Does a Regression Equation to Predict Maximal Strength in Untrained Lifters Remain Valid When the Subjects Are Technique Trained?

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ABSTRACT
This study was implemented to determine if predicting 1 repetition maximum (1RM) bench press strength in untrained lifters from a 7–10RM strength test remains valid when subjects practiced the proper bench press technique. Thirty men 18–26 years of age participated in 2 testing sessions to assess 1RM and 7–10RM bench press strength. The sessions were separated by a minimum of 48 hours. Regression analysis indicated the following equation to predict 1RM strength from weight lifted during the 7–10RM strength test: 1RM = 8.841 + (1.1828*7–10RM). Analysis of predictive accuracy of the regression equation indicated correlation of $r = 0.969$ (SEE = 4.2 kg or 5.56% of the measured [M] 1RM). Subjects were randomly assigned to an experimental group or a control group. The experimental group practiced proper lifting technique during 4 training sessions during a 2-week period. The control group did not lift weights during this period. Following training, all subjects were reassessed for 1RM and 7–10RM bench press strength. Using the regression equation developed before training, the experimental group demonstrated a correlation of $r = 0.983$ (SEE = 3.1 kg or 4.2% of M 1RM). The control group demonstrated a correlation of $r = 0.989$ (SEE = 2.5 kg or 8.8% of the M 1RM). An independent t-test comparing the differences between posttraining bench press scores indicated no significant difference in bench press lifting ability between the experimental group (82.96 kg) following technique training and the control group (75.69 kg). Although the experimental group demonstrated a trend for increased lifting ability following instruction, results suggest that lifting technique does not affect the accuracy of the regression equation to predict 1RM strength.

Key Words: bench press, 1 repetition maximum, 7–10 repetition maximum, regression analysis


Introduction
Resistance training will always be essential to a fitness routine. To prescribe a strength training program for untrained lifters, it is necessary to first assess their muscular strength. The best method of assessing muscular strength is to determine a lifter’s 1 repetition maximum (1RM) lifting ability. However, this type of assessment may be contraindicated in untrained lifters, because lifting maximal weight may create the potential for test-induced muscle soreness and possible muscular injury in previously untrained individuals (3). This realization prompted several investigators to develop strength tests capable of predicting 1RM maximal strength based on submaximal testing (2, 3, 7, 10); however, evidence suggests that resistance training alters the relationship between maximal and submaximal strength (3). Therefore, a regression equation to predict maximal strength developed based on submaximal lifting performance of untrained lifters may not be applicable to experienced resistance trainers. The objective of this investigation was to determine if proper lifting technique is responsible for altering the relationship between maximal and submaximal strength in trained subjects.

Methods
Subjects
Thirty men 18–26 years of age, who had not weight trained during the previous 6 months and who were free of physical limitations that would prohibit them from lifting maximal weight, volunteered to participate in this study. The procedures for this study were approved by Mississippi State University’s Institutional Review Board.

Procedures
During an orientation, the testing procedures and time commitments required for participation in this study were explained to potential subjects. Following this,
subjects who agreed to participate in this study were asked to complete a medical history form and to sign an informed consent form. Subjects (N = 30) were assessed for height, weight, age, and percent body fat based on skinfold measurements (11). A Lange skinfold caliper was used to take skinfold measurements from 7 sites to estimate body density (6). Percent body fat was determined based on body density using the Siri equation (15). Resting heart rate, resting systolic blood pressure, and resting diastolic blood pressure were also assessed following a 5-minute seated rest. The physiological and anthropometric characteristics of the entire sample population are presented in Table 1. Following these assessments, subjects were instructed on the proper lifting technique for performing the bench press. Proper technique for performing a bench press includes the following: lying horizontally on the bench press. Proper technique for performing a bench press. The physiological and anthropometric characteristics of the control group are presented in Table 2. The 15 control subjects were asked to refrain from all forms of weight training. The physiological and anthropometric characteristics of the experimental subjects are presented in Table 2. The 15 subjects in the experimental group were randomly assigned to an experimental group or a control group. The 15 subjects in the experimental group were required to practice the proper lifting technique by participating in 4 training sessions during a 2-week period. During the first week, subjects participated in 2 training sessions, where they were required to lift 2 sets of 7–10 repetitions at 50% of 1RM. During the second week, subjects participated in 2 training sessions and were required to lift 2 sets of 7–10 repetitions at 60% of 1RM. Trained personnel instructed the subjects on the proper bench press lifting technique. The physiological and anthropometric characteristics of the experimental subjects are presented in Table 2. The 15 control subjects were asked to refrain from all forms of weight training. The physiological and anthropometric characteristics of the control subjects are presented in Table 3. Following the 2-week training period, subjects were reassessed for posttraining 1RM and 7–10RM...
bench press strength, using the same testing procedures as described during the pretraining testing sessions. The order of these tests was randomized.

**Statistical Analyses**

Stepwise multiple regression analysis was used to develop a linear regression equation to predict pretraining 1RM strength test from the weight lifted during the pretraining 7–10RM strength test and the number of repetitions lifted during the 7–10RM strength test. This analysis indicated that the weight lifted during the 7–10RM strength test was the only significant predictor of 1RM strength. The number of repetitions the weight was lifted during the 7–10RM strength test, therefore, was dropped as a predictor variable from the regression equation to predict 1RM strength. The same regression equation was used to predict pretraining 1RM strength from the weight lifted during the posttraining 7–10RM strength test. The accuracy of the regression equation was assessed using the mean difference (t), the Pearson product correlation coefficient (r), and the SEE between measured and predicted 1RM bench press strength. The SEE was calculated as $\frac{Sy}{1 - R^2}$, where Sy equaled the SD of the measured 1RM strength and $R^2$ equaled the explained variance between the correlated variables. Since there was no significant difference between pretraining bench press scores, an independent t-test was used to determine if significant differences existed between posttraining bench press scores. An alpha level of 0.05 was required for statistical significance.

**Results**

Based on the initial assessment, regression analysis indicated the following formula to predict 1RM bench press strength from the weight lifted during the 7–10RM bench press strength test (N = 30): $1RM = 8.8147 + 1.1828 \cdot (7–10RM)$.

Using the regression formula, a predicted 1RM was calculated for each subject. The measured and predicted bench press strength values were 74.3 ± 17.1 and 73.0 ± 12.1 kg, respectively. The correlation between measured and predicted 1RM was significant ($r = 0.969$). The SEE was 4.2 kg or 5.56% of measured 1RM.

Following the initial measurements of 1RM and 7–10RM bench press strength, subjects were randomly assigned to an experimental group (N = 15) or to the control group (N = 15). Subjects were reassessed for 1RM and 7–10RM bench press strength following the testing protocol described earlier. Results from the posttraining 7–10RM strength test were entered into the pretraining regression equation to predict 1RM bench press strength. The experimental subjects’ measured and predicted bench press strengths were 82.9 ± 14.5 and 79.7 ± 14.0 kg, respectively. The correlation between experimental subjects’ measured and predicted 1RM was significant ($r = 0.983$). The SEE was 3.1 kg or 4.2% of measured 1RM. Control subjects’ measured and predicted bench press strengths were 75.7 ± 19.0 and 78.5 ± 19.8 kg, respectively. The correlation between the control subjects’ measured and predicted 1RM was significant ($r = 0.989$). The SEE was 2.5 kg or 8.8% of measured 1RM. Independent t-test analysis demonstrated that the experimental group did not have significant strength gains when compared with the control group’s posttraining strength gains. The experimental group did demonstrate a significant increase in lifting ability (8.63 kg) when comparing the pretraining and posttraining bench press scores with a paired sample t-test ($t = 12.84; p = 0.0001$). The lack of significance when comparing the differences between the posttraining bench press strength scores of the experimental and the control group may result from the large SD within the experimental and control subjects’ posttraining bench press scores. The X and SD of the experimental and control groups’ pretraining and posttraining strength scores are presented in Table 4.

**Table 4. Independent t-test analysis between the experimental and control groups’ pretraining and posttraining bench press strength scores.***

<table>
<thead>
<tr>
<th></th>
<th>Pretreatment</th>
<th>Posttreatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
</tr>
<tr>
<td>Experimental</td>
<td>74.33 ± 14.38</td>
<td>82.96 ± 14.47</td>
</tr>
<tr>
<td>Control</td>
<td>74.33 ± 20.04</td>
<td>75.69 ± 19.09</td>
</tr>
</tbody>
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* Measurements in kilograms.

**Discussion**

The results of this study demonstrated that the initial regression equation to predict 1RM bench press strength produced a positive correlation between predicted and measured 1RM in 30 untrained men ($r = 0.97; \text{SEE} = 4.2\text{ kg}$, which represents 5.6% of the measured initial bench press strength). Following the initial assessment, subjects were randomly assigned to a control group or an experimental group. All subjects were reassessed on 2 separate occasions for 1RM and 7–10RM bench press strengths. The accuracy of predicting 1RM strength from 7–10RM strength values, using the pretraining regression equation, was high in the control group (SEE = 2.5 kg or 8.8% of measured bench press) and experimental group (SEE = 3.1 kg or 4.2% of measured bench press). This indicates that technique training did not affect the accuracy of the pretraining regression equation to predict 1RM strength following training. Based on these results, it was concluded that it is not necessary to spend 2 weeks teaching proper lifting technique before assess-
ment of 1RM; however, since bench press lifting ability increases during the first 2 weeks of training, 7–10RM bench press strength should be reassessed to update the strength training exercise prescription. Since lifting ability is a dynamic factor, 7–10RM strength should be reassessed on a periodic basis.

The current study demonstrated an apparent increase in maximal bench press strength after 2 weeks. The experimental group demonstrated greater strength gains than did the control group (experimental = 8.6-kg increase; control = 1.4-kg increase). Previous research (5, 9), however, indicates the initial increase in strength during a training program occurs too rapidly to be explained by muscular adaptation. An increase in strength, therefore, may be attributed to improved lifting technique. Several studies have demonstrated that short periods (5–8 weeks) of strength training may increase voluntary strength without evoking maximal twitch and tetanic tension. These findings may indicate that initial strength training does not increase the intrinsic contractile forces of the muscles but rather improves the trainees’ coordination and activation of the contractile fibers (4, 8).

The correlation coefficient and SEE of the regression equation generated in this study compare favorably with the regression equations for predicting maximal bench press strength developed by Mayhew et al. (7) and Braith et al. (3). The regression equation developed by Mayhew et al. was applied to trained and untrained college students, college football players, high school athletes, and high school nonathletes. Mayhew et al. (7) demonstrated that the regression equation developed in their study could accurately predict maximal bench press strength ($r > 0.95; p < 0.001$) in all the mentioned groups, with an SEE equal to 6.4 kg.

Braith et al. (3) investigated the effects of training influence on the relationship between maximal and submaximal strengths. The study by Braith et al. indicated that 1RM predictions based on pretraining 7–10RM strength tests can be made with an acceptable degree of accuracy (SEE = 10% of group mean) within specific populations. This study also demonstrated that, as an individual becomes accustomed to resistance training, the relationship between maximal strength and submaximal strength changes. Sale (13) indicated that following strength training additional motor units may be recruited during submaximal exercise, thereby improving submaximal performance, even though fiber hypertrophy has not occurred, which is essential to enhance maximal performance. Using a prediction equation developed for untrained subjects would not be appropriate to use in trained subjects (3).

Becque and Pick (1) evaluated several equations to predict 1RM. A cross-validation study demonstrated that these regression equations proved to be valid with untrained subjects with considerable individual variability. However, 1RM prediction equations do not provide valid estimates of 1RM strength for trained subjects.

Studies (1, 3) demonstrate that a regression equation based on pretraining data is no longer applicable to strength-trained subjects. The current investigators questioned whether the regression equation became invalid because of improved lifting technique during training or because of increased maximal muscle twitch and tetanic tension. The results of the present study suggest that improved lifting technique has little to no effect on the accuracy of the regression equation to predict 1RM strength based on 7–10RM strength. Further research is needed to determine the exact cause of the loss of prediction accuracy of regression equations based on the initial assessment following strength training. Since the findings of this study are only applicable to healthy, young men, more research is needed to determine if the regression equation developed in this study is applicable to other populations, such as elderly men and women.

**Practical Applications**

Regression equations to predict 1RM strength from submaximal 7–10RM strength testing in untrained lifters have been demonstrated to be ineffective in predicting 1RM strength once the individual becomes technique trained. The question, therefore, is whether the regression equation loses its predictive accuracy due to using a proper lifting technique or due to physiological adaptations within the muscle fibers, that is, enhancement of submaximal muscular strength. Enhancement of submaximal muscular strength may alter the relationship between maximal and submaximal performance. The experimental design of this study allowed for enough time to practice proper lifting technique without improving muscular strength. Since the predictive accuracy of the regression equation was unchanged from pretraining to posttraining, and the subjects in the experimental group substantially improved their lifting abilities, this study clearly demonstrated that proper lifting technique does not alter the relationship between maximal and submaximal lifting performances. This study also demonstrated that lifting performance increases substantially early in the training program because of the use of proper lifting technique; therefore, submaximal testing to predict 1RM should be performed on a periodic basis.

**References**


