

**PREDICTION OF ONE REPETITION MAXIMUM STRENGTH USING FOUR TO SIX
AND SEVEN TO TEN REPETITION MAXIMUM STRENGTH TESTS IN YOUNG
ADULT FEMALES**

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AND SEVEN TO TEN REPETITION MAXIMUM STRENGTH TESTS IN YOUNG
ADULT FEMALES**

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ABSTRACT

The purpose of this investigation was to determine if one repetition maximum (1-RM) strength could be predicted from a 4-6 RM submaximal strength test with a greater accuracy than the commonly used 7-10 submaximal strength test. Thirty-four healthy females between the ages of 19 and 32 participated in this study. Subjects completed 1-RM, 4-6 RM, and 7-10 RM strength assessments in random order with a minimum of 48 hours between each strength assessment. During each session, subjects performed strength assessments for the bench press, incline press, triceps extension, biceps curl, and leg extension. Multiple regression analysis was used to produce equations for predicting 1-RM strength from 4 to 6 or 7 to 10 repetition maximum tests. The 4-6 RM prediction equations improved the predictive accuracy of 1-RM strength compared to the 7-10 RM prediction equations based on the adjusted R^2 and standard error of estimate. Since no injuries or symptoms of delayed onset of muscle soreness were reported during either the 7-10 RM or the 4-6 RM submaximal strength assessments, the results of this study indicate that when attempting to predict 1-RM strength in healthy, young, males, a 4-6 RM submaximal strength assessment appears to be the more accurate test.

Key Words: one repetition maximum (1-RM), strength prediction, submaximal strength.

INTRODUCTION

Intensity for strength training exercises is often prescribed based on using a percentage of the one-repetition maximum (1-RM). One-RM strength is the greatest amount of weight that an individual can lift only one time for a specific exercise (Fleck and Kramer, 1997). For exercise prescription, assessment, and goal setting it is helpful to know the 1-RM. However, one-RM testing may not be appropriate for certain groups including adolescents, the elderly individuals and cardiac patients (Braith et al., 1993) due to an increased risk of injury (Braith et al., 1993; Mayhew et al., 1995). Many strength training programs in school and adult fitness settings encourage participants to train with maximum resistances that can be lifted for 7 to 10 repetitions (7 to 10-RM). Prediction equations would be useful in estimating maximal strength from resistances used during training (Braith et al., 1993) since clients would not need to perform 1-RM lifts for each exercise.

Several studies have generated regression equations for predicting 1-RM strength using either a generalized prediction equation (Bryzicki, 1993; Lander, 1985) or prediction equations for specific exercises (Dohoney et al., 2002; Kuramoto and Payne, 1995). It should be noted that most of the generalized equations are based on the bench press exercise (Bryzicki, 1993), since it is one of the more frequently performed exercises. Other studies developed regression equations for the prediction of 1-RM bench press strength using the YMCA bench press test (Kim et al., 2002; Rose and Ball, 1992). Regression equations typically include the number of repetitions completed and the resistance used (Kim et al., 2002), although some equations include body weight (Rose and Ball, 1992).

Another issue to consider in developing and using prediction equations is training status. A prediction equation for 1-RM leg extension developed using untrained subjects was not accurate for the same individuals following 18 weeks of strength training (Braith et al., 1995). However, a

prediction equation for bench press 1-RM using 55 to 95% of the 1-RM and as many repetitions as possible in one minute was accurate for untrained and trained subjects (Mayhew et al., 1992). Differences between studies may be due to the amount of strength gained during the resistance training program or the specific exercise and muscle groups used. Typically, subjects can complete a greater number of repetitions with a given percentage of 1-RM after training than before training. Mayhew et al. (1992), referring to the data of Hoeger et al. (1987), pointed out that the difference between the number of repetitions completed before training and after training with a given percentage of 1-RM was greatest for smaller muscle mass exercises (ex. arm curls, leg extensions, leg curls, and latissimus dorsi pulls), but not different for larger muscle mass exercises such as the bench press and leg press. Specific technique practice for the bench press did not alter the predictive accuracy of a prediction equation developed using the same group of subjects before technique practice (Abadie et al., 1999).

Muscular endurance becomes an important factor, when a greater the number of repetitions are completed for one set (Fleck and Kramer, 1997) Therefore, 4 to 6-RM prediction equations may have greater accuracy than 7 to 10-RM equations, since the performance of 4 to 6 repetitions is less dependent upon muscular endurance than the completion of 7 to 10 repetitions. The majority of studies that have reported prediction equations for 1-RM strength used a 7 to 10-RM submaximal strength test (Abadie et al., 1999; Braith et al., 1993; Knutzen et al., 1999). The purpose of this study was to develop regression equations for the prediction of 1-RM strength for several exercises in young, non-strength trained females, and to compare the accuracy of prediction equations using 4 to 6 repetitions with those using 7 to 10 repetitions.

METHODS

Subjects

Thirty-six healthy females between the ages of 18 and 26 years, who had not participated in strength training within the last year, volunteered to participate in this study. All procedures for the study were approved by the institutional review board of the university, and informed consent was obtained from all participants. Subjects were instructed to refrain from participating in strenuous activity for 24 hours prior to each testing session, and to avoid alcohol, caffeine, smoking and the consumption of large meals for at least three hours prior to testing.

Study Design

Body weight was measured on a Detecto scale (Cardinal Scale Manufacturing, Web City, MO). The sum of three skinfold measures was used to estimate body density (Jackson et al., 1980), which was used to calculate percent body fat using the Siri equation (Siri. 1961).

Subjects completed 1-RM, 4 to 6-RM, and 7 to 10-RM strength assessments in random order with a minimum of 48 hours between strength assessments. During each session, subjects performed strength assessments for the bench press, incline press (28° incline), leg extension, biceps curl, and triceps extension in random order. While being assessed for bench press and incline press strength, subjects lifted a free weight Olympic bar (20.4 kg) with weighted plates. During the bench press and incline press, subjects laid with their back flat on the bench and their feet in full contact with the floor throughout the lift. Subjects grasped the bar with a thumb-lock grip at a position slightly greater than shoulder width. Trained spotters assisted the subjects in lifting the bar from the support rack, and the subject lowered the bar to the chest, then pressed the bar to full arm extension. Leg extensor strength was assessed using a Cybex® leg extension machine (Cybex International, Medway, MA).

Subjects were seated with the resistance bar positioned in line with the medial malleolus. Subjects lifted the weight to near full extension of the knee. Biceps curl strength was assessed on a Paramount[®] preacher biceps curl machine (Paramount Fitness Corp., Los Angeles, CA). Subjects sat in the preacher curl machine with the seat adjusted in order to achieve 28⁰ of elbow flexion. The triceps were flat on the curling pad and subjects' feet maintained full contact with the floor throughout the lifts. Subjects lifted a free weight bar with additional weight plates using a supine grip at shoulder width. Spotters assisted the subjects in lifting the bar to the proper starting position. Subjects curled the bar to 90⁰ of elbow flexion. Triceps extension strength was assessed on a Body Masters[®] triceps extension machine (Body Masters Sports Industries, Rayne, LA). With the subject positioned against a backrest, a spotter positioned the resistance bar so that the subject was at 90⁰ of elbow flexion. Subjects used an overhand grip and attempted to extend their arms until near full extension of the elbow was achieved. During all submaximal strength assessments, if subjects could lift the weight greater than the desired number of repetitions indicated by the test protocol, subjects rested for 5 to 10 minutes and repeated the lift with additional weight.

Statistical Analysis

Stepwise multiple regression analysis was used to generate regression equations for predicting 1-RM strength from the 4-6 RM and 7-10 RM submaximal strength tests. Four variables (weight lifted during the submaximal strength test, the number of repetitions completed, the subject's body weight and percent body fat) were initially entered into the stepwise regression equation. The variables selected to predict 1-RM for the exercises from both the 4 to 6-RM and 7 to 10-RM submaximal strength tests were the weight lifted during the submaximal strength test and the number of repetitions completed. The degree of relationship for each regression equation for predicting 1-RM

strength from either 4 to 6-RM or 7 to 10-RM submaximal strength tests and the actual 1-RM was determined using the correlation coefficient (r) and adjusted R^2 . The adjusted R^2 value equals the explained variance between the correlated values. The standard error of estimate (SEE) between the measured and predicted 1-RM for each exercise was used as a measurement of accuracy of the prediction equation. SEE also was expressed as a percentage of the 1-RM in order to allow for a comparison between various exercises.

RESULTS

The anthropometric characteristics of the subject population, as well as the 1-RM strength for each exercise, are presented in Table 1. The regression equations for predicting 1-RM from 4 to 6-RM and 7 to 10-RM submaximal tests are presented in Table 2. The corresponding correlation coefficients (r) between predicted and measured 1-RM strength, the adjusted R^2 , standard error of estimate (SEE), and SEE as a percentage of the actual 1-RM are also reported in Table 2. Since regression equations using metric units of mass cannot be converted simply to equations using pounds and many fitness facilities use pounds, the regression equations for use with pounds are presented in Table 3.

Based on the correlation coefficient (r), the adjusted R^2 , and the SEE/1-RM, the degree of relationship between each regression equation for predicting 1-RM strength and the actual 1-RM was high for both the 4 to 6-RM and 7 to 10-RM submaximal strength tests for the bench press and inclined press. Although the 4-6-RM equation for the biceps curl had a high degree of relationship with 1-RM strength and high predictive accuracy, the 7-10-RM equation for the biceps curl has a modest degree of relationship with 1-RM strength and predictive accuracy. The predictive accuracy was lowest for both the 4-6-RM and 7-10-RM leg extension and for the 7-10-RM biceps curl.

DISCUSSION

This paper presents strength prediction equations for five common strength training exercises developed for young women with two different repetition ranges. For every exercise, except the bench press, the prediction equation based on a 4 to 6-RM set was a better predictor of 1-RM strength than the prediction equation using a 7 to 10-RM set based on the adjusted R^2 and the SEE. For the inclined press this difference was small. For the bench press, the accuracy of the 1-RM prediction equation from the 7 to 10-RM set was slightly greater than the equation using a 4 to 6-RM set. In males, the predictive accuracy was greater for all five exercises when using a prediction equation based on a 4 to 6-RM set compared with a 7 to 10-RM set (Dohoney et al., 2000). Since muscular endurance becomes more significant as more repetitions are performed, it might be expected that prediction equations based on fewer repetitions would be more accurate than equations based on sets using a higher number of repetitions. However, this may not always be accurate. There was no difference in the predicting 1-RM for the bench press when subjects were able to complete less than 8 repetitions, 8 to 15 repetitions, or more than 15 repetitions in one minute with various percentages of 1-RM (Mayhew et al., 1992). For practical purposes, both the 4 to 6-RM and 7 to 10-RM prediction equations can be used without an excessive loss of accuracy.

The predictive accuracy of the equations presented in this paper are similar to or slightly greater than the accuracy of previously published equations. Coefficients of variation of 7.3% to 9.8% were reported for a 1-RM bench press prediction equation based on the number of repetitions completed with 55 to 95% of the 1-RM in one minute (Mayhew et al., 1992). The coefficients of variation for the 1-RM bench press equations developed in the current study are slightly greater than the

coefficients of variation reported for equations developed using a YMCA bench press test in women (Kim et al., 2002); however, the adjusted R^2 values are similar or greater in the present study compared to those reported in these studies (Kim et al., 2002). The adjusted R^2 , SEE and coefficient of variation reported for a 1-RM prediction equation for the knee extension exercise from a 7 – 10 RM set (Braith et al., 1993) indicated greater predictive accuracy than the prediction equation using a 7 to 10-RM in the current study.

The results of this study suggest that the accuracy of the prediction equations is greatest for upper body exercises, such as the bench press and incline press, compared to lower body exercises, such as the leg extension. Because this study utilized only one lower body test, this outcome may not be true of all lower body exercises. The adjusted r^2 values were lowest (with one exception) and SEE greatest for the leg extension 1-RM prediction equations compared with the other four prediction equations for both the 4 to 6-RM and 7 to 10-RM tests. This is consistent with 1-RM prediction equations based on 4 to 6-RM and 7 to 10-RM sets developed for several exercises in males (Dohoney et al., 2002). Perhaps, individuals who do not routinely perform strength training exercise are more familiar with producing maximal muscular contractions with the upper body compared to the lower body.

In general, the accuracy of the 1-RM prediction equations reported in the present study is less than the accuracy of equations that we previously reported for males for the same exercises (Dohoney et al., 2002). Mayhew et al. (1987) also noted that the correlation between predicted and actual 1-RM was slightly higher for men than for women. The equations developed in the current study have acceptable predictive accuracy and add to the available equations that may be used, especially for women.

PRACTICAL APPLICATIONS

These prediction equations were developed for use on non-strength trained individuals. Prediction equations developed using untrained subjects are not applicable to strength-trained individuals (Braith et al., 1993; Hoeger et al., 1990). Prediction equations are specific to the training status of the individuals and resistance training has been found to alter the relationship between maximal and submaximal strength (Braith et al., 1993). Typically, a strength-trained individual can complete more repetitions with any given percentage of their 1-RM than an individual who is not strength-trained (Hoeger et al., 1990).

Many strength prediction equations have been published including generalized equations and exercise specific equations (Abadie et al., 1999; Bryzicki, 1993; Dohoney et al., 2002; Kuramoto and Payne, 1995; Mayhew et al., 1995). These equations should have general usefulness with novice female lifters when preparing an exercise prescription particularly when 1-RM strength tests may be problematic (Braith et al., 1993; Knutzen et al., 1999). The equations developed in the current study have acceptable predictive accuracy and add to the available equations that may be used for women.

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**Table 1. Anthropometric and Performance Measurements
for Sample Population (n=36).**

Variable	Mean \pm Std. Dev.	Minimum	Maximum
Age (yrs)	21.3 \pm 2.0	18	26
Height (cm)	165.3 \pm 7.9	139.7	177.8
Weight (kg)	63.0 \pm 11.2	45.4	94.1
Percent Body Fat	26.9 \pm 2.3		
Bench Press 1-RM (kg)	36.8 + 8.8	25.0	61.4
Inclined Press 1- RM (kg)	32.7 + 7.5	25.0	59.1
Triceps Extension 1-RM (kg)	26.2 + 4.7	18.2	36.4
Biceps Curls 1-RM (kg)	21.8 + 4.9	14.8	33.0
Leg Extension 1- RM (kg)	84.1 + 22.7	45.4	142.0

Table 2. Regression equations for predicting 1-RM from 4-6 and 7-10-RM tests.

Resistance Exercise	Prediction Equations for 4 to 6-RM tests	r	Adjusted r²	SEE (kg)	SEE/1-RM (%)
Bench Press	2.19 + (1.01 x Wt) + (0.46 x reps)	0.89	0.78	4.0	
Inclined Press	-5.94 + (1.12 x Wt) + (1.38 x reps)	0.94	0.89	2.5	7.5
Triceps Extension	-0.93 + (1.03 x Wt) + (0.72x reps)	0.86	0.72	2.4	9.2
Biceps Curl	-3.46 + (1.12 x Wt) + (0.71 x reps)	0.90	0.81	2.0	9.3
Leg Extension	-22.35 + (1.31 x Wt) + (4.07 x reps)	0.87	0.74	11.2	13.3
Resistance Exercise	Prediction Equations for 7 to 10-RM tests	r	Adjusted r²	SEE (kg)	SEE/1-RM (%)
Bench Press	0.16 + (1.07 x Wt) + (0.75 x reps)	0.91	0.81	3.7	10.1
Inclined Press	-4.42 + (1.13x Wt) + (1.02 x reps)	0.92	0.84	2.6	7.8
Triceps Extension	-5.08 + (1.12 x Wt) + (0.97 x reps)	0.82	0.65	2.7	10.4
Biceps Curl	2.02+ (0.95 Wt) + (0.39 x reps)	0.82	0.65	2.8	12.8
Leg Extension	-2.60 + (1.18 x Wt) + (2.73 x reps)	0.77	0.57	14.5	16.0

Table 3. Regression equations for predicting 1-RM from 4-6 and 7-10-RM tests using pounds as the unit of measurement.

Resistance Exercise	Prediction Equations for 4-6 RM tests
Bench Press	$4.81 + (1.01 \times \text{Wt}) + (1.00 \times \text{reps})$
Inclined Press	$-13.07 + (1.12 \times \text{Wt}) + (3.05 \times \text{reps})$
Triceps Extension	$-2.05 + (1.03 \times \text{Wt}) + (1.59 \times \text{reps})$
Biceps Curl	$-7.62 + (1.12 \times \text{Wt}) + (1.57 \times \text{reps})$
Leg Extension	$-49.16 + (1.31 \times \text{Wt}) + (8.95 \times \text{reps})$
Resistance Exercise	Prediction Equations for 7-10 RM tests
Bench Press	$0.36 + (1.07 \times \text{Wt}) + (1.64 \times \text{reps})$
Inclined Press	$-9.70 + (1.13 \times \text{Wt}) + (2.25 \times \text{reps})$
Triceps Extension	$-11.19 + (1.12 \times \text{Wt}) + (2.14 \times \text{reps})$
Biceps Curl	$4.44 + (1.00 \times \text{Wt}) + (0.86 \times \text{reps})$
Leg Extension	$-5.72 + (1.18 \times \text{Wt}) + (6.00 \times \text{reps})$