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PREDICTION OF ONE REPETITION MAXIMAL STRENGTH FROM A 5-10 REPETITION SUBMAXIMAL STRENGTH TEST IN COLLEGE-AGED FEMALES**BEN R. ABADIE AND MILDRED C. WENTWORTH**

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ABSTRACT

Prediction of one repetition maximal strength from a 5-10 repetition submaximal strength test in college-aged females. BEN R. ABADIE AND MILDRED C. WENTWORTH. *JEP*online. 2000, 4(2):1-6. The purpose of this investigation was to develop three regression equations to predict 1-RM chest press strength (CPS), shoulder press strength (SPS), and knee extension strength (KES) from a 5-10 RM CPS, SPS, and KES test in females 19-26 years of age. Thirty healthy adult females were tested for 1-RM and 5-10 RM strength. The order of testing was counterbalanced to minimize the effect of improved technique. Simple regression analysis produced the following equation to predict 1-RM CPS from submaximal CP testing: [1-RM (lb) = 7.24 + (1.05 SCP)]. The correlation between predicted and measured 1-RM CP was $r=0.91$. The SEE was 2.5 kg or 7.8% of measured 1-RM CPS. The mean and standard deviations for the measured 1-RM CPS and the predicted 1-RM CPS was 32.3±5.4 kg and 32.3±6.0 kg respectively. Regression analysis also produced the following equation to predict 1-RM SPS from submaximal SP testing: [1-RM (lb) = 1.43 + (1.20 SPS)]. The correlation between predicted and measured 1-RM SPS was $r=0.92$. The SEE was 1.6 or 7.6% of the measured 1-RM SPS. The mean and standard deviations for the measured 1-RM SPS and the predicted 1-RM SPS were 21.4±4.0 kg and 21.4±3.7 kg respectively. Regression analysis also produced the following equation to predict 1-RM KES from submaximal KE testing: [1-RM (lb) = 4.67 + (1.14 KES)]. The correlation between predicted and measured 1-RM KES was $r=0.94$. The SEE was 2.3 kg or 6.3% of measured 1-RM KES. The mean and standard deviations for the measured 1-RM KES and the predicted 1-RM KES were 38.5±7.6 kg and 38.4±6.8 kg respectively. The results of this study indicate that 1-RM CPS, SPS, and KES may be predicted with an acceptable degree of accuracy in untrained female subjects.

Key Words: Regression Analysis, Bench Press, Shoulder Press, Leg Extension Press**INTRODUCTION**

Resistance training is an intricate component of a fitness routine and is one factor of several that can retard bone mineral loss during aging (1,2). This is especially true for female subjects, who experience an increased risk for bone mineral loss after menopause. To prescribe a strength training

program for novice lifters, it is essential to assess an individual's muscular strength. A resistance training program is then prescribed based on a percent of a subject's maximum muscular strength. The best method for assessing muscular strength is to determine an individual's one repetition maximum (1-RM) lifting capacity. However, this type assessment may be contraindicated in subjects who

have no prior lifting experience (3,4), since maximal strength testing may produce test induced muscle soreness and muscular injury from muscle strain in previously untrained individuals. Based on this realization, several investigators developed submaximal strength tests to predict 1-RM maximal strength. This assessment allows fitness instructors to prescribe a resistance training program without subjecting the individual to a 1-RM strength assessment.

Several investigators have developed regression equations to predict 1-RM strength from the number of submaximal lifts performed (3,4,5,6,7,8). The above studies were able to predict 1-RM strength in male subjects, based on the number of repetitions of submaximal weight one could lift. In 1961, Berger (5) measured 1-RM strength as well as 5-RM and 10-RM bench press strength. Berger estimated 1-RM bench press from the weight lifted during the 5-RM and 10-RM strength test. Berger then developed a chart to predict 1-RM bench press strength from the weight lifted during the 5-RM and the 10-RM submaximal strength test. The average percent of 1-RM from the 5-RM and the 10-RM strength tests were 89.8 and 79.9 respectively. The mean percentages were then interpolated to estimate percentage of 1-RM weight lifted during a 2-RM, 3-RM, 4-RM, 6-RM, 7-RM, 8-RM and 9-RM submaximal strength test. Therefore, one could perform a submaximal strength test between 2 and 10 lifts and estimate 1-RM strength. The correlation between the measured 1-RM and the predicted 1-RM strength from the Berger Chart was $r=0.96$.

Since the development of the Berger Chart, several investigators have attempted to refine the prediction of 1-RM strength. In 1993, Braith et al. (3) attempted to predict 1-RM knee extension strength from the amount of weight lifted during a 7-10 RM submaximal strength test. Braith et al. selected 7-10 submaximal strength test because in a training setting, a weight is typically lifted 7 to 10 repetitions per set. Braith et al. demonstrated the relationship between measured and predicted 1-RM strength in previously untrained subjects was linear. The correlation between measured and predicted knee extension strength was $r=0.94$, $SEE=9.3$ kg.

Mayhew et al., 1991 (9) attempted to determine the relationship of structural dimensions of subjects to bench press strength in college males. Multiple regression analysis indicated that upper arm cross-sectional area, percent body fat, and chest circumference could predict 1-RM bench press strength. The correlation of the prediction of 1-RM bench press strength based on a regression equation incorporating on the above structural dimensions and the measured 1-RM bench press strength was $r=0.83$, $SEE=11.6$ kg.

Little research exists to predict 1-RM strength from submaximal weight lifted by female subjects. Rose and Ball (10) evaluated untrained to moderately trained female subjects 18 to 25 years of age to determine if 1-RM strength can be predicted from the number of submaximal lifts performed in this population. Each subject was measured for 1-RM bench press strength and two submaximal bench press strength assessments. During the submaximal assessments, subjects were asked to bench press 15.9 kg and 20.4 kg as many times as they could to determine muscular endurance with these two weights. Regression analysis using muscular endurance during the 15.9 kg and the 20.4 kg assessment predicted 1-RM bench press strength with correlations of $r=0.78$ and 0.82 respectively. When body weight was added to muscular endurance within the regression equation, the correlation between measured and predicted for the 15.9 kg and the 20.4 kg assessment increased the correlation $r=0.81$ and 0.84 respectively. The above authors concluded from their study, that the closer the submaximal weight lifted was to the weight lifted during the 1-RM assessment the more accurate the regression equation to predict 1-RM strength. The authors also concluded that the addition of physiological data (ie. body weight) had minimal influence on the regression equation to predict 1-RM strength.

Mayhew et al., 1992 (11) required subjects (male and female) to perform as many correct repetitions of the bench press lifts as possible at a weight equal to 55 to 95% of 1-RM strength in a one minute period to predict 1-RM bench press strength. Since the relationship between 1-RM strength and reps performed during the submaximal strength

assessment were not significantly different in slope and intercept, the investigators combined the data for males and females. The correlation between measured and predicted 1-RM strength was $r=0.80$, $SEE=6.4$ kg. These authors also concluded that the closer the submaximal weight lifted was to the weight lifted during the 1-RM assessment the more accurate the regression equation to predict 1-RM strength.

In 1998, Cummings and Finn (12) investigated 57 females 18 to 50 years of age who had not undergone any muscular strength training to determine if a 4-8 RM submaximal bench press strength test could predict 1-RM bench press strength. The investigators included the weight lifted during the 4-8 RM submaximal strength test, the number of repetitions performed during this test, and the biacromial breadth to predict 1-RM bench press strength. The relationship between predicted and measured 1-RM strength was $r=0.94$, $SEE=1.67$ kg.

Regression equations are specific to variables such as age range, gender, muscle group measured, and the technique in which the muscle group strength is assessed (ie. free weights or machine weights). The purpose of this investigation was to develop regression equations to predict 1-RM chest press strength (CPS), shoulder press strength (SPS), and knee extension strength (KES) from 5-10 RM CPS, SPS, and KES tests on machine weights in females 19-26 years of age.

METHODS

Subjects

Thirty female subjects 19 to 26 years of age, who have not participated in a strength training program during the previous year, and were free of physical limitations that would prohibit them from lifting maximal weight, volunteered to participate in this study. The procedures of this study were approved by Mississippi State University's Institutional Review Board.

Procedures

During an orientation session, the testing procedures and time commitment required for participation in this study were verbally explained to potential subjects. Following the orientation, all subjects

agreed to participate in this study, and were asked to complete a medical history form and sign an informed consent form. Subjects were then assessed for height, weight, age, and percent body fat based on skinfold calibration (13). A Lange skinfold caliper was used to take skinfold measurements from seven sites (14). Body density was determined based on the Siri equation (15). Resting heart rate, and resting systolic and diastolic blood pressures were assessed following a 5-minute seated rest. Following these assessments, subjects were instructed on the proper lifting technique for performing the chest press, shoulder press and knee extension press.

During the second and third testing sessions, subjects were assessed for one repetition maximal (1-RM), or submaximal 5-10 repetition (5-10 RM) for CPS, SPS, and KES. The order of testing (1-RM or 5-10 RM strength tests) was randomized to reduce a learning effect when performing the lifts. All of the strength assessments were conducted on Sprint weight lifting machines (Hoggan Health Industries). If subjects were able to perform more lifts than designated by the testing protocol, subjects were allowed a minimum of 2 min rest and were reassessed. For the 1-RM test, subjects initially lifted a weight approximating 50% of the estimated 1-RM. The increments of weight were dependent upon the effort required for the lift. The weight added became smaller as the effort to lift the weight increased. When the subject could only lift the weight once, the last weight successfully lifted was considered the subject's 1-RM strength. The 5-10 submaximal strength test also required subjects to lift a weight initially 25% to 35% of the estimated 1-RM. Weight was added in subsequent lifts according to the procedures stated for the 1-RM assessment. When the subject could only lift the weight 5-10 times, that weight was considered the subject's 5-10 RM strength. A minimum of 48 hours separated the 1-RM and 5-10 RM assessments. Subjects were also asked to refrain from strenuous physical activity for at least 24 hours before testing.

For all of the 1-RM and 5-10 RM CPS assessments, the movement was performed in a seated, upright position. The subject grasped the handles, palms

down, thumbs over the bar, hands positioned slightly wider than shoulder width, and seated in a comfortable position straddling the machine. The lower back and hips stayed in contact with the backrest, and subjects were instructed to keep their feet in contact with the floor. The elbows were held high, but not over the plane of the shoulder joint. Subjects were instructed to exhale as they pushed the bar forward until the arms were near full extended (not locking the elbows). Subjects were instructed to inhale as they slowly returned the bar to its starting position. The lift was performed in a controlled manner, taking approximately 2 seconds for each of the concentric and eccentric phases.

For all of the 1-RM and 5-10 RM SPS assessments movements were performed in a seated, upright position, straddling the bench facing the machine. The hands were positioned on the hand-grips slightly wider than shoulder width. The palms were facing forward, grasping the hand-grip in an open, relaxed manner. Subjects were instructed to slide the hips forward until the shoulders and the hips were aligned vertically under the hand-grips. During the lift, the subjects pressed the hand-grips upward until the arms were near full extension, exhaling and without arching the back. The subjects then returned the weight slowly back to the starting position. The lift was performed in a controlled manner, as described for the CPS assessments. The subject's feet remained in contact with the floor during the entire lift.

For all 1-RM and 5-10 RM KES assessments, the movements were performed in a seated position. The height of the seat allowed for a 90-degree angle at the knees. Subjects grasped the handles, palms facing in. Subjects tucked their ankles behind the roller pad and lifted the roller pad upward, while refraining from arching the back. Subjects exhaled as they lifted the roller pad upward until the knees were near full extension. Subjects inhaled as they slowly returned the roller pad to the starting position. The lift was performed in a controlled manner, as described for the CPS assessments.

Statistical Analyses

The following variables were entered into three stepwise multiple regression analyses to predict 1-RM CPS, SPS and KES: weight lifted during the 5-

10 RM submaximal strength test, repetitions lifted during the 5-10 RM test, age, height, weight, percent body fat, RHR, RSBP, RDBP, and biacromial breadth. The only variable selected to predict each of CPS, SPS, KES 1-RM was the weight lifted during the respective 5-10 RM submaximal strength tests. Therefore, simple linear regression equations were used to predict 1-RM CP, SP, and KE strength from the weight lifted during the respective 5-10 RM CPS, SPS, and KES tests. The accuracy of the regression equation was determined using the correlation coefficient (r), and the standard error of the estimate (SEE) between the measured and predicted 1-RM CPS, SPS, and KES. The SEE was calculated as $Sy/1-R^2$, where $Sy=SD$ of the measured 1-RM strength and $R^2=$ the explained variance between the correlated variables. An alpha level of 0.05 was required for statistical significance. Data are presented as mean \pm SD. Weight data are expressed as kg in text, and due to the equipment used as lb in the regression equations and figures.

RESULTS

The physiological and anthropometric characteristics of the subject population are presented in Table 1. Simple regression analysis produced the following equation to predict 1-RM CP strength from submaximal 5-10 RM CPS testing: [1-RM (lb) = 7.24 + (1.05 CPS)]. The correlation between predicted and measured 1-RM chest press was $r=0.91$. The SEE was 5.5 lb or 7.8% of measured 1-RM CPS. The mean and standard deviations for the measured and predicted 1-RM CPS were 32.3 \pm 5.4

Table 1: Physiological and anthropometric measurements for sample population (n = 30)

Variables	Mean \pm SD
Age (yr)	22.2 \pm 1.2
Height (cm)	163.3 \pm 5.3
Weight (kg)	62.0 \pm 9.7
Body Density (gm/cc)	1.05 \pm 0.03
Body Fat (%)	21.9 \pm 5.4
RHR (b/min)	67.0 \pm 10.2
RSBP (mm Hg)	119.4 \pm 8.9
RDBP (mm Hg)	73.6 \pm 6.3

RHR = Resting Heart rate, RSBP = Resting Systolic Blood Pressure. RDBP = Resting Diastolic Blood Pressure

kg and 32.3±6.0 kg respectively. The relationship between predicted and measured CPS is illustrated in Figure 1.

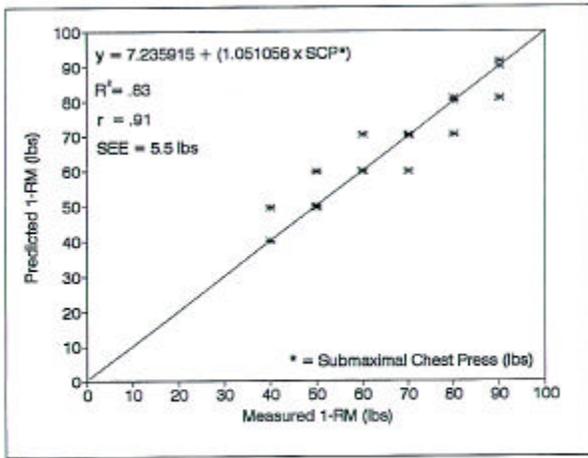


FIGURE 1. RELATIONSHIP BETWEEN PREDICTED AND MEASURED 1-RM CHEST PRESS STRENGTH

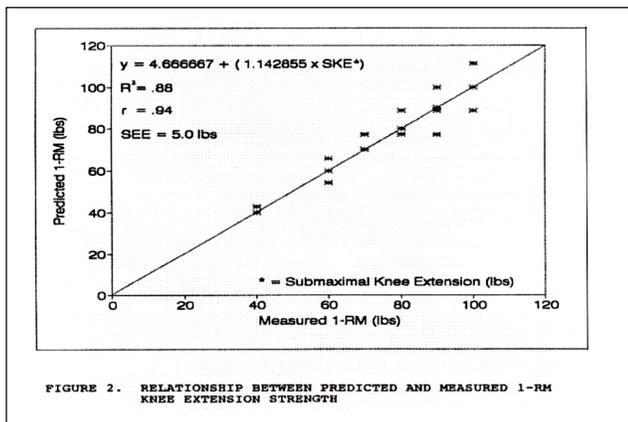


FIGURE 2. RELATIONSHIP BETWEEN PREDICTED AND MEASURED 1-RM KNEE EXTENSION STRENGTH

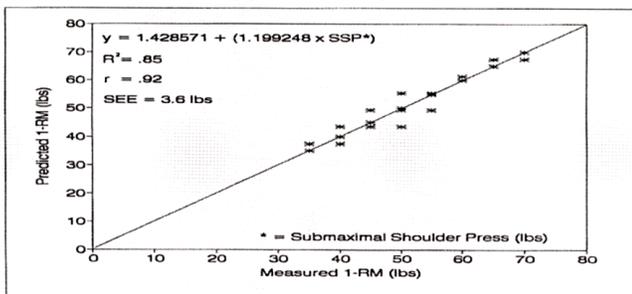


FIGURE 3. RELATIONSHIP BETWEEN PREDICTED AND MEASURED 1-RM SHOULDER PRESS STRENGTH

Simple regression analysis also produced the following equation to predict 1-RM KES from submaximal 5-10 RM knee extension testing: [KES 1-RM (lb) = 4.67 + (1.14 KES)]. The correlation

between predicted and measured 1-R KES was $r=0.94$. The SEE was 2.3 kg or 6.3% of the measured 1-RM KE strength. The mean and standard deviations for the measured and predicted 1-RM KES were 38.5±7.6 kg and 38.4±6.8 kg respectively. The relationship between predicted and measured KES is illustrated in Figure 2.

Simple regression analysis produced the following equation to predict 1-RM SPS from submaximal 5-10 RM SPS testing: [1-RM (lb) = 1.43 + (1.20 SPS)]. The correlation between predicted and measured 1-RM SPS was $r=0.92$. The SEE was 1.6 kg or 7.6% of measured 1-RM SPS. The mean and standard deviations for the measured and predicted 1-RM SPS were 21.4±4.0 kg and 21.4±3.7 kg respectively. The relationship between predicted and measured SPS is illustrated in Figure 3.

DISCUSSION AND CONCLUSION

The results of this study demonstrated a significant positive correlation between predicted and measured 1-RM CPS, SPS, and KES in 30 untrained female subjects. These results are consistent with the findings of studies that have attempted to predict 1-RM strength from submaximal strength tests in male (3,4,5,6,7,8) and female (10,11,12) subjects. Based on the limits of sample size and the use of Sprint weight lifting machines, the regressions equations generated in this study may be used to predict 1-RM CPS, SPS, and KES from a 5-10 RM CP, SP, and KE strength test in young adult female subjects. Unlike several studies reviewed in the introduction, the current study did not demonstrate that the inclusion of physiological structural dimensions (9,10,12), or the number of repetitions performed during the submaximal strength test (5,6,7,11,12) improved the accuracy of the regression equations developed in this study.

There were no reported incidents of muscular injury following the 1-RM or 5-10 RM strength assessments; 3 of the 30 subjects within this study reported mild symptoms of delayed onset of muscle soreness following the 1-RM strength test. In two of the three cases, subjects performed the 1-RM strength assessment prior to performing the 5-10 submaximal strength tests. Both subjects reported the delayed onset of muscle soreness did not limit

their abilities to perform the submaximal strength test. There were no reported incidents of delayed onset of muscle soreness following the 5-10 RM submaximal strength tests. The results of this study support the concerns of previous investigators (3,4) who believed that a 1-RM test may induce muscle soreness following the assessment. These findings imply that not only is the prediction of 1-RM strength from a 5-10 submaximal strength test practical, the 5-10 submaximal strength test is effective in limiting the occurrence of delayed onset of muscle soreness that may be associated with 1-RM strength assessments.

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