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Validation of Submaximal Prediction Equations for the 1 Repetition Maximum Bench Press Test on a Group of Collegiate Football Players

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ABSTRACT

The purpose of the study was to determine the accuracy of 11 prediction equations in estimating the 1 repetition maximum (1RM) bench press from repetitions completed by collegiate football players (N = 69) using 225 lb. The demographic variables race, age, height, weight, fat-free weight, and percent body fat were measured to determine whether these variables increased the accuracy of the prediction equations; race was the most frequently selected variable in the regression analyses. The validity of the prediction equations was dependent upon the number of repetitions performed, i.e., validity was higher when fewer repetitions were completed. Explained variability of 1RM was slightly higher for all 11 equations when demographic variables were included. A new prediction equation was also developed using the number of repetitions performed and the demographic variables height and fat-free weight.

Key Words: muscular strength, strength prediction, percentages, muscular endurance

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Introduction

Resistance training has become an integral part of athletic conditioning. One of the major benefits of participating in a resistance training program can be a significant increase in muscular strength (4). Wathen (21) defined muscular strength as the force that a muscle or muscle group can exert against a resistance in 1 maximal effort through a full range of motion. The most common method of assessing muscular strength is the 1 repetition maximum (1RM) test (1, 10). One of the most popular measurements of upper body strength is the 1RM bench press (1, 7, 11, 12, 14, 15, 17, 21). However, because of perceived safety concerns and time constraints, 1RM testing has been viewed as both dangerous and impractical (2, 7, 14, 15). Consequently, many coaches and strength and conditioning specialists have implemented submaximal testing to estimate the 1RM in the bench press.

One of the most common submaximal tests utilized by the National Football League (NFL) and at the collegiate level is the 225-lb bench press with repetitions to fatigue (14). Investigators have completed numerous studies evaluating different submaximal percentages of maximal strength (2, 6–8, 11–13, 15). Results from these studies have led to the development of several formulas to estimate 1RM from repetitions to fatigue. The basis of the formulas is the strong association between 1RM and number of repetitions (10 or fewer) needed to reach fatigue (10). However, when more than 10 repetitions are performed, there appears to be greater difference between the actual 1RM and the predicted 1RM (3). Therefore, the validity of the prediction equations is in question.

Many resistance programs are based on percentages of an athlete's 1RM (16). For example, an athlete may perform a specified number of sets and repetitions at 75%, 80%, and 85% of his or her 1RM. However, an athlete's estimated 1RM varies depending on the prediction equation. It is critical for the estimated 1RM to be as accurate as possible because of the increased risk of injury from overpredicting 1RM. The increased risk in injury may also lead to lost training time. In addition, prediction equations that underpredict 1RM may require coaches and strength personnel to adjust the estimated 1RM to the proper level, causing further delays in the athlete's resistance program.

Therefore, there is a need to evaluate the validity of prediction equations to estimate the 1RM bench press test using repetitions completed with 225 lb.

Because of the lack of prior research concerning the effects of demographic variables on strength prediction, there is also a need to evaluate the influence of these variables on the accuracy of prediction equations. The addition of these demographic variables may increase the accuracy of prediction equations, and athletes differing in height, weight, race, age, percent body fat, fat-free weight (FFW), and weight training experience may need to be evaluated using different equations.

Methods

Experimental Approach to the Problem

In this study, we investigated both the validity of prediction equations in estimating the 1RM bench press test results from repetitions completed with 225 lb and the influence of demographic variables on the accuracy of these prediction equations. All subjects were tested for their 1RM and 225-lb repetition test maximum on the supine bench press. In addition, all subjects were measured for a number of demographic variables: height, weight, race, age, percent body fat, and fat-free weight.

Subjects

Sixty-nine men 18–24 years of age were recruited from the East Tennessee State University football team (Division I-AA) for the study. Thirty-two of the subjects were African American, and 37 were white. Team members included redshirt freshmen, sophomores, redshirt sophomores, juniors, redshirt juniors, seniors, and redshirt seniors. The study was approved by the Institutional Review Board of East Tennessee State University, and all subjects signed informed consents before they were allowed to participate.

Anthropometric Measurements

The subjects were measured for height, weight, and body composition during afternoon training sessions. Body composition was predicted using the sum of 7 skinfolds technique (5). The 7 sites included chest, axilla, triceps, subscapular, abdominal, suprailiac, and thigh. Each site was measured twice in nonsequential order to assure maximum accuracy. When the 2 measurements differed by ±1 mm, a third measurement was taken.

1RM Bench Press and 225-lb Repetition Tests

The 1RM bench press test was used to assess upper body muscular strength. Subjects performed the 1RM bench press test at the end of the 9-week off-season strength program. Subjects performed the 225-lb repetition test 3 days after the 1RM bench press test. The 1RM bench press test and the 225-lb repetition test were both performed during afternoon training sessions. Both tests utilized a MuscleMaxx (Knoxville, TN) free-weight supine bench press.

Each subject was allowed as much time as needed to properly warm up. For 1RM testing, the individual subject decided upon the number of warm-up sets and repetitions. Researchers have not identified a best warm-up regime for 1RM testing. According to researchers, enough warm-up sets should be employed to raise core temperature and allow for mental preparation and task focus (4, 19, 21). Subjects were allowed a 3- to 5-minute rest interval between 1RM attempts (21). For the 225-lb repetition testing, a mandatory warm-up was included. All subjects completed 1 set of 10 repetitions using the bar (45 lb) and 2 sets of 10 repetitions using 135 lb. Performance of more warm-up sets was optional.

Spotters were used during both the 1RM and the 225-lb repetition test. The spotters helped lift the bar from the support racks. The subject lowered the bar slowly to his chest and then returned the bar to the fully extended position. The spotters helped the subject rack the weights. During the lifts, the subjects were in a supine position on the bench, with both feet flat on the floor and both hands on the bar using an overhand grip. Subjects utilized various grip widths for both the 1RM and the 225-lb repetition test. However, exact grip widths were not measured. At no time during the lifts were subjects allowed to lift their buttocks off the bench. If the subject's buttocks did lose contact with the bench, the lift did not count. If the subject bounced the bar off his chest or if the spotters touched the bar during the lift, the lift did not count. All test measurements were supervised by the primary investigator or the head strength and conditioning coach of East Tennessee State University.

Statistical Analyses

Statistical analyses consisted of paired *t*-tests, Pearson product-moment correlation analyses, and regression analyses and were conducted utilizing SPSS. Analyses were performed on the following repetition ranges: composite sample, 1–10, and 11–20.

Paired *t*-tests were used to determine whether differences between actual 1RM and estimated 1RM achieved through prediction equations were significantly different from zero. Paired *t*-tests were also used to determine paired differences between actual 1RM and estimated 1RM. The paired differences show how much (mean ± *SD*) a prediction equation underestimates or overestimates actual 1RM. Pearson product-moment correlation analyses were used to compare the linear relationship between the values achieved (actual 1RMs) and those predicted by the equations.

Regression analyses were used to determine how much variance was explained by demographic variables race, age, height, weight, fat-free weight (FFW), and percent body fat. A multiple regression analysis was also used to develop a new prediction equation based on the population in this study. Paired *t*-tests and Pearson product-moment correlation analyses were then performed on the new equation. Significance was accepted at $p \leq 0.05$.

Results

The characteristics of the 69 collegiate football players participating in this study are listed in Table 1. Strength testing data consisted of the 1RM bench press test and the 225-lb repetition test. The formulas for the 11 prediction equations are listed in Table 2.

Table 3 presents the statistical analyses for the composite sample ($N = 69$). The Mayhew et al.$_{(1)}$, O'Conner, Lombardi, and Chapman et al. equations significantly underestimated actual 1RM by averages of -7 ± 22 lb, -17 ± 20 lb, -25 ± 30 lb, and -7 ± 18 lb, respectively. The Lander and Brzycki equations significantly overestimated actual 1RM by averages of 32 ± 63 lb and 33 ± 69 lb, respectively. Only the Wathen, Epley and Mayhew combo, Epley, Mayhew et al.$_{(2)}$, and Slovak et al. equations produced values that did not differ significantly from actual 1RM values.

Thirty-one subjects performed between 1 and 10 repetitions (Table 4). The Brzycki, O'Conner, and Chapman et al. equations significantly underestimated actual 1RM by averages of -5 ± 10 lb, -10 ± 11 lb, and -5 ± 10 lb, respectively. The Mayhew et al.$_{(1)}$ equation significantly overestimated actual 1RM by an average 5 ± 11 lb. The Lander, Epley, Epley and Mayhew combo, Wathen, Lombardi, Mayhew et al.$_{(2)}$, and Slovak et al. equations produced values that did not differ significantly from actual 1RM values. The Lander and Brzycki equations were the most accurate in predicting actual 1RM ($r_{La} = 0.898$, $r_B = 0.898$).

The statistical analyses of 11–20 repetitions ($n = 33$) are given in Table 5. The Lombardi, Mayhew et al.$_{(1)}$, O'Conner, and Chapman et al. equations significantly underestimated actual 1RM by averages of -39 ± 28 lb, -16 ± 24 lb, -25 ± 24 lb, and -11 ± 23 lb, respectively. The Lander and Brzycki equations significantly overestimated actual 1RM by averages of 39 ± 39 lb and 40 ± 41 lb, respectively. Only the Wathen, Epley and Mayhew combo, Epley, Mayhew et al.$_{(2)}$, and Slovak equations produced values that did not differ significantly from actual 1RM values. The Lombardi and Wathen equations were the most accurate in predicting actual 1RM ($r_{Lo} = 0.675$, $r_{Wa} = 0.675$).

Results of the stepwise multiple regression analyses for the composite sample ($N = 69$) are shown in Table 6. Demographic variables increased the explained variance in all 11 equations: O'Conner, $R^2_O = 0.856$; Epley, $R^2_E = 0.856$; Epley and Mayhew combo, $R^2_{EM} = 0.856$; Mayhew et al.$_{(2)}$, $R^2_{M(2)} = 0.856$; Chapman et al., $R^2_{Ch} = 0.856$; Slovak et al., $R^2_S = 0.856$; Mayhew et al.$_{(1)}$, $R^2_{M(1)} = 0.852$; Wathen, $R^2_{Wa} = 0.850$; Lander, $R^2_{La} = 0.830$; Brzycki, $R^2_B = 0.824$; and Lombardi, $R^2_{Lo} = 0.792$. Table 7 shows which demographic variables loaded with each equation and how much each demographic variable increased the R^2 value.

A multiple regression analysis was performed to develop a new prediction equation based on the population in this study, the Whisenant et al. equation ($R = 0.933$, SEE $= \pm 16.5$ lb): 1RM (lb) = 307.909 + 5.21367[reps(repetition weight/FFW)] + (0.769843*FFW) + (−2.99795*height), where repetition weight and fat-free weight (FFW) are measured in pounds and height is measured in inches.

Table 1. Subject characteristics ($N = 69$).

Variables*	Mean ± *SD*	Minimum	Maximum
Age (y)	20 ± 1	18	24
Height (in.)	71.6 ± 2.7	64.8	76.5
Weight (lb)	224 ± 42	150	369
Percent Fat	16.6 ± 6.5	6.0	33.0
FFW (lb)	184.4 ± 21.7	35.5	247.2
Repetitions	12 ± 6	1	27
1-RM (lb)	307 ± 45	225	425

* FFW = fat-free weight; 1RM = 1 repetition maximum.

Discussion

This study differed from previous studies in a number of ways. In the current study, a predetermined submaximal weight (225 lb) was used for testing. In previous research, such as studies directed by LeSuer and McCormick (9) and LeSuer et al. (10), subjects chose submaximal weights that brought them to fatigue in 10 or fewer repetitions. Subjects in studies by Mayhew et al. (13) and Ware et al. (20) selected a random weight and performed as many repetitions as possible. In the Mayhew et al. study ($N = 220$), 74 subjects performed less than 10 repetitions and 147 subjects performed 10 or more repetitions (13). Repetitions in the Ware et al. study ($N = 45$) ranged from 9 to 20, with an average of 14 (20).

Chapman et al. (3), Mayhew et al. (14), and Slovak et al. (18) conducted studies in which a predetermined submaximal load (225 lb) was used. However, none of these investigators evaluated the influence of demographic variables on the prediction equations. Chapman et al. tested the validity of the 225-lb repetition test as a submaximal estimate of 1RM but did not analyze the validity of each individual prediction equation.

Previous studies designed to evaluate the validity of estimating 1RM from repetitions predominantly utilized only four prediction equations: Brzycki, Epley, Lander, and Mayhew et al. LeSuer et al. (10) conducted

Table 2. Prediction equation formulas.

Equation	Formula
Brzycki	Repetition weight/[1.0278 − 0.0278(reps)]
Chapman et al.	223.1 + 6.67(reps@225)
Epley	[0.033(reps)](repetition weight) + (repetition weight)
Epley and Mayhew combo	The average of the Epley and Mayhew et al. formulas
Lander	(100)(repetition weight)/[101.3 − 2.67123(reps)]
Lombardi	(repetition weight[reps(0.1)]
Mayhew et al.$_{(1)}$	(100)(repetition weight)/(52.2 + 41.9 · e − 0.055 reps)
Mayhew et al.$_{(2)}$	226.7 + 7.71(reps@225)
O'Conner	(repetition weight){1 + [0.025(reps)]}
Slovak	221.8 + 7.17(reps@225)
Wathen	(100)(repetition weight)/48.8 + 53.8 · e − 0.075 reps)

Table 3. Predicted 1RM values* for combined sample ($N = 69$) and comparisons with the actual value of 307 ± 45 lb.

Equation	Predicted 1RM	Paired differences	*t*	*r*
Brzycki	341 ± 102	33 ± 69	4.042†	0.844
Chapman et al.	300 ± 40	−7 ± 18	−3.292†	0.916
Epley	311 ± 45	3 ± 18	1.535	0.916
Epley and Mayhew combo	306 ± 37	−2 ± 19	−0.776	0.917
Lander	340 ± 96	32 ± 63	4.306†	0.850
Lombardi	283 ± 19	−25 ± 30	−6.799†	0.861
Mayhew et al.$_{(1)}$	301 ± 29	−7 ± 22	−2.613†	0.917
Mayhew et al.$_{(2)}$	309 ± 43	1 ± 18	0.615	0.916
O'Conner	290 ± 34	−17 ± 20	−7.332†	0.916
Slovak	305 ± 43	−3 ± 18	−1.248	0.916
Wathen	312 ± 43	4 ± 18	1.887	0.917
Whisenant et al.	307 ± 42	−0.09 ± 17	−0.044	0.926

* Mean ± *SD.* 1Rm = 1 repetition maximum.
† $p \leq 0.05$, significantly different from actual 1RM.

Table 4. Predicted 1RM values* based on prediction equations for 1–10 repetitions ($n = 31$) and comparisons with the actual value of 269 ± 22 lb.

Equation	Predicted 1RM	Paired difference	*t*	*r*
Brzycki	265 ± 23	−5 ± 10	−2.491†	0.898
Chapman et al.	264 ± 18	−5 ± 10	−2.753†	0.896
Epley	271 ± 20	2 ± 10	0.874	0.896
Epley and Mayhew combo	272 ± 17	3 ± 10	1.705	0.896
Lander	267 ± 22	−2 ± 10	−1.193	0.898
Lombardi	266 ± 17	−3 ± 13	−1.264	0.829
Mayhew et al.$_{(1)}$	274 ± 15	5 ± 11	2.347†	0.895
Mayhew et al.$_{(2)}$	270 ± 19	1 ± 10	0.701	0.896
O'Conner	260 ± 15	−10 ± 11	−4.817†	0.896
Slovak	266 ± 19	−3 ± 10	−1.805	0.896
Wathen	272 ± 23	3 ± 10	1.371	0.895
Whisenant et al.	269 ± 21	0.25 ± 11	0.129	0.874

* Mean ± *SD.* 1RM = 1 repetition maximum.
† $p \leq 0.05$, significantly different from actual 1RM.

Table 5. Predicted 1RM values* based on prediction equations for 11–20 repetitions ($n = 33$) and comparisons with the actual value of 333 ± 31 lb.

Equation	Predicted 1RM	Paired difference	t	r
Brzycki	374 ± 54	40 ± 41	5.620†	0.652
Chapman et al.	323 ± 20	−11 ± 23	−2.715†	0.671
Epley	336 ± 22	2 ± 23	0.550	0.671
Epley and Mayhew combo	327 ± 18	−7 ± 23	−1.640	0.673
Lander	372 ± 51	39 ± 39	5.724†	0.653
Lombardi	294 ± 6	−39 ± 28	−8.145†	0.675
Mayhew et al.$_{(1)}$	318 ± 13	−16 ± 24	−3.671†	0.674
Mayhew et al.$_{(2)}$	333 ± 20	−1 ± 23	−0.231	0.671
O'Conner	309 ± 17	−25 ± 24	−6.012†	0.671
Slovak	329 ± 21	−5 ± 23	−1.190	0.671
Wathen	338 ± 19	4 ± 23	1.108	0.675
Whisenant et al.	332 ± 20	−2 ± 22	−0.044	0.730

* Mean ± *SD*. 1RM = 1 repetition maximum.
† $p \leq 0.05$, significantly different from actual 1RM.

Table 6. Regression analyses ($N = 69$) conducted with and without demographic variables.

	R		R^2		
Equation	Without	With	Without	With	Change
Brzycki	0.844	0.908	0.712	0.824	0.112
Chapman et al.	0.916	0.925	0.839	0.856	0.017
Epley	0.916	0.925	0.839	0.856	0.017
Epley and Mayhew combo	0.917	0.925	0.841	0.856	0.015
Lander	0.850	0.911	0.723	0.830	0.107
Lombardi	0.861	0.890	0.741	0.792	0.051
Mayhew et al.$_{(1)}$	0.917	0.923	0.841	0.852	0.011
Mayhew et al.$_{(2)}$	0.916	0.925	0.839	0.856	0.017
O'Conner	0.916	0.925	0.839	0.856	0.017
Slovak	0.916	0.925	0.839	0.856	0.017
Wathen	0.917	0.922	0.841	0.850	0.009

Table 7. Effects of demographic variables ($N = 69$) on R^2 values.

	R^2			
Equation	Without	With	Change	Loaded variables*
Brzycki	0.712	0.824	0.112	Race (+0.040), FFW (+0.033), HT (+0.025), BF% (+0.014)
Chapman et al.	0.839	0.856	0.017	Race (+0.017)
Epley	0.839	0.856	0.017	Race (+0.017)
Epley and Mayhew combo	0.841	0.856	0.015	Race (+0.015)
Lander	0.723	0.830	0.107	Race (+0.039), FFW (+0.030), HT (+0.025), BF% (+0.013)
Lombardi	0.741	0.792	0.051	FFW (+0.025), HT (+0.026)
Mayhew et al.$_{(1)}$	0.841	0.852	0.011	Race (+0.011)
Mayhew et al.$_{(2)}$	0.839	0.856	0.017	Race (+0.017)
O'Conner	0.839	0.856	0.017	Race (+0.017)
Slovak	0.839	0.856	0.017	Race (+0.017)
Wathen	0.841	0.850	0.009	Race (+0.009)

* FFW = fat-free weight; HT = height; BF% = percent body fat.

the only study that utilized the Wathen equation. In addition, Mayhew et al. (13) conducted the only study that used the Epley and Mayhew combo equation. However, although the previous studies that evaluated the Wathen and Epley and Mayhew combo equations have been limited in number, findings from these studies support the current research. LeSuer et al. (10) found that the Wathen equation was only 1 of 2 equations (out of 7) that did not differ significantly from the actual 1RM (1.2 ± 7.7 lb, $r_{Wa} = 0.992$). Mayhew et al. (13) found that the Epley and Mayhew combo equation produced a nonsignificant mean overestimation of 0.5 kg and a high correlation ($r_{EM} = 0.97$) between predicted and actual 1RM in the composite sample. Results from the current study show similar high correlations between predicted and actual 1RM in the composite sample for the Wathen and Epley and Mayhew combo equations ($r_{Wa} = 0.917$, $r_{EM} = 0.917$), respectively. In addition, in the current study, neither the Wathen (4 ± 18 lb) or Epley and Mayhew combo (−2 ± 19 lb) equations produced values that differed significantly from the actual 1RM.

The data obtained in this study also suggest that the validity of prediction equations varies with the number of repetitions performed. In the combined sample, the Wathen, Mayhew et al., and Epley and Mayhew combo equations were the most accurate ($r_{Wa} = 0.917$, $r_{M} = 0.917$, $r_{EM} = 0.917$). When 1–10 repetitions were performed, the Lander and Brzycki equations were the most accurate ($r_{La} = 0.898$, $r_{B} = 0.898$). When 11–20 repetitions were performed, the Lombardi and Wathen equations were the most accurate ($r_{Lo} = 0.675$, $r_{Wa} = 0.675$).

The influence of demographic variables on prediction equations has not been thoroughly investigated. Chapman et al. (3) tested the correlation between training experience and 1RM but found only a moderate correlation ($r = 0.35$, $p < 0.001$). Variance explained by subjects with ≥1 year of training experience vs. those with <1 year of experience was only slightly higher ($R^2 = 0.94$ and $R^2 = 0.90$, respectively).

In only the present study have height, weight, percent body fat, and fat-free weight been measured. These variables, along with race and age, increased the explained variance in the combined sample for the Brzycki, Chapman et al., Epley, Epley and Mayhew combo, Lander, Lombardi, Mayhew et al.$_{(1)}$, Mayhew et al.$_{(2)}$, O'Conner, Slovak et al., and Wathen equations. However, race was the only variable that increased the explained variance in 8 of the 11 prediction equations (Chapman et al., Epley, Epley and Mayhew combo, Mayhew et al.$_{(1)}$, Mayhew et al.$_{(2)}$, O'Conner, Slovak et al., Wathen). Furthermore, the demographic variables increased the explained variance for the composite sample by less than 2% in the Chapman et al. (1.7%), Epley (1.7%), Epley and Mayhew combo (1.5%), Mayhew et al.$_{(1)}$ (1.1%), Mayhew et al.$_{(2)}$ (1.7%), O'Conner (1.7%), Slovak et al. (1.7%), and Wathen (0.9%) equations. Demographic variables increased the explained variance in the Brzycki, Lander, and Lombardi equations by 11.2%, 10.7%, and 5.1%, respectively (Table 6). Thus, when coaches and strength and conditioning personnel utilize the preceding equations, demographic variables should be included to ensure maximum accuracy.

Although in the current study the validity of prediction equations varied with repetition ranges and the utilization of demographic variables, more research is needed. Because of the small sample size, generalization of the findings to the collegiate football population as a whole is not possible. Therefore, a similar study should be conducted with a larger student-athlete population. Additional research also needs with a population that predominantly performs 21 or more repetitions, such as the athletes attending the NFL combines. All future research should test the influence of demographic variables on the accuracy of prediction equations.

Practical Applications

Many athletic coaches and strength and conditioning personnel utilize the 225-lb repetition test with their football players to evaluate strength levels and formulate new training programs. The results of the present study have demonstrated that the validity of the prediction equations is dependent upon the number of repetitions performed. Athletes who perform 1–10 repetitions with 225 lb should use the Lander equation or the Brzycki equation to predict their 1RM. The Lombardi equation or the Wathen equation should be used when 11–20 repetitions are performed. When a combined sample is utilized, the Wathen, Epley and Mayhew combo, or Mayhew et al.$_{(1)}$ equations should be used. The newly developed Whisenant et al. equation holds promise but needs further testing with new populations of student athletes.

Inclusion of the demographic variables height, weight, percent body fat, fat-free weight, race, and age increased the explained variance in the combined sample for the Brzycki, Chapman et al., Epley, Epley and Mayhew combo, Lander, Lombardi, Mayhew et al.$_{(1)}$, Mayhew et al.$_{(2)}$, O'Conner, Slovak et al., and Wathen equations.

References

1. Arthur, M. NSCA tests and measurements survey results. *Natl. Strength Cond. Assoc. J.* 3:38. 1982.
2. Brzycki, M. Strength testing: Predicting a one-rep max from reps-to-fatigue. *J. Phys. Educ. Rec. Dance.* 64:88–90. 1993.
3. Chapman, P.P., J.R. Whitehead, and R.H. Binkert. The 225-lb reps-to-fatigue as a submaximal estimate of 1-RM bench press performance in college football players. *J. Strength Cond. Res.* 12:258–261. 1998.

4. Fleck, S.J., and W.J. Kraemer. *Designing Resistance Training Programs* (2nd ed.). Champaign, IL: Human Kinetics, 1997.
5. Heyward, V.H. *Advanced Fitness Assessment and Exercise Prescription* (3rd ed.). Champaign, IL: Human Kinetics, 1998.
6. Hoeger, W.W.K., D.R. Hopkins, S.L. Barette, and D.F. Hale. Relationship between repetitions and selected percentages of one repetition maximum: A comparison between untrained and trained males and females. *J. Appl. Sport Sci. Res.* 4:47–54. 1990.
7. Invergo, J.J., T. Ball, and M. Looney. Relationship of push-ups and absolute muscular endurance to bench press strength. *J. Appl. Sport Sci. Res.* 5:21–125. 1991.
8. Landers, J. Maximums based on reps. *Natl. Strength Cond. Assoc. J.* 6:60–61. 1985.
9. LeSuer, D.A., and J.H. McCormick. Prediction of a 1-RM bench press and 1-RM squat from the repetitions to fatigue using the Brzycki formula [Abstract]. *J. Strength Cond. Res.* 7(3): 186. 1993.
10. LeSuer, D.A., J.H. McCormick, J.L. Mayhew, R.L. Wasserstein, and M.D. Arnold. The accuracy of prediction equations for estimating 1-RM performance in the bench press, squat, and deadlift. *J. Strength Cond. Res.* 11:211–213. 1997.
11. Mayhew, J.L., T.E. Ball, M.D. Arnold, and J.C. Bowen. Relative muscular endurance performance as a predictor of bench press strength in college men and women. *J. Appl. Sport Sci. Res.* 6:200–206. 1992.
12. Mayhew, J.L., T.E. Ball, and J.C. Bowen. Prediction of bench press lifting ability from sub-maximal repetitions before and after training. *Sports Med. Train. Rehabil.* 3:195–201. 1992.
13. Mayhew, J.L., J.L. Prinster, J.S. Ware, D.L. Zimmer, J.R. Arabas, and M.G. Bemben. Muscular endurance repetitions to predict bench press strength in men of different training levels. *J. Sports Med. Phys. Fitness* 35:108–113. 1995.
14. Mayhew, J.L., J.S. Ware, M.G. Bemben, B. Wilt, T.E. Ward, B. Farris, J. Juraszek, and J.P. Slovak. The NFL-225 test as a measure of bench press strength in college football players. *J. Strength Cond. Res.* 13:130–134. 1999.
15. Mayhew, J.L., J.R. Ware, and J.L. Prinster. Using lift repetitions to predict muscular strength in adolescent males. *J. Strength Cond. Res.* 15(6):35–38. 1993.
16. Pauletto, B. *Strength Training for Coaches.* Champaign, IL: Leisure Press, 1991.
17. Prinster, J.L., J.L. Mayhew, J.R. Arabas, J.W. Ware, and M.G. Bemben. Prediction of maximal bench press strength from relative endurance performance in college men [Abstract]. *J. Strength Cond. Res.* 7(3):185–186. 1993.
18. Slovak, J.P., T.E. Ward, and J.L. Mayhew. Cross-validation of NFL-225 tests for predicting 1 repetition maximum bench press performance for a college football team [Abstract]. *J. Strength Cond. Res.* 13:433. 1999.
19. Stone, M., and H. O'Bryant. *Weight Training.* Minneapolis: Burgess International, 1987.
20. Ware, J.S., C.T. Clemens, J.L. Mayhew, and T.J. Johnston. Muscular endurance repetitions to predict bench press and squat strength in college football players. *J. Strength Cond. Res.* 9(2):99–103. 1995.
21. Wathen, D. Load assignment. In: *Essentials of Strength Training and Conditioning.* T.R. Baechle, ed. Champaign, IL: Human Kinetics, 1994. pp. 435–446.

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