Predicting Trained Females’ One-Repetition Maximum Bench Press: The use of an 85 lb. Repetitions-To-Fatigue Test

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Abstract

The purpose of this study was to determine an appropriate absolute load to use for a repetitions-to-fatigue test to predict 1 RM bench press in trained females. To assess the efficacy of using an 85lb reps-to-fatigue test, 33 competitive college students and competitive well trained college aged women were recruited by a word of mouth and signed an IRB approved informed consent. Subjects’ 1RM bench press and repetitions-to-failure with 85 lb. were measured. The 33 females were recruited to derive a predictive equation that was correlated with 1 RM (r=0.88) and allowed reasonably accurate predictions (SEE=8.02). No difference was found between actual 1 RM and the current study’s 85lb predictive equation results (t=0.001 and p>.05). The equations of Mayhew et al. (1992) and Brzycki (1993), and the data from this study’s subject, also accurately predicted 1 RM. To add support for the use of a repetitions-to-fatigue test, a comparison of mean times was made between the 85 lb reps-to-fatigue test and the actual 1 RM test (mean=0.7 min with S.D.=0.30) (mean=6.2 min. S.D.=3.34) respectively. Thus, the present study supports the idea that a heavier load, such as the 85 lb reps-to-fatigue test, is an effective, time efficient means of reasonably predicting 1 RM in trained females.

Keywords: Predicting Strength, Bench Press test, Trained females’ strength test.

1. Introduction

The most frequently used method for measuring strength is the one repetition maximum (1-RM) procedure (Brzycki, 1993; Invergo et al, 1991; Kuramoto, and Payne, 1995, Mayhew et al, 1999; Rose and Ball, 1992; Ware et al, 1995).

In addition, the 1-RM procedure is commonly used as a performance indicator and predictor for athletes, especially those in power sports (Berg et al, 1990; Fry and Kraeimer, 1991). Furthermore, training loads or resistance participants in sport use in their training programs are often based on a percentage of one’s 1RM for a particular exercise or as a percentage of body mass.

The 1-RM bench press is often used to assess upper- body strength (Brzycki, 1993; Invergo et al, 1991; Mayhew, 1992; McCurdy et al 2004). However, due to the number of trials and recovery time needed between trials, an actual 1-RM can be impractical. Although no injury data are available for 1-RM lifts, the potential for injury may be magnified with the use of heavier loads especially in early season training (Mayhew, 1992; Ware et al, 1995). Conducting the 1RM with its standard procedure is also very challenging for the strength and conditioning coach or fitness professional who trains large number of individuals at one time (Brzycki, 1993; Chapman et al 1996;Invergo et al, 1991; Kuramoto, and Payne, 1995;Mayhew, 1992;Mayhew et al, 1999; Rose and Ball, 1992; Ware et al, 1995). Contraindications to 1-RM testing that have been recognized include: unreasonable amounts of stress on the muscles, bones, and connective tissues; increases in blood pressure beyond that which is normally encountered in submaximal lifts; fractures; spondylolisthesis; and torn ligaments (Brzycki, 1993; Kuramotoand Payne, 1995).

Furthermore, it has been noted that a certain degree of skill or technique is advantageous for maximal lifts, that could confound attempts to precisely determine
strength (Brzycki, 1993; Invergo et al, 1991; Mayhew, 1992; Mayhew et al, 1999; Ware et al, 1995; Thomas and Roger, 2008). Thus, it is clear that strength and fitness professionals need to identify a safe and practical yet reasonably accurate means by which maximum muscular strength may be predicted, using a load less than 1-RM, (Brzycki, 1993; Ware et al, 1995). Reynolds et al. (2006) developed prediction equation of 1RM in bench press depending on multiple RM tests and some anthropometric measurements, gender and age. In their study they aimed to determine the optimal number of repetitions to be used by men and women of different ages.

Currently, the national football league test (NFL-225) is a widely used method for estimating the 1-RM of trained individuals especially among competitive teams. This method saves time, increases safety, and is thought to be a good predictor of an individual's 1 RM. The test consists of completing as many bench press repetitions as possible with an absolute load of 225 lb (102.27 kg) until failure to accurately perform further repetitions. A predictive equation is then used to calculate the estimated 1-RM for each individual. The NFL-225 test is based on the premise that absolute muscular endurance is related to muscular strength (Mayhew et al, 1999).

Much of the literature support the premise of a direct relationship between absolute muscular endurance and muscular strength, and various predictive equations have been derived from these studies (Arnold and Mayhew, 1995; Ball et al, 1995; Harman and Frykman, 1995; LeSuer and McCormick, 1993; Mayhew, 1995; Shaver, 1995; Thomas and Roger, 2008). These studies found a high correlation between the repetitions to fatigue tests (using an absolute load or a relative to 1-RM load) and the measured 1-RM on a given exercise. However, Mayhew et al. (2008) suggested that resistance training could alter the relationship between strength and muscular endurance in young females compared to untrained females without compromising the accuracy of predicting maximum strength.

A study by Start and Graham (1963) may offer some insight into the relationship between muscular strength and muscular endurance. Start and Graham state that when intramuscular tension becomes sufficient to cause intramuscular vascular occlusion, a relationship between absolute endurance and maximum strength (both measured isometrically) exists. If a constant demand is made, endurance varies in relation to the total amount of energy available and if the build-up of tension to occlusion levels is instantaneous, the energy available is the same reserve as that tapped in a maximum contraction used to give an estimate of isometric strength (Start and Graham, 1963). However, because measurements were made isometrically, this physiological explanation may not be relevant for dynamic exercise.

Although the many recent studies indicate a positive correlation between muscle strength and muscle endurance, there are, however, some older studies that seem to contradict this finding (Berger, 1970; Shaver, 1970). Shaver (1970) reviewed eight studies and found low or negative relationships between muscle strength and muscle endurance. However, Shaver points out that each of those low or negative correlations (ranging from -.63 to .04) were comparisons between strength and relative endurance (a percentage of each individual’s maximum load rather than a fixed absolute-load endurance). And of those eight, two found medium to high correlations between strength and absolute endurance. And three others found medium to high correlations between strength and endurance (with no designation of relative or absolute loading). It should
also be noted that of those eight studies, only Martens and Sharkey (1966), Berger (1970), and Shaver (1970) studies employed the use of dynamic strength and dynamic endurance measures. All others were static/isometric. Shaver’s study was the only one in which *dynamic* strength was compared with *absolute dynamic* endurance (using bench press lifts) \( r=0.93 \) (Shaver, 1970).

Chandler et al. (1995), recruited college baseball players as subjects (n=30) for his study, he concluded that repetitions to failure (dynamic endurance) was not a good predictor of maximum strength (\( r=0.37 \)). However, two design problems existed in Chandler’s study. First, a relative (60% of 1-RM) load was used for one of the endurance tests, and, as was previously noted by earlier literature, relative endurance loads do not correlate as highly with strength measures as do absolute loads. Secondly, a comparison was made between two different exercise modalities (lat-pull and pull-ups). Interestingly, Chandler et al. also included same-exercise correlation measures which resulted in lat-pull work and lat-pull predicted and actual 1 RM being highly related at \( r=0.86 \) and \( r=0.74 \) respectively, thus agreeing with other more recent highly correlated findings of prediction accuracy from repetitions tests within a given exercise.

Several studies carried out over the past 30 years have examined directly the prediction of bench press 1-RM from bench press reps-to-fatigue and found a high correlation and prediction capability of multiple repetitions of 1-RM (Arnold and Mayhew, 1995; Brzycki, 1993; Chapman et al 1996; Everette et al 1996).

Chapman et al. (1996) and Mayhew et al. (1999) studied absolute loads of 225 lb (102.27 kg) (as used by the NFL) for their reps-to-fatigue tests. Both studies found the 225 lb (102.27 kg) reps-to-fatigue test to be a valid predictor of 1-RM bench press. Chapman et al. (1996) reported that the 225 (102.27 kg) reps-to-fatigue data were collected in less than half the time it took to obtain the 1-RM data, thus supporting the practical use of absolute load reps-to-fatigue testing as a time saver.

Although several studies investigated the prediction of 1RM included women as subjects (Arnold and Mayhew, 1995; Ball et al, 1996; Everette et al, 1996; Kuramoto and Payne, 1995; LeSuer and McCormick, 1995; Rose and Ball, 1992), only few indicated employing trained or highly trained females as subjects (Mayhew et al, 1992; Mayhew et al, 1995). The results of these studies showed that the prediction equation by Mayhew et al.1992 produced high correlations (\( r>0.98 \)) between reps-to-fatigue testing and measured 1-RM testing. LeSuer and McCormick (1993) also reported a high correlation (\( r=0.99 \)) between reps-to-fatigue and prediction of 1-RM by using the Brzycki equation. However, only untrained female participant were included in LeSuer and McCormick’s study (Kuramoto and Payne, 1995).

Mayhew et al. (1992) reported that trained women performed significantly more repetitions in the reps-to-fatigue test than untrained women. Rose and Ball also deduced that heavier loads from 79 lb(36 kg) to 89.7 lb (40 kg) may be more appropriate than lighter loads from 35 lb (15.9 kg) to 44 lb (20.4 kg) for well-trained females in the reps-to-fatigue test (Mayhew and Ware, 1999). Interestingly, both the Mayhew et al. and the Rose and Ball studies used relative loads in their reps-to-fatigue tests, a contradiction with the previous conclusion that lower correlations (ranging from -.63 to .04) exist between maximum strength and relative load endurance tests than with absolute load endurance tests, as derived from the Shaver study (1970). Therefore, there exists a need
for further research in the accuracy between absolute and relative load reps-to-fatigue tests as 1-RM predictors, particularly for well-trained women.

The purpose of this study was to: a) Determine the accuracy of absolute load reps-to-fatigue testing in predicting individual’s 1-RM on the bench press; b) Derive a predictive equation using an absolute load which could be especially useful for well to moderately-trained female athletes; c) Evaluate time requirements of using absolute load reps-to-fatigue testing relative to 1-RM testing; d) Compare the correlative results of all four common predictive equations:

1. Mayhew et al. (1992) predictive equation:
   \[ \% \text{1-RM} = 52.2 + 41.9 e^{-0.055 \text{reps}} \]
2. Brzycki (1993) predictive equation:
   \[ \text{1-RM} = \frac{\text{weight lifted}}{1.0278 - .0278(\text{reps})} \]
3. A derived lower load predictive equation using the 85 lb load.
4. A derived lower load predictive equation using the 115 lb load.

2. Methods
2.1. Subjects:

Since only few studies were conducted with some trained and highly trained females, the need for further research involving highly trained female subjects is apparent (Mayhew, 1992; Mayhew et al., 1995). Therefore, the current study recruited 33 college age women that are somewhat trained and well-trained athletes to investigate our goals. Subjects performed three bench press tests over a period of four weeks in counter-balanced cross-over design. Thirty female subjects (collegiate athletes and well-trained individuals from the general population 18-30 years old) volunteered for this study. All subjects have their 1-RM bench press tested by standard 1RM test. All subjects performed a reps-to-fatigue test using barbell with the 85 lb (38.6 kg) resistance. When Subjects were able to lift as much as 115 lb they also performed a reps-to-fatigue test using 115 lb (52.2 kg) load.

Subjects were recruited by "word of mouth", posting flyers, and personal request. To be eligible for participation, each subject had to be involved in a regular, weekly exercise program. Subjects included Division 1AA collegiate athletes who met this criterion due to the high intensity training cycles which were already incorporated into their strength and conditioning programs. Institutional Review Board approved (IRB) informed consent was signed by all subjects in accordance with the procedures for the protection of human subjects.

2.2. Experimental Protocols and Design:

A pre-test questionnaire was administered to the subjects regarding previous and present exercise experience. Measures of body weight, body density, and percent body fat were taken by means of medical scales, skinfold calipers (Lange), and the three-skinfold site Jackson and Pollock equation (for men: chest, abdomen, and thigh; for women: triceps,
supra-iliac, and thigh) (Jackson and Pollock, 1985). All measures were taken according to the American College of Sports Medicine's guidelines.

Each subject was tested three times in a counter-balanced order. One test was an actual measure of the individual's bench press 1-RM. The test-retest reliability of the 1RM benchmark press has been shown a quite high correlation (r=0.99) (Invergo et al, 1991). The 1-RM procedure followed the standard "touch and go" protocol in which the bar be lowered to the chest before being pressed to full arm extension. Hips were required to remain on the bench at all times. Each subject was required to warm-up using light weights. Following the warm-up, each subject was encouraged to reach her 1-RM within 4 to 6 attempts. Subjects were allowed enough time to rest between given attempts. A standard Olympic bar and plates was used for all lifts and a grip slightly wider than shoulder width was used

Another test was a reps-to-fatigue test using an absolute load of 85 lb. (38.64 kg). And a third test was a reps-to-fatigue test using 115 lb. (52.2 kg). All three tests were completed within 4 weeks. For both reps-to-fatigue tests, each subject was required to perform as many repetitions as possible using a 115 lb. (52.2 kg) or 85 lb. (38.64 kg) barbell. Subjects were required to warm-up. Then, using the same grip as in the 1-RM test, the subject was required to slowly lower the bar to the chest each time and, without bouncing the weight, extend the arms fully on each repetition. Hips were required to remain on the bench at all times. No more than a 2-second rest was allowed during an individual attempt of the repetition test. The test was terminated when the subject could not complete a repetition with proper form. For all tests a spotter was in position for safety.

While many of the studies reviewed suggested that reps-to-fatigue tests offer time saving advantages, only the one study (Chapman et al 1996)measured the time requirement and stated that the reps-to-fatigue tests took half as much time as the measured 1-RM test. As a result, in the present study each test was timed by stopwatch. Timing began after the subject’s warm-up and as soon as the subject began his or her first repetition of either the measured 1-RM test or the reps-to-fatigue test. Then, the clock was stopped as soon as the last repetition of that test was completed.

2.3. Data Analysis:

To determine the accuracy of a reps-to-fatigue test to predict 1-RM, the measured 1-RM and the predicted 1-RM from the reps-to-fatigue test were correlated. Because both the Mayhew (1992) equation [% 1-RM = 52.2+41.9 e^{0.055 \text{reps}}] and the Brzycki (1993) equation [1-RM = weight lifted / 1.0278-.0278/(reps)] had high correlations, have been commonly used, and have included female participants, these equations were used for all reps-to-fatigue -tests regardless of load. Simple regression analysis was used to derive a predictive equation for the 85 lb reps-to-fatigue test. A paired t-test was used to detect a significant difference between actual and predicted 1 RM. And finally, each test was timed by means of a stop watch. Then, the mean time required for the reps-to-fatigue group and the mean time of the measured 1-RM group were compared.
3. Results
Table 1 illustrates the physical and performance characteristics of the subjects. The predictive equations and their corresponding authors are shown in Table 2. These three equations were used with the repetitions-to-fatigue data found for each subject to predict the subjects’ 1 RM. In a paired-samples test, using the subject data from the current study’s 85 lb reps.-to-fatigue test, the correlations between actual 1 RM and the predicted 1 RM as derived by the Brzycki, (1993) and Mayhew et al. (1992), and the current study equations were .84, .88, and .88 respectively.

The reps.-to-fatigue test findings using the absolute load of 115 lb were not reported due to the small number of subjects able to lift that load. Only 13 out of 33 subjects (39%) could lift 115 lb, and only 5 of the 33 (15%) were able to lift that load for more than 1 repetition.

Table 3 compares the accuracy of the Mayhew et al. (1992) equation results with that of the current study. The Mayhew results reported in Table 3 are only those derived from the college-age women used in his study since only college age women were used in the present study. Figure 1 illustrates the linear relationship between the actual 1 RM and the predicted 1 RM by means of the current equation.

The mean and S.D. of the times it took to complete the 85 lb reps-to-fatigue test and the actual 1 RM test were .651 min. (S.D.=.298) and 6.18 min. (S.D.=3.54) respectively.

4. Discussion
The current findings indicate that muscular endurance repetitions using an absolute load of 85 lbs can be used to predict 1 RM in bench press strength with reasonable accuracy in trained females. The correlation between predicted and actual 1 RM was r=0.883 and the SEE was 8.02. As indicated in Table 3 there was a not significant difference between actual 1 RM and the current study’s 85 lb predictive equation results with t=0.001 p.>.05. When observing the means of the predicted 1 RM and the actual 1 RM (Table 3), this equation underpredicted the 1 RM by 0.001 kg (.0022 lb) while the Mayhew (1992) study underpredicted the 1 RM of college age women by 0.1 kg (.22 lb).

This 85 lb load, a weight half way between the Rose and Ball (1992) suggested load of 36 kg to 40.8 kg for well-trained females, appears to be a load which nears the 1 RM of most trained females. Stone and O’Bryant (2003) suggested that the closer the repetition’s test load is to the individual’s 1 RM, the more accurate the prediction of maximum strength. Chapman et al. using an absolute load, reported that the prediction was better when the repetitions were below 10 (R²adj. = .85) than when repetitions were greater than 10 (R²adj. = .76) (Chapman et al 1996). Morales and Sobonya(1996) support this thinking as they found that athletes produce better predictions of 1 RM bench press when using loads greater than 80% of actual 1 RM than when using lighter loads (<75% 1 RM). Brzycki also gives support to this idea by stating that his test may become less accurate for estimating 1 RM if the reps-to-fatigue exceed 10 reps. Brzycki(1995) explains that this may be due to a non-linear relationship beyond about 10 reps. Ware et al. (1995) also concluded from studies by Epley and Lander, that for higher repetitions with lighter weights, linear equations are not effective predictors of 1 RM values in bench press. This seems to be the reason for Mayhew’s (1992) use of an antilog to express
exponential decay in his equation, and because his equation accounts for this exponential decay, it may be a more widely useful predictive equation at lower relative loads such as those which are <75% of an individual’s 1 RM.

However, one of the purposes for this study was to determine an effective absolute load for well-trained females. Whereas the average untrained female will need to use lower relative loads of 15.9kg (35 lb.) to 20.5 (45 lb.) like those used in the Rose and Ball (1992) study, the present study gives support that a heavier load, such as the 85 lb. used, is also an effective means of reasonably predicting 1 RM among trained females. This is probably due to the fact that the 85 lb. load represents a higher percentage of the trained females actual 1 RM and yet remains enough of a submaximal effort so as not to become as much of a risk for injury as a true 1-RM test might be. And to add support to the convenience of using an 85 lb. reps-to-fatigue test as a predictor of 1 RM the mean times should be noted. With the actual 1 RM test taking an average of 6.2 min. (S.D.=3.34) while the average 85 lb. reps-to-fatigue test took 0.7 min. (S.D. =0.30), the 85 lb. reps-to-fatigue test would be much less time consuming for the strength and conditioning professional.

While an even higher load reps-to-fatigue test might be needed for stronger females, it should be considered that the 115 lb load was simply too much for most of the subjects in this study which included 57% collegiate athletes. It is, therefore, concluded that 85 lb. is both a heavy enough load to predict 1 RM with reasonable accuracy without being too heavy, as indicated by the fact that only 15% of all the females tested in this study were able to lift the 115 lb load for more than 1 repetition, to produce repetitions for use in a predictive equation, particularly if the number of repetitions falls around 10 or under.

Further study in this area should include trained females who can lift above 115 lb to continue to evaluate the accuracy of a predictive equation. It is, of course, to be expected that the highest correlated equation would be that of the current study since it was derived from the current study’s subject data. And because no cross-validation group was used to compare all three equations, these correlations should not be used as a conclusive determinant for which equation is the best predictor. Furthermore, a drawback of this study was the lack of a cross-validation group to check the accuracy of the current study’s predictive equation for varying populations of trained females.
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Figure 1: Regression Analysis of 1 Rm and the current study’s predicted 1 RM.
### Table 1. Subject Characteristics (N=34).

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<th>Variable</th>
<th>Mean</th>
<th>SD</th>
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<td>Age</td>
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<td>2.91</td>
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<tr>
<td>Training Frequency/wk.</td>
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<td>1.03</td>
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<td>Height</td>
<td>168.52</td>
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<tr>
<td>Weight</td>
<td>64.57</td>
<td>7.39</td>
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<tr>
<td>% Body Fat</td>
<td>19.29</td>
<td>4.3</td>
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</table>

(Div. IAA Athletes N=19)
Table 2.
Equations used to predict 1 RM.

<table>
<thead>
<tr>
<th>Author</th>
<th>Equation</th>
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<tr>
<td>Brzycki, 199</td>
<td>1 RM = wt. lifted / 1.0278 - 0.0278 (reps)</td>
</tr>
<tr>
<td>Mayhew et al. 199</td>
<td>1 RM = wt. lifted / [% 1 RM = 52.2 + 41.9e^{-0.055\text{reps}}]</td>
</tr>
<tr>
<td>Current study</td>
<td>1 RM = 82.293 + 2.347 (reps)</td>
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Table 3:
Accuracy of early prediction equations.

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<tr>
<th>Equation</th>
<th>R Value</th>
<th>SEE</th>
<th>Actual 1RM(kg)</th>
<th>SD</th>
<th>Predicted 1RM(kg)</th>
<th>SD</th>
<th>t</th>
<th>p</th>
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</thead>
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<td>Mayhew et al. 199 (N=101)\a</td>
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<td>3.6\a</td>
<td>37.0\a</td>
<td>9.2\a</td>
<td>36.9\a</td>
<td>8.3\a</td>
<td>.3\a</td>
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</tr>
<tr>
<td>Current Study (N=34)</td>
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<td>8.023</td>
<td>48.347</td>
<td>7.649</td>
<td>48.346</td>
<td>6.755</td>
<td>.001</td>
<td>.999</td>
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</table>

\a College age women