untrained persons on seven different weight training exercises. The number of repetitions performed at a selected percentage of 1RM varied among exercises. The author suggested that this difference might be related to the amount of muscle mass involved with each exercise. In a second study Hoeger et al. (1990) compared this relationship between trained and untrained subjects. The difference in number of repetitions performed at selected percentages of 1RM for all exercises proved to be significantly different between trained and untrained females. These findings were not confirmed in the male group. Based on these data and the existing controversy as to the number of repetitions that can be performed at different percentages of 1RM, the present study was undertaken. It was the aim of this study to determine the relationship between the number of repetitions that can be lifted at different percentages of the 1RM load in leg curl and bench press in males and females, comparing long distance runners to sprinters.

**METHODS:** Seven male and seven female sprinters participated in the study, as well as nine female and seven male long distance runners. All thirty subjects gave informed consent. All of them were competitive at a high national level in sprint running or long distance running. They all had training experience with both strength tests: the seated leg curl and bench press. The

subjects were tested once a week over a 5 week period. All subjects reduced their normal strength training program to one session weekly during this testing period, the training session took place at least two days before or two days after the test session. Each test session was preceded by a standardized warmup. The first session aimed to accustom the subjects to the standardized test protocol. On the basis of this first session the test leader selected the starting load for the second session that occurred one week later. For each session it was the objective to establish two new loads for which the maximum number of repetitions was between 1 and 25. During the second session the subjects had to perform a maximal number of repetitions with the two different loads. The repetitions for each lift were performed in a continual cadence, with no pause between repetitions. Both series of repetitions were separated by a recovery period of ten minutes. By means of this protocol it was possible to determine within a four week period, the number of repetitions with eight selected loads between 1RM and 25RM for each subject for seated leg curl and bench press.

On the basis of the eight data points an individual polynomial regression analysis was performed for each subject in seated leg curl and in bench press. This resulted in the estimation of the 5RM, 10RM, 15RM, 20RM and 25RM loads expressed as a percentage of 1RM for each individual separately. One-way MANOVAs (SAS) were performed, with exercise (seated leg curl, bench press), type of training (endurance, sprint), or gender as the independent variable, and the percentage of 1RM for a given number (5, 10, 15 ,20 and 25) of repetitions as the dependent variable.

**RESULTS and DISCUSSION:**

**Table 1 Mean (± SD) Estimated Percentage of 1RM for a 5RM, 10RM, …, 25RM-Load for Males and Females, for Sprint and Endurance Trained Athletes and for Leg Curl and Bench Press (*: p<0.05 compared to bench press value, µ: p<0.05 compared to endurance group)**

| | 5-RM | 10-RM | 15-RM | 20-RM | 25-RM |
|---|---|---|---|---|---|
| **Leg curl** | | | | | |
| Sprint | 92.7 ± 2.41* | 84.7 ± 4.15* | 77.8 ± 4.87* | 71.9 ± 4.92* | 67.1 ± 5.56* |
| Endurance | 92.7 ± 2.01* | 85.1 ± 3.66* | 78.8 ± 4.31* | 73.5 ± 4.96* | 68.2 ± 5.80* |
| Males | 92.9 ± 2.57* | 85.3 ± 4.54* | 78.8 ± 5.52* | 73.3 ± 5.81* | 69.0 ± 6.12* |
| Females | 92.5 ± 1.84* | 84.6 ± 3.13* | 77.9 ± 3.47* | 72.4 ± 3.98* | 68.1 ± 6.38* |
| **Bench press** | | | | | |
| Sprint | 88.9 ± 1.25 | 78.9 ± 1.84µ | 70.4 ± 2.46µ | 63.8 ± 3.76 | 59.0 ± 6.76 |
| Endurance | 86.7 ± 2.25 | 74.5 ± 3.24 | 65.9 ± 3.76 | 60.3 ± 3.39 | 57.2 ± 3.50 |
| Males | 87.9 ± 1.36 | 76.5 ± 2.39 | 68.2 ± 2.59 | 62.9 ± 2.59 | 60.4 ± 4.04 |
| Females | 87.7 ± 2.68 | 76.5 ± 4.05 | 68.2 ± 4.80 | 62.1 ± 5.98 | 59.4 ± 9.69 |

The results of the estimation of 5RM, 10RM, …, 25RM loads expressed as a percentage of 1RM are presented in Table 1. It is clear that all subjects performed their leg curl exercise for a given number of repetitions at a higher percentage of 1RM compared to the bench press

exercise. Statistical analysis revealed significant differences between all leg curl percentages and all bench press percentages at a given RM. No significant differences were noticed between males and females. When comparing the percentages of endurance trained to sprint trained athletes a significant difference was found for 10RM and 15RM percentages in the bench press exercise. No differences were found in leg curl when comparing the sprint group to the endurance group. These results suggest that it is correct to use different
equations for different exercises and different groups. Taking into account the differences between leg curl and bench press in general (Table 1) and the differences between the endurance group and sprint group in bench press more specifically (Table 1) , finally three different regression equations were calculated. These regressions are presented in Table 2.

**Table 2 Estimation of the Percentage of 1RM (y) on the Basis of the Maximal Number of Repetitions (x) that can be Performed with a Specific Training Load in Bench Press and Leg Curl**

| EXERCISE | GROUP | REGRESSION | $r^2 \times 100$ |
|---|---|---|---|
| Leg curl | Sprint/Endurance | $Y=(0.0280x^2)-(1.9511x)+101.58$ | 87% |
| Bench press | Sprint | $Y=(0.0473x^2)-(2.7608x)+101.31$ | 96% |
| Bench press | Endurance | $Y=(0.0646x^2)-(3.3287x)+101.65$ | 95% |

The regression formulas in Table 2 are graphically presented in Figure 1. The regression line for the sprint group and the endurance group is almost identical in leg curl. Therefore only one regression equation and one regression line is presented in Table 2 and Figure 1 respectively.
The current findings differ from those of Hoeger *et al*. (1987, 1990), as no significant differences were found between males and females in this investigation. This can probably be explained by the highly trained status of the female subjects in this study. The differences between leg curl and bench press as noticed by Hoeger *et al*. (1990) are confirmed by the findings in this analysis. The analysis of the differences between a sprint group and an endurance group was not performed in previous studies. In this study the results indicate that the significant differences between sprint group and endurance group are restricted to the bench press exercise.

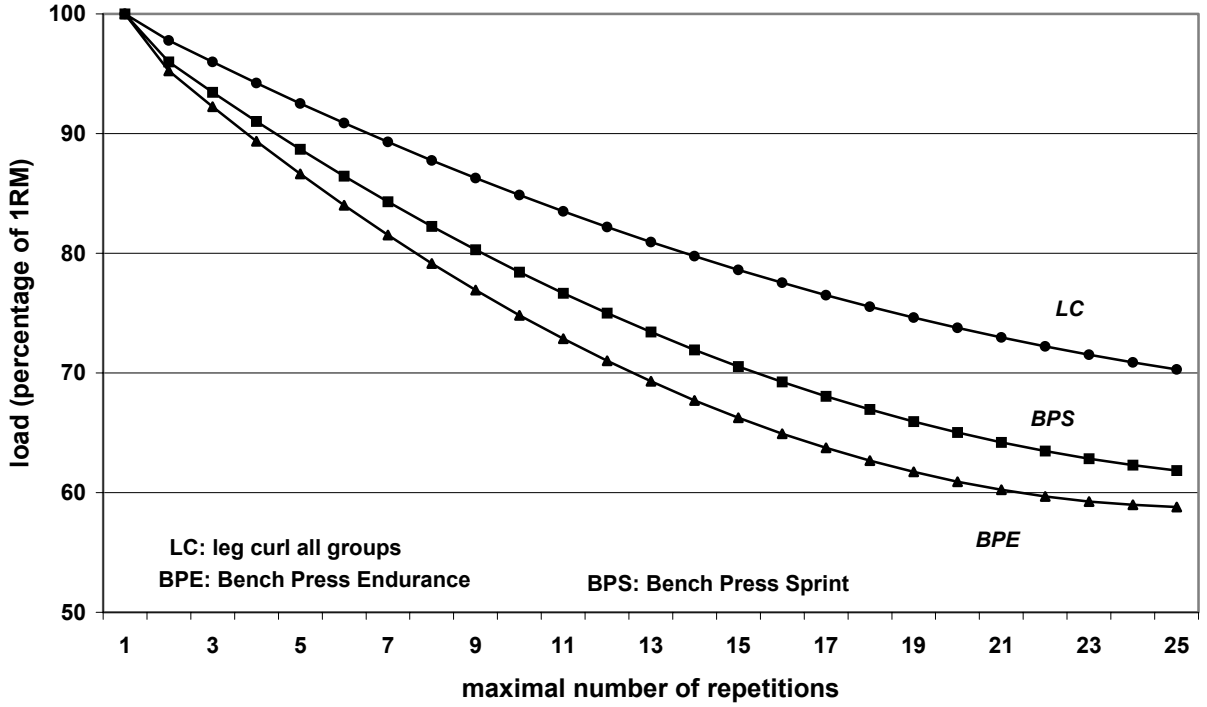


**Figure 1 - Regression line for the 1RM percentage (y) estimated on the basis of the maximal number of repetitions (x) that can be performed with a specific training load in bench press and leg curl. The regression formulas are presented in Table 2.**

**CONCLUSIONS:** In training practice it is crucial to determine the 1RM load of the individual, or to determine the number of repetitions that can be performed with a selected load. As working with a 1RM-load can include some major risks, in some groups it is recommended to determine the 1RM indirectly by counting the number of repetitions that can be performed with a submaximal load. This latter method can only predict the maximal strength of a person if the relation between the number of repetitions and the load, expressed as a percentage of 1RM, has been determined. The data in this study suggest that this relationship is different between seated leg curl and bench press (Table 2). When working with highly trained athletes, it is recommended that different regression equations are used when sprint-trained or endurance-trained athletes are considered. In training practice it is important to keep in mind that the regression formulas presented in this study (Table 2) are only applicable between 1RM and 25RM-loads.

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