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Original empirical article

THE RELATIONSHIP BETWEEN THE SELECTED PERCENTAGES OF ONE REPETITION MAXIMUM AND THE NUMBER OF REPETITIONS IN TRAINED AND UNTRAINED MALES

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Abstract. *The purpose of this study was to determine the relationship between the maximum number of repetitions and selected percentages of one repetition maximum which could be performed by trained and untrained males, especially using free weights. Nine trained (T) and 9 untrained (UT) males participated in this study. The subjects performed one set to failure at 75, 85, and 95% of 1RM in the back squat, bench press, and arm curl, which were randomized, balanced, and matched. Data were analyzed using two-way analysis of variance. There were significant differences ($p < 0.05$) between T and UT at 85 and 95% of 1RM in the arm curl. At 75 and 85% of 1RM, T and UT performed more repetitions ($p < 0.05$) during the back squat than the bench press or arm curl. Both groups performed significantly ($p < 0.05$) more repetitions during 75% of 1RM than 85 and 95% of 1RM (75 > 85 > 95%). The rating of perceived exertion (RPE) was greater ($p < 0.05$) for high intensity than moderate intensity. In conclusion, the number of repetitions is dependent on the amount of muscle mass and exercise intensity, while the training status of the subjects has a minimal impact. When percentage of 1RM increases, the RPE increases as well.*

Key words: *intensity, weight training, free weight, rating of perceived exertion.*

INTRODUCTION

Resistance exercise intensity is usually determined by the repetition maximum (RM) or based on a percent of 1RM. The training intensity is the most important variable to consider when designing a resistance training program to target maximum strength in

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athletes (Tan, 1999; Ha¨kkinen et al., 1987). In general, people participating in resistance training desire to enhance either muscle strength or muscle endurance, or both. The training protocols used for these programs are different, although the total volume of work may be identical. Gains in muscle strength are accomplished by lifting heavy weights (e.g., 70–90% of 1 repetition maximum [1RM]) with few repetitions. In contrast, gains in muscle endurance are realized by lifting comparatively light (e.g., 30–50% of 1RM) weights with a high number of repetitions (Kraemer et al., 1993; Warren et al., 1992; Yarasheski et al., 1993). Individuals who use resistance training to enhance muscular strength must use 1-6RM in the number of repetitions during the sets (Stone & Coulter, 1994).

Unfortunately, few studies have evaluated the relationship between the percentages of 1RM and number of repetitions during resistance exercises (back squat, bench press and arm curl).

Previous studies indicated that, when the percentage of 1RM increases, the number of repetitions decreases (Hoeger et al., 1987; Hoeger et al., 1990; Shimano et al., 2006). Trained subjects performed equal (Kraemer et al., 1990) and/or better than untrained subjects in terms of the number of repetitions (Braith et al., 1993; Pick & Becque, 2000). Large muscle groups have been shown to perform more repetitions than small muscle group (leg press vs. arm curl) (Hoeger et al., 1987; Hoeger et al., 1990). Other authors have indicated that 10 repetitions could be performed at 55% of 1RM for knee flexion exercises (Clarke & Irving, 1960), 8-12 repetitions at 70% of 1RM, 5-6 repetitions at 80% of 1RM, and 1-3 repetitions at 90% of 1RM (O'shea, 1976). Pollock et al. reported that, at 75% of 1RM, trained subjects performed more repetitions than untrained subjects (20-25 reps vs. 12-15 reps) (Pollock et al., 1984). Landers found that two repetitions can be accomplished at 95% of 1RM, 4 at 90% of 1RM, 6 at 85% of 1RM, 8 at 80% of 1RM and 10 at 75% of 1RM (Landers, 1985).

It is important to note, that the above mentioned studies used resistance training machines. Machine exercises are less like real life activities and do not require motor coordination and balance to a significant extent as compared to free weight exercises (Kraemer et al., 2002). Only, Shimano et al. examined the relationship among 60, 80, and 90% of 1RM, in the case of different free weight exercises, and reported more repetitions during back squat versus the bench press and or arm curl at all intensities (Shimano et al., 2006). Previous investigations have used either machine exercises or endurance and power intensities. Maximal and submaximal intensities (75, 85, and 95%) were typically used by young resistance trainers and bodybuilders; there is also a necessity of carrying out studies to determine the relationship between these intensities and resistance exercises (back squat, bench press and arm curl [a comparison of different amounts of muscle mass]) in trained and untrained individuals.

Moreover, no research, to our knowledge, has examined the relationships between various exercises and training status with the use of free weights at 75, 85, and 95% of 1RM. Therefore, the purpose of this study was to determine the relationship between the number of repetitions at 75, 85, and 95% of 1RM in 3 different exercises: the back squat, bench press, and arm curl in trained and untrained males. This investigation relied on free weight exercises: (a) to determine the relationship between the number of repetitions and the selected percent of 1RM in trained and untrained males; and (b) the relationship between exercises involving different amounts of muscle mass and the number of repetitions.

THE METHOD

The participants

Nine trained male (T) and 9 untrained male (UT) subjects were used in this study. The T participants performed resistance weight-training using weights and involved all the major muscle groups during the training sessions three times per week for more than 6 months. The UT participants had never been involved any type of resistance training. The participants did not report skeletal muscle and cardiovascular limitations. The participants reported that they were free of controlled and performance-enhancing drugs (anabolic steroids) at the time of this study. The participants were informed about the aims, nature and potential risks of the study and provided written informed consent to take part prior to the investigation, which was approved by the current laws of Iran, and all the procedures were acknowledged by the regional ethics committee. The initial characteristics of the participants are shown in Table 1. Body weight and 1RM for the back squat, bench press, and arm curl for the T participants were significantly ($p < 0.05$) greater than for the UT group.

Table 1. Initial characteristics of the experimental groups. Data are mean ± *SD*

	Trained (n = 9)	Untrained (n = 9)
Age (y)	20.78 ± 1.6	20.6 ± 2.0
Height (cm)	175 ± 4.18	174.4 ± 3.6
Body mass (kg)	76.44 ± 5.02*	70.9 ± 3.9
Body fat (%)	12.51 ± 2.38	13.5 ± 1.9
1RM back squat (kg)	115.5 ± 20.83*	73.0 ± 10.3
1RM bench press (kg)	96.67 ± 15*	46.6 ± 7.9
1RM arm curl (kg)	52.44 ± 8.7*	27.2 ± 4.4

* Significant difference ($p<0.05$) with untrained group.

The experimental design

The participants received an explanation of the experimental testing procedures (the back squat, bench press, and arm curl) during a control day about one week before the 1RM testing. During the familiarization session, the participants' initial characteristics (age, height, and body mass) were obtained. In addition, the participants had 3 skin fold sites (chest, abdomen, and thighs) measured to determine body composition or percent of body fat. The measurement was carried out using the method of Jackson & Pollock, 1985.

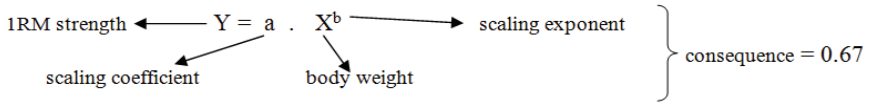
One repetition maximum testing procedure

The procedure used for assessing 1RM was described by Kraemer & Fry, 1995. The participants performed a warm-up set of 8-10 repetitions at a light weight (approximately 50% of 1RM). A second warm-up consisting of a set 3-5 repetitions with moderate weight (approximately 75% of 1RM), and third warm-up including 1-3 repetitions with a heavy weight (approximately 90% of 1RM) followed. After the warm-up, the participants performed 1RM strength exercises by enhancing the load during consecutive trials until the participants were unable to properly perform a proper lift, complete range of motion and correct technique. Three five-minute rests were provided between the attempts for each participant. The T participants performed the 1RM testing once, while the UT participants took part in the 1RM testing during two sessions to ensure the baseline measurements.

Percentages to be tested

The participants took part in 3 testing sessions (except the familiarization session). The sequence of the exercises were performed during 3 days of testing, during which the participants performed 1 set to failure for the back squat, bench press, and arm curl with volitional lifting velocity. The participants performed the selected percentages of 1RM for 3 different exercises on different days. Each participant attempted 3 different exercises at 75, 85, and 95% of 1RM, which was balanced, matched, and randomized. For example, 3 testing sessions consisted of; (1): 75% of 1RM for the back squat, 85% of 1RM for the bench press, and 95% of 1RM for the arm curl; (2): 95% of 1RM for the back squat, 75% of 1RM for the bench press, and 85% of 1RM for the arm curl; (3): 85% of 1RM for the back squat, 95% of 1RM for the bench press, and 75% of 1RM for the arm curl.

Before the testing, the participants performed a general warm-up consisting of ballistic movements and flexibility exercises to increase blood circulation and temperature of the involved muscle groups for a period of 10 minutes. Also, a specific warm-up of 1 set of 5 repetitions at 50-60% of 1RM was performed by the participants before an exercise at 80 or 90% of 1RM. The rest between the exercises was 20-30 minutes and the participants could rest at least 48 hours between each testing session. Repetitions performed with poor technique or which were not performed properly were not taken into account. But, a repetition that was performed by a participant for more than half of the range of motion was taken into account as 0.5 repetition. The participants were encouraged to perform the repetitions consecutively and immediately, and were permitted less than 3 seconds of pauses between the repetitions. The rating of the perceived exertion (RPE) was obtained by the Borg 10-category scale after each set of exercises (Borg, 1982). The $Y = a \cdot X^b$ equation was used to correct body weight to determine the relationship between strength and the number of repetitions performed at 75, 85, and 95% of 1RM for the back squat, bench press, and arm curl (Shimano et al., 2006; Atkins, 2004).



Therefore,
Correct strength = 1RM / 0.67 power of body weight

Statistical analyses

All of the values presented in this article are mean ± *SD*. A two-way analysis of variance was used to analyze the data. In the event of a significant *F* ratio, the Tukey post hoc test was used for pair-wise comparisons. The Pearson (*r*) correlation coefficient test was used to determine selected pair-wise relationships. The level was set at $P \leq 0.05$ for statistical significance.

THE RESULTS

The results of the analysis of the number of repetitions performed by trained and untrained males at 75, 85, and 95% of 1RM for the back squat, bench press, and arm curl are shown in Figure 1.

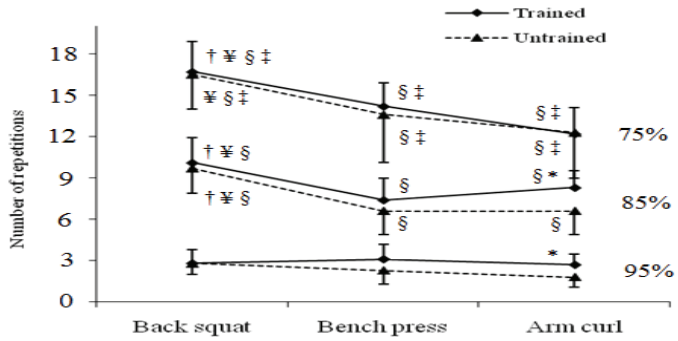


Fig. 1. The number of repetitions at 75, 85, and 95% of 1 repetition maximum (1RM) for the back squat, bench press, and arm curl in trained and untrained groups.
Values are mean ± *SD*.
* Significantly different ($p < 0.05$) from the corresponding untrained group.
† Significantly different ($p < 0.05$) from the corresponding bench press value.
¥ Significantly different ($p < 0.05$) from the corresponding arm curl value.
‡ Significantly different ($p < 0.05$) from the corresponding 85% value.
§ Significantly different ($p < 0.05$) from the corresponding 95% value.

There were no significant differences ($p > 0.05$) between the T and UT groups (except at 85 and 95% of 1RM in the arm curl). The T and UT groups performed significantly ($p < 0.05$) more repetitions at 75% of 1RM vs. 85, and 95% of 1RM, and 85% of 1RM as opposed to 95% of 1RM for the back squat, bench press, and arm curl (75 > 85 > 95%). At 75, and 85% of 1RM, the T subjects showed significantly ($p < 0.05$) more repetitions during the back squat than the bench press and/or arm curl. The UT subjects performed significantly ($p < 0.05$) more repetitions during the back squat than the bench press and arm curl at 85, and 75% of 1RM, respectively. Moreover, there were no significant differences ($p > 0.05$) between the bench press and arm curl at 75 and 85% of 1RM for the T and UT participants. The RPE at 75, 85, and 95% of 1RM for the back squat, bench press, and arm curl are shown in Figure 2.

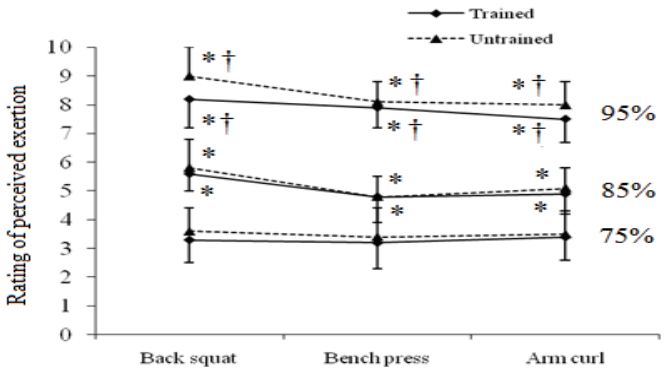


Fig. 2. Rating of perceived exertion at 75, 85, and 95% of 1 repetition maximum (1RM) for the back squat, bench press, and arm curl in trained and untrained groups.
Values are mean ± *SD*.
* Significantly different ($p < 0.05$) from the corresponding 75% value.
† Significantly different ($p < 0.05$) from the corresponding 85% value.

There were no significant differences ($p > 0.05$) between the T and UT participants at RPE. The participants reported that, when the percentage of 1RM increases, the RPE increases (the RPE: 95 > 85 > 75%). The correlation coefficients between the corrected strength and number of repetitions are shown in Table 2. There was no significant relationship ($p > 0.05$) between corrected strength value and the number of repetitions for any of the percentages and exercises.

Table 2. Correlation coefficients (Pearson *r*) between corrected strength and the number of repetitions for 75, 85 and 95% of 1 repetition maximum (1RM) for back squat, bench press, and arm curl.

	75% 1RM	85% 1RM	95% 1RM
Back squat	–0.127	0.063	0.065
Bench press	–0.054	0.175	0.330
Arm curl	–0.031	0.420	0.401

DISCUSSION

In the present study, it was determined that (a) there were no significant differences in the number of repetitions between the T and UT (except at 85 and 95% of 1RM in the arm curl): (b) we also determined that more repetitions could be performed in the back squat than the bench press and arm curl. The number of repetitions that can be performed during free weight exercises is dependent on the amount of muscle mass. At 75, and 85% of 1RM for T and UT, the number of repetitions in the back squat was greater than the number of repetitions performed in either the bench press, or arm curl, or both. The current findings are similar to those of Shimano et al. who reported more repetitions for the back squat rather than the bench press, and/or arm curl at lower intensities in the T and UT participants. They also found more repetitions at 90% 1RM for the back squat vs. bench press or arm curl (Shimano et al., 2006). We, on the other hand, found no significant difference among the exercises at high intensity (95% 1RM). It seems that the number of repetitions that could be performed by T and UT participants are similar to high intensity for all the exercises. Similar findings have been reported in studies using machine-based resistance exercises. Hoeger et al. found that more repetitions could be performed in the leg press than during any other exercises (lateral pulldown, leg curl, knee extension and the bench press) (Hoeger et al., 1990; Hoeger et al., 1987). They showed that when the performance of exercises involves a large amount of muscle mass, the number of repetitions increases. There are mechanisms for greater number of repetitions for the back squat vs. bench press and or arm curl at submaximal exercise intensities; (a) using multiple joints (the hip and knee) for the lower extremities during the back squat exercise; (b) asynchronously recruiting motor units, which served to delay fatigue (Shimano et al., 2006).

The results of this study indicated that there was a significant difference between the T and UT in the number of repetitions performed at 85 and 95% of 1RM for the arm curl. These findings similar to those of Pick & Becque who reported that T participants could perform a significant difference in the number of repetitions vs. the UT during the back squat at 85% of 1RM (Pick & Becque, 2000). Hoeger et al. also found significant differences between T and UT males in the number of repetitions performed at 40, 60, and

80% of 1RM in the arm curl and knee extension (Hoeger et al., 1990). Current results are in contrast to Shimano et al. who stated that UT participants could performed significantly more repetitions than T participants during the back squat at 90% of 1RM (Shimano et al., 2006). The T subjects had appropriate neuromuscular adaptation, because they trained resistance weight-training. Therefore, they could perform more repetitions than the UT. Moreover, the differences between the results may be due to the habitual resistance training routine of the subjects. However, it seems that the T subjects can perform more repetitions during the arm curl at very high intensities (85 and 95% 1RM), but the mechanism for these results may be due to the use of heavier absolute resistance.

In this investigation both groups indicated that with an increase in intensity, the number of repetitions decreases (i.e., number of repetitions 75 > 85 > 95%). The current results agree with those of Shimano et al. & Hoeger et al. who found that when comparing the percentages of 1RM, there were significant differences among 60, 80, 90 and 40, 60, and 80% of 1RM for the number of repetitions (Shimano et al., 2006; Hoeger et al., 1990). Of course, it is important to note that intensity is exercise-dependent. For example, we found that at 75% 1RM the load corresponded to 16.5RM for the back squat, ~14RM for the bench press, and 12RM for the arm curl. Also, at 85% 1RM the load corresponded to ~10RM for the back squat, 6.5-7.5RM for the bench press, and 6.5-8RM for the arm curl. At 95% 1RM the load corresponded to 3RM for the back squat, 2-3RM for the bench press, and 1.5-2.5RM for the arm curl. Therefore, we found that the amount of muscle mass used during the exercise should be considered when prescribing loads based on the presence of 1RM.

In this study, rating of perceived exertion was found to be significantly greater in higher percentages than in lighter percentages for all the exercises. The current results are consistent with those of Gearhart et al. Eston & Llewelyn Evans & Suminski et al. who reported that when the volume of external work was increased by adding weight, the participants reported higher RPE (Gearhart et al., 2001; Eston & Llewelyn Evans., 2009; Suminski et al., 1997). The results of the current study disagree with Shimano et al. who indicated that there was no significant difference between the percentages of 1RM for RPE (except 60% of 1RM for the back squat) (Shimano et al., 2006). There is a strong linear relationship between RPE and exercise intensity during resistance exercises. This means that during a resistance movement, corollary discharges from the motor cortex are concurrently sent to both the recipient muscle and the somatosensory cortex. The higher load results in greater tension development and increased motor unit recruitment and firing frequency (Gearhart et al., 2001). A positive slope in RPE, indicating an increase in the intensity of the perceptual signal originating in the active skeletal muscle throughout each set of exercises, may be related to metabolic and/or neurological factors associated with fatigue. Fatigue during resistance exercises could be due to the depletion of plasma creatinine, decreasing the pH with increasing muscle lactate accumulation, or carbohydrate depletion (Wilmore & Costill., 1994; Marieb, 1992; Nobel & Robertson., 1996). Nevertheless, Shimano et al. believed that "if exercise goes to failure, the exertion of subjects is similar within any intensity level, and that RPE may not be an effective tool to reflect the intensity of the loading in such an exercise prescription (p-823)". Therefore, several studies need to determine the relationship between RPE and fatigue during resistance exercise.

Our data indicated that there were no significant differences between corrected strength values and the number of repetitions at any of the percentages and exercises. The current findings do agree with the findings of Shimano et al. who reported that no signifi-

cant correlations were observed between strength corrected for body mass and number of repetitions (except for the bench press at 90%) (Shimano et al., 2006). We propose that athletes and non-athletes should attend the amount of muscle mass required for resistance training at various exercises and different intensities.

CONCLUSION

The number of repetitions that can be performed during 75, 85, and 95% of 1RM are dependent on the amount of muscle used. When we use greater muscle mass, the number of repetitions increases for all the exercises. A relationship was found to exist between different percentages of 1RM and number of repetitions; with an increase the percentages, the number of repetitions decreases, and the situation was similar between trained and untrained participants. It is recommended that coaches, athletes, and weight trainers must attend that; type of exercise and percentages of 1RM during resistance weight-training are important variables for the number of repetitions.

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ODNOS IZMEĐU IZABRANIH PROCENATA PONAVALJANJA PRI UPOTREBI MAKSIMALNE SNAGE I BROJA PONAVLJANJA IZMEĐU ISTRENIRANIH I NETRENIRANIH MLADIĆA

Hamid Arazi, Abbas Asadi

Cilj ovog istraživanja bio je da se odredi odnos između maksimalnog broja ponavljanja i odabranih procenata ponavljanja pri upotrebi maksimalne snage istreniranih i netreniranih mladića, uz upotrebu tegova. Devet treniranih (T) i devet netreniranih (UT) mladića učestvovalo je u istraživanju. Ispitanici su radili po jedan set vežbi do greške pri 75, 85, i 95% maksimalne snage (zadnji čučanj, pretklon, i savijanje ruku) dok su sve vežbe nasumice bile izbalansirane i povezane. Svi podaci su analizirani upotrebom analize varijanse. Značajne razlike se mogu utvrditi između ($p < 0,05$) T i UT grupe pri 85 i 95% ponavljanja pri upotrebi maksimalne snage u vežbi savijanja ruku. Pri upotrebi 75 i 85% maksimalne snage, T i UT grupe su imale veći broj ponavljanja ($p < 0,05$) pri izvođenju zadnjeg čučnja nego pri pretklonu ili savijanju ruku. Obe grupe su imale značajno veći broj ponavljanja ($p < 0.05$) pri upotrebi 75% maksimalne snage nego pri upotrebi 85 i 95% maksimalne snage (75 > 85 > 95%). Stopa utvrđenog zamora (RPE) bila je veća ($p < 0,05$) kod vežbi sa većim nego srednjim intenzitetom. Kao zaključak možemo navesti da broj ponavljanja zavisi od količine mišićne mase i intenziteta vežbi, dok je istreniranost učesnika imala minimalni uticaj. Kada se stepen maksimalne snage poveća, poveća se i stopa zamora.

Ključne reči: *intenzitet, treniranje sa tegovima, opterećenje tegovima, stopa zamora.*