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The Use of Selected Anthropometric Measures in the Prediction of a One-Repetition Maximum for the Bench Press Weight-Lifting Exercise

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THE USE OF SELECTED ANTHROPOMETRIC MEASURES IN THE PREDICTION OF A ONE-REPETITION MAXIMUM FOR THE BENCH PRESS WEIGHT-LIFTING EXERCISE

by

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The purpose of this study was to determine if selected anthropometric measures would accurately predict a one-repetition maximum (1RM) for the bench press. Sixty-two college students, 29 males and 33 females, were measured on six selected anthropometric variables and the criterion measure, a 1RM for the bench press. The independent variables were upper arm circumference, chest circumference, wrist circumference, lean body mass, and a 10-repetitions maximum (10RM). Pearson product moment correlations and multiple regression analyses were calculated for all subjects and for each gender. Regression equations involving a number of different combinations of variables were explored. The results indicated the existence of a large standard error of estimate in relation to the explained variance. This limited the situations in which the 1RM prediction equation for the bench press exercise was useful.

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CHAPTER I

INTRODUCTION

In the field of weight-training there is a great deal of difference in the methods employed by instructors, trainers, and coaches. The greatest variance exists in the intensity of exercise and the number of repetitions employed in the design of the weight-lifting program. Some individuals employ programs high in repetitions and low in intensity, but others employ higher intensities and lower repetitions. Whether one method or the other is used, intensity is often based on an individual's one-repetition maximum (1RM). A 1RM represents the maximal resistance that an individual can lift for any exercise in a single effort. A percentage of the 1RM is then used to set the training intensity. As the general public's use of weight-training devices increases, professionals within the field have raised some concerns with regard to the use of the 1RM for setting intensity. Their primary concern is a perceived higher risk of injury and muscle soreness associated with measuring a 1RM. Because of these concerns, many professionals agree that a method of predicting a person's 1RM needs to be devised. An optimal prediction device would allow a professional to determine an individual's 1RM without a single lift being performed.

In past studies, the relationship between muscular strength and selected anthropometric measures provided conflicting results. However, there seems to be a relationship between selected anthropometric measurements and muscular strength. In a study by Mayhew, Ball, Ward, Hart, and Arnold (1991), high correlations were found between anthropometric measures such as lean body mass, upper arm circumference, chest circumference, body mass, and bench press performance. The purpose of this study was to investigate the relationship between selected anthropometric measures and bench press performance.

Statement of the Problem

This study explored the use of lean body mass, body mass, chest circumference, upper arm circumference, wrist circumference, and a ten-repetitions maximum (10RM) as predictors of the 1RM in the bench press weight-training exercise.

Need for the Study

The use of a 1RM to set exercise intensity is often associated with weight-training exercises. A high-intensity lift, such as the 1RM bench press, is not advisable for some populations due to the muscle soreness and high risk of injury associated with this maximum lift. From the use of an accurate predictor, an individual can set his or her intensity and begin a bench press exercise without the negative results from performing a 1RM bench press exercise.

Delimitations

The study was delimited to the following:

1. Participants were between the ages of 18 and 24 years old.

2. Participants were males and females enrolled at Western Michigan University, Kalamazoo during the Fall semester 1994.

3. A single maximum lift on the bench was performed.

4. Lean body mass, body mass, chest circumference, upper arm circumference, wrist circumference, and a 10RM were the independent variables measured in the testing period.

Limitations

The limitations of the study were as follows:

1. The subjects were selected from a relatively homogeneous population.

2. The subjects were chosen opportunistically rather than at random.

Assumptions

The study was conducted under the following assumptions:

1. The participants performed the bench press with a maximum effort so that a true 1RM could be determined.

2. The instrumentation used in the anthropometric measurements yielded accurate indications of the true measurements.

3. Participants complied with a request to limit their weight-training activity during the week of the testing.

Hypothesis

It was hypothesized in this study that certain anthropometric measures--lean body mass, body mass, chest circumference, upper arm circumference, and wrist circumference--and a 10RM would prove to be accurate predictors of the 1 RM for the bench press.

Definition of Terms

The following terms and definitions are important to the understanding of this study:

1. One-repetition maximum (1RM)--the largest amount of weight that can be lifted one time for a specific exercise.

2. Ten-repetition maximum (10RM)--the largest amount of weight that can be lifted ten times successively for a specific exercise.

3. Repetition--the movement of a weight from a position of full extension to a position of full flexion and back to full extension.

4. Strength--the force exerted by a muscle group against a resistance for one maximal effort (McArdle, Katch, & Katch, 1991).

5. Intensity--the amount of resistance used to overload the muscles involved in a specific weight-lifting exercise.

6. Lean body mass--the result of subtracting fat mass from body mass (Nieman, 1990).

7. Anthropometric measurement--the measurement of the body and its parts (Nieman, 1990).

8. Bench press--a weight-training exercise that is performed with a subject lying supine on a bench. A bar with preset resistance is lowered to mid-chest then pressed back to full extension.

9. HWLBM--lean body mass calculated by the hydrostatic weighing process.

10. SFLBM--lean body mass calculated by the skinfold process.

11. HWBF--body fat percentage calculated by the hydrostatic weighing method.

12. SFBF--body fat percentage calculated by the skinfold method.

13. HWRATIO--the result of dividing HWLBM by body weight.

14. SFRATIO--the result of dividing SFLBM by body weight.

CHAPTER II

REVIEW OF LITERATURE

Introduction

To date, there has been limited research on the prediction of the 1RM bench press exercise. However, research does date back to 1961, when Berger investigated the use of the 10RM as a predictor of the 1RM bench press performance. The majority of the research in this area has been performed in recent years. The recent research investigated the use of selected anthropometric measures as predictors of the 1RM bench press performance.

Related Studies

Berger seems to be among the first to investigate the use of variables to predict the 1RM bench press performance. In the Berger (1961) study, the 10RM was investigated as a predictor of the 1RM bench press performance. Berger (1961) used 94 male subjects who were enrolled in weight-training courses at the University of Illinois. All the subjects participated in a 12-week weight-training program prior to the study. Each subject performed a 1RM, a 5RM, and a 10RM. The subjects' scores were than converted into percentages of their 1RM. Berger (1961) reported average percentage scores of the 1RM for both the 5RM and the 10RM as 89.9 and 78.9, respectively. A correlation matrix was calculated between the 1RM 5RM, and 10RM. A relationship of $\underline{r}$ = .97 was reported between the 1RM and the 5RM. A relationship of $\underline{r}$ = .95 was reported between the 1RM and the 10RM.

More recent studies have investigated the use of selected anthropometric variables as predictors of the 1RM bench press performance. Mayhew et al. (1991) investigated the relationships of height, weight, lean body mass, percent fat, upper and lower arm length, shoulder and hip width, upper arm and chest circumferences, upper arm cross-sectional area, and drop distance with the 1RM. This study involved one hundred and seventy male subjects enrolled in required fitness classes. Each subject participated in a 14-week training program prior to the measurements. After the 14-week program each subject was tested for his or her 1RM bench press performance and selected anthropometric measurements. A multiple regression analysis and pearson product moment correlations were calculated for these subjects. The variables, upper arm cross sectional area, percent fat, and chest circumference, when combined, best predicted the 1RM bench press. These variables explained 69% of the total variance with a standard error of estimate of 11.6 kg. However, Mayhew et al. (1991) also reported that the use of upper arm circumference instead of upper arm cross sectional area only slightly lowered the effectiveness of the prediction equation. When upper arm cross sectional area was replaced by upper arm circumference, the variables, chest circumference and percent fat, along with upper arm circumference, explained 67% of the total variance, and the equation had a standard error of estimate of 11.8 kg. Two separate cross validation samples were also measured. The first validation sample involved 84 males who had trained in identical fashion to the original group. This validation sample produced a correlation of $\underline{r}$ = .74 between the actual and predicted bench press performance. The second validation sample involved 57 members who participated in a more extensive 15-week weight-training program. The second validation sample produced a lower correlation ($\underline{r}$ = .57) between the actual and predicted bench press performance. The correlation showed the following relationships between the 1RM and selected anthropometric measurements. Upper arm cross-sectional area had the highest relationship with the 1RM ($\underline{r}$ = .79). Upper arm circumference was slightly lower, with a relationship of $\underline{r}$ = .77 with the 1RM. Lean body mass showed a relationship of $\underline{r}$ = .73 with the 1RM. From these results, Mayhew et al. (1991) concluded that anthropometric measures are related to bench press performance and that extensive weight training could alter this relationship.

Mayhew, Piper, and Ware (1993) investigated the use of selected anthropometric measurements as predictors of the 1RM bench press, 1RM squat, and 1RM dead lift performance in resistance-trained individuals. College football players (n=58) participated in the study. The subjects participated in a 10-week heavy-resistance, low-repetition weight-training program prior to the measurements. Multiple regression analyses and pearson product moment correlations were calculated for these subjects. The variables, arm cross-sectional area, body mass index, and percent fat, when combined, best predicted the 1RM bench press. These variables explained 76% of the variance, with a standard error of estimate of 12.1 kg. The correlation matrix showed the following results. A relationship of r = .68 was shown between lean body mass and the 1RM. Arm cross-sectional area had the highest relationship (r = .79) with the 1RM. Arm circumference was slightly lower with a relationship of r = .71 with the 1RM. As with the other studies the author concluded that a significant relationship existed between anthropometric measurements and the 1RM bench press performance.

Anthropometric Measures

Chest Circumference

Chest circumference is used as a method of measuring frame size or muscular development. Mayhew et al. (1991) reported a relationship of $r = .72$ between chest circumference measures and the 1RM bench press performance. This relationship proved to be among the highest relationships with the 1RM bench press exercise. An inter-trial and inter-investigation reliability coefficient between $r = .94$ and $r = .99$ was reported by Weltman and Katch (1975).

Upper Arm Circumference

Upper arm circumference is used as a measure of muscle development. Mayhew et al. (1991) reported a relationship of $r = .77$ between upper arm circumference and the 1RM bench press exercise. Mayhew et al. (1993) also reported a high relationship ($r = .71$) between upper arm circumference and the 1RM bench press exercise. It was shown in the Mayhew et al. (1991) study that upper arm circumference ($r = .77$) was only slightly lower than upper arm cross-sectional area ($r = .79$). Bray et al. (1978) reported an inter-measurer variability of 2% in obese subjects after a 2-week period. An intra-measurer error of 0.1 to 0.4 mm and an inter-measurer error of 0.3 mm have been reported (Malina & Buschang, 1984; Zavaleta & Malina, 1982).

Wrist Circumference

Wrist circumference is used as a measure of frame size (Lohman, Roche, & Martorell, 1988). Wilmore and Behnke (1969) reported a intra-measurer correlation of r = .99.

Lean Body Mass

Lean body mass is body mass minus fat mass (Nieman, 1990). Lean body mass includes muscle mass, the skeletal system, organs, and bodily fluids. A relationship of r = .68 was reported by Mayhew et al. (1993) between lean body mass and the 1RM bench press performance. Mayhew et al. (1991) also reported a high relationship (r = .73) between lean body mass and the 1RM bench press performance.

10RM

The 10RM is the largest amount of weight that can be lifted 10 times for a specific exercise. Berger (1961) reported a relationship of r = .95 between the 1RM and the 10RM. Past studies were limited to anthropometric measures.

CHAPTER III

DESIGN AND METHODOLOGY

The purpose of this study was to determine whether selected anthropometric measurements lean body mass, body mass, chest circumference, upper arm circumference, and wrist circumference, along with the 10RM can be accurate predictors of an individual's 1RM in the bench press weight-training exercise. This chapter is organized into three content areas: (1) subject selection, (2) testing procedures, and (3) statistical analysis.

Subject Selection

Participants in the study were college male and female students between the ages of 18 and 24 years. Subjects were randomly selected from volunteers recruited from physical fitness classes in the Fall 1994 semester at Western Michigan University, Kalamazoo. Prior to the study, announcements were made with regard to the purpose of the study and the need for volunteers. Appendix A contains a copy of the consent form each subject signed before participation in the study. Appendix B contains the Human Subjects Institutional Review Board's letter of approval.

Testing Procedures

Initial Procedure

All testing was completed in the Exercise Physiology Lab in the University Recreation Center, at Western Michigan University, Kalamazoo. Prior to the study, a consent form was signed and dated by each of the subjects. Within the consent form the testing procedure and possible risks of the study were explained. Subjects were asked to wear clothing and footwear that were functional and appropriate for weight-training. Subjects were allowed time to become comfortable with the weight equipment before the testing process began. The testing for each individual was preceded by a warm-up and stretching routine.

Bench Press Test

Proper technique was explained to the subject prior to the test. The proper technique required the subject to lie supine on the bench with feet flat on the floor. The subject's hands were placed on the bar slightly wider than shoulder width apart. The bar was then lifted off the supports by the subject and lowered to mid-chest level. Then, the subject pressed the bar up until the arms were completely extended.

All testing was done using the Pyramid Premier Olympic Bench with Olympic Bar (600-lb capacity) purchased from Fitness Things West, Chicago, IL. A 1RM was determined on the bench press for each subject using the following procedure. The resistance of the initial lift performed by each subject was subjectively determined by consulting with the subject. If one repetition was completed successfully by the subject, weight was added in increments of 5 lb until the maximum lifting capacity was achieved (McArdle et al., 1991).

Skinfold Measurements

Skinfold measurements were taken with a Lange skinfold caliper. Three sites were used for men and three different sites were used for women. For men the sites were the chest, the abdomen, and the thigh. The sites for women were the triceps, the suprailium, and the thigh (Jackson & Pollock, 1985).

Skinfold measurements were taken using the following method. The skinfold was grasped with the thumb and the index finger of the left hand and pulled away from the body. With the caliper in the right hand, the head of the caliper was placed on the skinfold about 0.25 in. from the fingers, and a reading was taken to the nearest millimeter (Nieman, 1990). The Jackson and Pollock generalized equations were used to determine body fat percentages from the skinfold measurements (Jackson & Pollock, 1985).

Hydrostatic Weighing

Hydrostatic weighing is considered the gold standard for validating all other methods of body composition. Hydrostatic weighing estimates body fat percentages at an accuracy level of $\pm$ 2.5% of the true value (Lohman, 1981). Hydrostatic weighing uses Archimedes' principle. When submerged, body fat floats due to a slightly less density than water. When submerged, body muscle sinks due to its higher density than water (Kreighbaum & Barthels, 1990). Body mass was measured in water and in air. Residual volume was estimated using the formula of RV = 0.24 x VC for males and RV = 0.28 x vital capacity for females. Body density was calculated using the formula recommended by Powers and Howley (1990). The Siri equation for percent body fat was used to calculate body fat percentages (Powers & Howley, 1990). The formula, lean body mass = body mass - fat mass, was used to calculate lean body mass (McArdle et al., 1991).

Circumference Measurements

Circumference measurements were taken from the upper arm, wrist, and chest. All circumferences were measured with a Gulick tape (J. A. Preston Corporation, New York, NY).

Chest Circumference

The following procedure was used to measure chest circumferences. The subject was instructed to stand erect with arms slightly abducted. Measures were taken at the fourth sternal joint. The fourth sternal joint was located by the two-hand palpation method. In this process both index fingers were placed above the clavicles, and the thumbs were placed in the first intercostal spaces (Lohman et al., 1988). The measurer then replaced his or her thumbs with his or her index finger. This process was followed until the fourth intercostal joint was reached. At this point the measurer slid his or her index fingers toward the sternum until the fingers touched the sternum. A mark was placed in the middle of the sternum. The measurer then stood in front but slightly to the side of the subject and placed the tape on the mark at the fourth sternal joint. The free end of the tape was then passed around the subject and retrieved on the other side of the body. The free end of the tape was positioned between the axilla and the sternum. The tape housing was then pulled across the body until it passed over the free end of the tape. The measurer checked that the tape was horizontal in both the back and the front. The tape was in contact with the skin but not causing an indentation. The measurement was then taken.

Upper Arm Circumference

Due to the ease of measurement and only a slightly lower relationship than upper arm cross-sectional area, upper arm circumference was used in the present study. Upper arm circumference was taken using the following procedure. The subject stood erect with arms hanging freely at the sides of the body and palms facing the thighs. The mid-point of the upper arm was then located. To locate the mid-point the measurer instructed the subject to bend the elbow until a 90 degree angle was formed between the upper arm and the lower arm. The measurer then located the spinous process of the scapula and the acromial process. The free end of the tape was placed on the spinous process of the scapula, and the body of the tape was placed on the acromial process. The mid point was then marked. The subject extended the elbow and relaxed the arm. The measurer passed the tape around the subject's arm at the marked point. The tape was in contact with the skin and perpendicular to the long axis of the arm. The measurement was then taken (Lohman et al., 1988).

Wrist Circumference

Past studies did not include a measure for frame size, but the author believed that a measure of frame size could improve the prediction of the 1RM bench press performance. The following procedure was used to measure wrist circumference. The subject was instructed to stand with the right elbow flexed and palm facing up. The subject was also instructed to relax the hand muscles. The tape was placed just distal to the styloid process of the radius and the ulna. The tape was perpendicular to the long axis of the forearm and in contact with the skin around the entire circumference of the wrist. The measurement was then taken (Lohman et al., 1988).

Body Weight

Body weight was measured using a Health-O-Meter scale (Continental, Chicago, IL). The subject was instructed to wear normal activity clothing excluding shoes. The subject was instructed to stand erect and still on the scale. The measurement was then taken (Lohman et al., 1988).

Statistical Analysis

The raw data from the selected anthropometric measurements the 10RM, and the criterion measure, the 1RM, were analyzed. Stepwise multiple regression analyses and pearson product moment correlations were calculated for all subjects and for each gender. Stepwise regression analyses were calculated on following combinations: all variables except for the 10RM, all variables except for hydrostatic lean body mass, and all variables except for the 10RM and hydrostatic lean body mass.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of this study was to investigate the use of anthropometric measures as accurate predictors of an individual's 1RM in the bench press exercise. The study used 62 college age males and females (18 to 25 years of age) from Western Michigan University, Kalamazoo. It was hypothesized that certain anthropometric measures, lean body mass, body mass, chest circumference, upper arm circumference, and wrist circumference, along with a 10RM, would accurately predict the 1RM in the bench press exercise. A stepwise regression was used to analyze the data. Analyses were performed on all 62 subjects and on each genders separately. The results and discussion were presented as follows: (a) descriptive data, (b) correlations, (c) regression analysis, and (d) discussion.

Descriptive Data

The study involved 62 subjects, both males and females. Table 1 shows the means and standard deviations of all the variables measured for all subjects.

Table 1

Male and Female Subjects' Means and Standard Deviations for All Variables

Variables	Combined		Males		Females	
	M	SD	M	SD	M	SD
Age(years)	20.98	3.50	21.03	3.25	21.14	3.99
Weight(lb)	153.93	27.62	171.38	22.88	134.08	17.21
Chest(mm)	91.44	8.61	96.06	8.77	86.18	4.46
Arm(mm)	29.33	4.30	32.05	3.65	26.24	2.52
Wrist(mm)	15.93	1.42	16.92	0.93	14.81	0.95
Bench1(lb)	159.68	70.56	210.45	56.05	101.90	27.56
HWBF(%)	20.18	7.26	16.64	7.04	24.21	5.16
Bench10(lb)	111.37	54.49	151.82	43.48	65.34	13.62
SFBF(%)	16.81	6.60	12.94	6.25	21.21	3.56
SFLBM(lb)	128.28	25.84	148.32	15.53	105.48	12.93
HWLBM(lb)	122.94	24.91	149.99	15.96	101.27	12.14
SFRATIO(%)	0.83	0.07	0.87	0.06	0.79	0.04
HWRATIO(%)	0.80	0.07	0.83	0.07	0.76	0.05

Among all subjects, 33 were males and 29 were females. Males on the average were heavier than females with a mean weight of 171.38 lb and females with a mean weight of 131.08 lb. Males also displayed larger chest circumferences (96.06 mm) than females (86.18 mm). Arm and wrist circumferences were 32.05 mm and 16.92 mm, respectively, for males and 26.24 mm and 14.81 mm, respectively for females. The female subjects had a smaller proportion of lean body mass, 101.27 lb, from the hydrostatic weighting procedure and 105.48 lb from the skinfold procedure, than males who had 149.99 lb and 148.32 lb, respectively. The females lifted a lower weight in the 1RM (101.90 lb) than did males (210.45 lb). Males also had higher 10RMs (151.82 lb) than females (65.34 lb).

Correlations

Three pearson product moment correlation matrices, one for all subjects and one for each gender, were calculated showing the relationships between the independent variables and the criterion measure, 1RM, and also the relationships among the independent variables. Those relationships that were of particular interest to the investigator are presented below.

All Subjects

Table 2 displays the correlation matrix for the criterion variable, a 1RM, and the independent variables. The following relationships were deemed important:

1. The 10RM displayed a significant relationship with the criterion strength measure, 1RM $r(61) = .96$, $p < .01$.

2. Lean body mass calculated from the hydrostatic weighing procedure also showed a significant relationship with the criterion strength measure, 1RM $r(61) = .81$, $p < .01$.

The data revealed the following relationships among the independent variables:

1. Lean body mass, calculated from skinfold measures, indicated a significant relationship with weight $r(61) = .91$, $p <.01$.

2. Lean body mass, calculated from hydrostatic weighing, showed a significant relationship with weight $r(61) = .88$, $p < .01$.

3. Arm circumference also displayed a significant relationship with weight $r(61) = .80$, $p < .01$.

4. Lean body mass, calculated from skinfold measures and hydrostatic weighing both, showed a significant relationship with wrist circumference of $r(61) = .81$, $p < .01$.

Table 2

Correlation Matrix for All Subjects

Variable	Weight	Chest	Arm	Wrist	Bench1	HWBF
Chest	.75**					
Arm	.80**	.57**				
Wrist	.75**	.63**	.67**			
Bench1	.65**	.60**	.70**	.66**		
HWBF	-.04	-.12	-.16	-.34**	-.54**	
Bench10	.62**	.56**	.71**	.66**	.95**	-.57**
SFBF	-.12	-.13	-.22	-.41**	-.56**	-.80**
SFLBM	.91**	.70**	.78**	.81**	.79**	-.36**
HWLBM	.88**	.71**	.77**	.81**	.81**	-.50**
SFRATIO	.12	.13	.22	.41**	.56**	-.80**
HWRATIO	.04	.12	.16	.34**	.54**	-1.00**

*Significant at the .05 level **Significant at the .01 level

Table 2--Continued

Variable	Bench10	SFBF	SFLBM	HWLBM	SFRATIO	HWRATIO
SFBF	-.62**					
SFLBM	.79**	-.52**				
HWLBM	.80**	-.48**	.96**			
SFRATIO	.62**	-1.00**	.51**	.48**		
HWRATIO	.57**	-.80**	.36**	.50**	.80**	

*Significant at the .05 level **Significant at the .01 level

5. The hydrostatic ratio had a negative and significant relationship with skinfold body fat percentage $\underline{r}(61) = -.80$, $\underline{p} <.01$.

6. The 10RM had a signficant with body mass calculated from the hydrostatic weighing procedure $\underline{r}(61) =.80$, $\underline{p} < .01$.

7. Skinfold body fat percentage also had a significant relationship with the hydrostatic body fat percentage $\underline{r}(61) = .80$, $\underline{p} < .01$.

8. Skinfold lean body mass and hydrostatic lean body mass exhibited a significant relationship $\underline{r}(61) = .96$, $\underline{p} < .01$.

Males

Table 3 displays the correlation matrix for the criterion variable, 1RM, and the independent variables for the male subjects. The following relationship was deemed important: The 10RM displayed a significant relationship with the criterion strength measure, 1RM $\underline{r}(61) = .93$, $\underline{p} < .01$.

The data revealed the following relationship among the independent variables:

1. Weight showed a significant relationship with skinfold lean body mass $\underline{r}(61) = .81$, $\underline{p} <. 01$.

Table 3

Correlation Matrix for Males

Variable	Weight	Chest	Arm	Wrist	Bench1	HWBF
Chest	.55**					
Arm	.66**	.26				
Wrist	.46**	.36*	.38*			
Bench1	.33	.34	.50**	.25		
HWBF	.56**	.15	.28	.02	-.20	
Bench10	.20	.22	-.45**	.21	.93**	-.28
SFBF	.64**	.37*	.40*	-.13	-.12	.77**
SFLBM	.81**	.43*	.55**	.51**	.52**	.13
HWLBM	.73**	.53**	.54**	.54**	.54**	-.16
SFRATIO	-.64**	-.37*	-.40*	.13	.12	-.77**
HWRATIO	-.56**	-.15	-.28	.02	.20	-1.00

*Significant at the .05 level **Significant at the .01 level

Table 3--continued

Variable	Bench10	SFBF	SFLBM	HWLBM	SFRATIO	HWRATIO
SFBF	-.23					
SFLBM	.44*	.07				
HWLBM	.47**	.12	.87**			
SFRATIO	.23	-1.00	-.07	-.12		
HWRATIO	.28	-.77**	.13	.16	.77**	

*Significant at the .05 level **Significant at the .01 level

2. The relationship between skinfold lean body mass and hydrostatic lean body mass was $\underline{r}(61) = .90$, $\underline{p} < .01$.

Females

Table 4 displays the correlation matrix for the criterion variable, 1RM, and the independent variables for the female subjects. None of the variables showed a high enough relationship with the criterion measure to be deemed important.

The data indicated the following relationships among the independent variables:

1. Weight displayed a significant relationship with skinfold lean body mass $\underline{r}(61) = .94$, $\underline{p} < .01$.

2. Weight had a significant relationship with hydrostatic lean body mass $\underline{r}(61) = .85$, $\underline{p} < .01$.

3. Skinfold lean body mass showed a significant relationship with hydrostatic lean body mass $\underline{r}(61) = .89$, $\underline{p} < .01$.

Regression Analyses

All Subjects

Stepwise multiple regression analyses were calculated to determine those variables that contributed to the prediction of the criterion, 1RM, for the bench press exercise. Table 5 contains the summary of the regression

Table 4

Correlation Matrix for Females

Variable	Weight	Chest	Arm	Wrist	Bench1	HWBF
Chest	.75**					
Arm	.56**	.42*				
Wrist	.54**	.42*	.28			
Bench1	.09	.09*	-.06	.11*		
HWBF	.41*	.59**	.37*	-.20	-.44*	
Bench10	.11	.11	-.04	-.18	.71**	-.44*
SFBF	.26	.33	.26	.12	-.21	.57**
SFLBM	.94**	.65**	.48**	.51**	.17	.22
HWLBM	.85**	.47*	.39*	.46	.34	-.12
SFRATIO	-.26	-.33	-.26	-.12	.21	-.57**
HWRATIO	-.41	-.59**	-.37*	-.20	.44*	-1.00**

*Significant at the .05 level **Significant at the .01 level

Table 4--continued

Variable	Bench10	SFBF	SFLBM	HWLBM	SFRATIO	HWRATIO
SFBF	-.38*					
SFLBM	.25	-.08				
HWLBM	.36	-.03	.89**			
SFRATIO	.38*	-1.00	.08	.03		
HWRATIO	.45*	-.57**	-.22	.12	.57**	

*Significant at the .05 level **Significant at the .01 level

Table 5

Stepwise Regression for All Subjects
and All Variables

Variable	*B*	*SE* B	Beta	*t*	Sig. *t*
Bench10	1.115999	.076954	.861818	14.502	.0000
HWLBM	.344389	.168308	.121599	2.046	.0452
(Constant)	-6.953110	14.949525		-.465	.6436

Multiple *R*	.96204
R Square	.92553
Adjusted *R* Square	.92301
Standard Error	19.57866

analysis for all subjects and for all variables. Hydrostatic lean body mass and 10RM together explained 93% of the total variance. The regression equation for all subjects when all variables were included in the analysis was 1RM = 1.12(10RM) + .34(HWLBM) - 6.95.

A second regression equation was calculated for all variables except hydrostatic lean body mass. The rationale for this omission rested on the premise that any practical prediction of the 1RM for the bench press exercise should consider the difficulty and expenses associated with measuring the variables. Table 6 contains the summary of the regression analysis for all subjects and all variables with the exception of hydrostatic lean body mass. The variables, 10RM and chest circumference, when combined, explained 93% of the total variance. This regression equation for all subjects and using all variables with the exception of hydrostatic lean body mass was 1RM = 1.18(10RM) + .71(chest circumference) - 36.94.

A third regression equation was calculated for all variables except the 10RM. The rationale for this omission rested on the premise that a prediction of the 1RM without any lifts being performed would decrease the chance of injury and muscle soreness associated with a maximum lift. Table 7 contains the summary of the regression analysis for all subjects and all variables with the exception of the 10RM. The variables, hydrostatic lean body mass, skinfold

Table 6

Stepwise Regression for All Subjects and All Variables With the Exception of Hydrostatic Lean Body Mass

Variable	B	SE B	Beta	t	Sig. t
Bench10	1.178814	.055619	.910326	21.194	.0000
Chest	.714479	.351806	.087559	2.031	.0468
(Constant)	-36.941635	29.252807		-1.263	.2116

Multiple R	.96201
R Square	.92546
Adjusted R Square	.92293
Standard Error	19.58833

Table 7

Stepwise Regression for All Subjects and All Variables
With the Exception of Bench10

Variable	B	SE B	Beta	t	Sig. t
HWLBM	1.322947	.349631	.467113	3.784	.0004
SFRATIO	288.012998	86.972496	.269540	3.312	.0016
Arm	4.608400	1.819474	.280738	2.533	.0140
(Constant)	-377.744750	73.059261		-5.170	.0000

Multiple R	.85201
R Square	.72591
Adjusted R Square	.71174
Standard Error	37.88323

ratio, and arm circumference, when combined, explained 73% of the total variance. This regression equation for all subjects 1.32(HWLBM) + 288.01(SFRATIO) + 4.61(arm circumference) - 377.74.

A fourth regression equation was calculated for all variables except the 10RM and hydrostatic lean body mass. The rationale for these omissions rested on the premise that a prediction of the 1RM bench press exercise should not only consider the difficulty and expense associated with measuring hydrostatic lean body mass, but also consider the chance of injury and muscle soreness associated with the 10RM. Table 8 contains the summary of the regression analysis for all subjects and all variables with the exception of hydrostatic lean body mass and the 10RM. The variables, skinfold lean body mass, weight, arm circumference, and chest circumference, when combined, explained 73% of the total variance. This regression equation for all subjects using all variables with the exception of hydrostatic lean body mass and the 10RM was 1RM = 2.89(SFLBM) + -2.03(weight) + 6.10(arm circumference) + 2.00(chest circumference) - 259.43.

Males

Stepwise multiple regression analyses were calculated to determine those variables that contributed to the

Table 8

Stepwise Regression for All Subjects and All Variables With the Exception of Hydrostatic Lean Body Mass and Bench10

Variable	B	SE B	Beta	t	Sig. t
HWLBM	2.967409	.488616	1.086727	6.073	.0000
Weight	-1.590570	.477573	-.622494	-3.331	.0015
Arm	5.728146	2.013447	.348952	2.845	.0061
(Constant)	-144.162094	35.441071		-4.068	.0001

Multiple R	.83684
R Square	.70030
Adjusted R Square	.68480
Standard Error	39.61358

prediction of the criterion, 1RM, for the bench press exercise. Table 9 contains the summary of the regressionand weight together explained 88% of the total variance. The regression equation for males when all variables were included in the analysis was 1RM = 1.16(10RM) + .37(weight) - 29.06.

A second regression equation was calculated for all variables except hydrostatic lean body mass. The rationale for this omission rested on the premise that any practical prediction of the 1RM for the bench press exercise should consider the difficulty and expenses associated with measuring some of the variables. Table 10 contains the summary of the regression analysis for males using all variables with the exception of Hydrostatic lean body mass. The variables, 10RM and weight, when combined, explained 88% of the total variance. This regression equation for males using all variables with the exception of hydrostatic lean body mass was 1RM = 1.16(10RM) + .37(weight) - 29.06.

A third regression equation was calculated for all variables except the 10RM. The rationale for this omission rested on the premise that a prediction of the 1RM without any lifts being performed would decrease the chance of injury and muscle soreness associated with a maximum lift. Table 11 contains the summary of the regression analysis for males using all variables with the exception of the 10RM. The variable, hydrostatic lean body mass explained

Table 9

Stepwise Regression for Males
and All Variables

Variable	*B*	*SE* B	Beta	*t*	Sig. *t*
Bench10	1.162362	.080138	.901705	14.504	.0000
Weight	.367881	.152305	.150160	2.415	.0220
(Constant)	-29.060162	26.771062		-1.086	.2863

Multiple *R*	.94259
R Square	.88847
Adjusted *R* Square	.88104
Standard Error	19.33081

Table 10

Stepwise Regression for Males and All Variables With the Exception of Hydrostatic Lean Body Mass

Variable	B	SE B	Beta	t	Sig. t
Bench10	1.162362	.080138	.901705	14.504	.0000
Weight	.367881	.152305	.150160	2.415	.0220
(Constant)	-29.060162	26.771062		-1.086	.2863

Multiple R	.94259
R Square	.88847
Adjusted R Square	.88104
Standard Error	19.33081

Table 11

Stepwise Regression for Males and All Variables
With the Exception of Bench10

Variable	*B*	*SE* B	Beta	*t*	Sig. *t*
HWLBM	1.925307	.527701	.548093	3.648	.0010
(Constant)	-62.918682	75.385302		-.835	.4103

Multiple *R*	.54809
R Square	.30041
Adjusted *R* Square	.27784
Standard Error	47.62824

30% of the total variance. This regression equation for was 1RM = 1.93(HWLBM) - 62.92.

A fourth regression equation was calculated for all variables except the 10RM and hydrostatic lean body mass. The rationale for these omissions rested on the premise that a prediction of the 1RM bench press exercise should not only consider the difficulty and expense associated with measuring hydrostatic lean body mass, but also should consider the chance of injury and muscle soreness associated with the 10RM. Table 12 contains the summary of the regression analysis for males using all variables with the exception of hydrostatic lean body mass and the 10RM. The variable, skinfold lean body mass explained 27% of the total variance. This regression equation for males using all variables with the exception of hydrostatic lean body mass and the 10RM was 1RM = 1.19(SFLBM) - 68.24.

Females

Stepwise multiple regression analyses were calculated to determine those variables that contributed to the prediction of the criterion, 1RM, for the bench press exercise. Table 13 contains the summary of the regression analysis for females with all variables. The variable, 10RM explained 51% of the total variance. The regression

Table 12

Stepwise Regression for Males and All Variables With the Exception of Hydrostatic Lean Body Mass and Bench10

Variable	B	SE B	Beta	t	Sig. t
SFLBM	1.879019	.553168	.520815	3.397	.0019
(Constant)	-68.236398	82.479612		-.827	.4144

Multiple R	.52081
R Square	.27125
Adjusted R Square	.24774
Standard Error	48.61065

Table 13

Stepwise Regression for Females and All Variables

Variable	*B*	*SE* B	Beta	*t*	Sig. *t*
Bench10	1.439615	.273573	.711563	5.262	.0000
(Constant)	7.825149	18.247831		.429	.6715

Multiple *R*	.71156
R Square	.50632
Adjusted *R* Square	.48804
Standard Error	19.72109

equation for females when all variables were included in the analysis was 1RM = 1.44(10RM) + 7.83.

A second regression equation was calculated for all variables except hydrostatic lean body mass. The rationale for this omission rested on the premise that any practical prediction of the 1RM for the bench press exercise should consider the difficulty and expenses associated with measuring some of the variables. Table 14 conatains the summary of the regression analysis for females using all variables with the exception of hydrostatic lean body mass. The variable, 10RM explained 51% of the total variance. This regression equation for females using all variables with the exception of hydrostatic lean body mass was 1RM = 1.44(10RM) + 7.83.

A third regression equation was calculated for all variables except the 10RM. The rationale for this omission rested on the premise that a prediction of the 1RM without any lifts being performed would decrease the chance of injury and muscle soreness associated with a maximum lift. Table 15 conatains the summary of the regression analysis for females using all variables with the exception of the 10RM. The variables, hydrostatic body fat percentage and chest circumference, when combined, explained 37% of the total variance. This regression equation for females using all variables with the exception of the 10RM was 1RM = -3.96(HWBF) + 3.22(chest circumference) - 80.06.

Table 14

Stepwise Regression for Females and All Variables
With the Exception of Hydrostatic Lean Body Mass

Variable	B	SE B	Beta	t	Sig. t
Bench10	1.439615	.273573	.7115363	5.262	.0000
Constant)	7.825149	18.247831		.429	.6715

Multiple R	.71156
R Square	.50632
Adjusted R Square	.48804
Standard Error	19.72109

Table 15

Stepwise Regression for Females and All Variables
With the Exception of Bench10

Variable	B	SE B	Beta	t	Sig. t
HWBF	-2.329711	.925161	-.436108	-2.518	.0180
(Constant)	158.295640	22.882714		6.918	.0000

Multiple R	.43611
R Square	.19019
Adjusted R Square	.16020
Standard Error	25.25808

A fourth regression equation was calculated for all variables except the 10RM and hydrostatic lean body mass. The rationale for these omissions rested on the premise that a prediction of the 1RM bench press exercise should not only consider the difficulty and expenses associated with measuring hydrostatic lean body mass, but also consider the chance of injury and muscle soreness associated with the 10RM. None of the remaining variables showed a significant relationship with the criterion measure, 1RM. Therefore, the prediction of the 1RM was not possible in this situation.

Discussion

Correlations

It was reported by Mayhew et al. (1991) that circumference measures showed the highest relationships with the 1RM. A second study by Mayhew et al. (1993) also reported that circumference measures exhibited the highest relationships with the 1RM. Although the current study produced high relationships between circumference measures and the 1RM, the highest relationships occurred when the 10RM and lean body mass were correlated with the 1RM.

Arm Circumference

In the data from Mayhew et al. (1991), the cross-sectional area of the arm showed the highest relationship with the 1RM (r = .79). This high relationship was also noted in the Mayhew et al. (1993) study which displayed a relationship of r = .79. However, the data from the Mayhew et al. (1991) study reported that arm circumference was slightly lower, r = .77. In the current study only arm circumference was measured due to the ease of measurement and the previously noted close relationship with arm-cross sectional area. The relationship between arm circumference and the 1RM, in the current study, was close to but lower (r = .70) than that reported by Mayhew et al. (1991) (r = .77).

Chest Circumference

Chest circumference displayed a lower but significant relationship with the 1RM (r = .72) in the Mayhew et al. (1991) study. The current study showed a lower relationship (r = .60) between chest circumference and the 1RM.

Skinfold Lean Body Mass

The relationship between skinfold lean body mass and the 1RM (r = .79) was higher than that reported by Mayhew et al. (1991) ($\underline{r}$ = .73) and that reported by Mayhew et al. (1993) ($\underline{r}$ = .68).

Skinfold Body Fat Percentage

The relationship between skinfold body fat percentage and the 1RM in the current study was a negative relationship ($\underline{r}$ = -.56) compared to the positive relationship ($\underline{r}$ = .29) reported by Mayhew et al., (1991).

Weight

The relationship of weight and the 1RM ($\underline{r}$ = .65) was lower than that shown by Mayhew et al. (1991), $\underline{r}$ = .68. However it was higher than that reported by Mayhew et al. (1993), $\underline{r}$ = .53.

10RM

The relationship between the 10RM and the 1RM, $\underline{r}$ = .95, was the same in the current study for all subjects as that reported by Berger (1961). The study performed by Berger (1961) involved 94 male subjects who were enrolled in a weight-lifting course at University of Illinois. The current study involved 62 male and female subjects enrolled in an activity course at the Western Michigan University. When the current study was split by gender, relationships between the 10RM and the 1RM were lower. The 29 males had a relationship of r = .93 between the 10RM and the 1RM. The 33 females had a relationship of r = .71 between the 10RM and the 1RM. However, the lower relationships could be contributed to the low number of subjects when the subjects were split by gender.

Multiple Regression

In the Mayhew et al. (1993) study, multiple regression analyses were calculated to determine those variables that contributed to the prediction of the criterion, 1RM, for the bench press exercise. The variables, arm cross-sectional area, body mass index, and skinfold body fat percentage explained 76% of the total variance. The current study produced quite different results.

In the current study the variables 10RM and hydrostatic lean body mass combined to explain 93% of the total variance. However, when the 10RM was removed from the regression analysis the variable, arm circumference, did appear in the prediction equation. The variables hydrostatic lean body mass, skinfold ratio, and arm circumference combined to explain 73% of the variance. Arm circumference also appeared in the multiple regression equation when hydrostatic lean body mass and the 10RM were removed from the regression equation. The variables, skinfold lean body mass, weight, arm circumference and chest circumference, when combined explained 73% of the total variance. The study by Mayhew et al. (1991) also had arm circumference in the prediction equation. Also, multiple regression analyses were calculated and the variables arm circumference, chest circumference, and percent body fat, when combined, explained 82% of the total variance. As in the Mayhew et al. (1991) study chest circumference appeared in the regression analyses of the current study. However, it only appeared when both hydrostatic lean body mass and the 10RM were removed from the multiple regression analysis.

Standard Error of the Estimate

The appearance of large standard errors of estimate were of some concern in the present study. A standard error of estimate of 19.58 lb was calculated in the present study when all variables and all subjects were included in the multiple regression analysis. However, this standard error of estimate was smaller than that of 26.01 lb reported by Mayhew et al. (1991). The Mayhew et al. (1993) study also produced a higher standard error of estimate (26.68 lb.) than the present study.

Regression Equation

Some of the prediction equations developed in this study were not of the accuracy needed for use in many situations. The large standard errors of estimate and the failure to explain a substantial portion of the total variance were obvious limitations. However, there were some situations, e.g., the beginner lifter, in which these prediction equations could be used. A beginning lifter could use the prediction equation when setting the training resistance for the bench press exercise. In this situation accuracy is not as crucial. Poor technique and neural inhibition substantially reduce the accuracy of the 1RM of beginning weight lifters.

The most accurate 1RM prediction equation occurred when all subjects, both males and females were included. The variables 10RM and hydrostatic lean body mass explained 93% of the total variance and developed a 1RM prediction equation that had a standard error of estimate of 19.58 lb. Most facilities do not have a hydrostatic weighing tank readily available. Also, the time and expense involved in the hydrostatic weighting procedure is significant. therefore, this prediction equation may not be the most practical. When hydrostatic weighting was removed from the regression analyses, the variables 10RM and chest circumference were primary. These variables explained 93% of the variance and had a slightly higher standard error of estimate, 19.59 lb. As stated earlier, this equation would be useful with a beginning lifter to set the initial training resistance. For the advanced lifter, a standard error of estimate of $\pm$ 19.58 lb is too large. Many advanced lifters perform the 1RM bench press to judge their strength development. Strength development often occurs in small increments (5lb to 10lb), and this prediction equation would not produce the accuracy needed for such a situation. However, due to the involvement in weight-training, the advanced lifter would develop little muscle soreness and would possess good technique, and thus would experience a lower risk of injury. Therefore, the need to substitute for a 1RM bench press does not exist.

In the 1RM bench press prediction equation for males, the variables 10RM and weight together explained 88% of the total variance. A large standard error of estimate (19.33 lb) was also shown. This is the most practical 1RM bench press prediction equation for males. As with the combined group, the only application for this prediction equation would be with the beginning lifter. For the advanced lifter, the total variance explained and the standard error of estimate would be too large for any practical application.

In the 1RM bench press prediction equation for females, the 10RM explained 51% of the total variance. A large standard error of estimate (19.72 lb) was also shown. This was the best 1RM bench press prediction equation for females. However, with the low total variances explained and the large standard error of estimates no prediction equations proved useful.

CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

The scope of this study was to determine if selected anthropometric measures and the 10RM could produce an accurate 1RM prediction equation for the bench press exercise. This chapter was organized in the following manner: (a) Summary, (b) Findings, (c) Conclusions, and (d) Recommendations.

Summary

The purpose of this study was to determine if selected anthropometric measures; body mass, lean body mass, chest circumference, arm circumference, and wrist circumference along with the 10RM could produce an accurate 1RM prediction equation for the bench press exercise.

A total of 62 subjects, 29 males and 33 females, participated in the study. Each subject performed a 10RM and a 1RM and the selected anthropometric measurements were taken.

All variables were measured in one session. The 1RM and the 10RM were measured on a flat bench and expressed in pounds. Chest circumference, arm circumference, and wrist circumference were measured with a Gulick tape and recorded to the nearest millimeter. Lean body mass was measured by both the hydrostatic method and the skinfold method. Body weight was measured to the nearest 0.25 lb.

Twelve multiple regression analyses were calculated using the following variables: (a) 10RM, (b) hydrostatic lean body mass, (c) skinfold lean body mass, (d) chest circumference, (e) arm circumference, (f) wrist circumference, (g) skinfold ratio, (h) hydrostatic weighing ratio, (i) body weight, (j) hydrostatic body fat percentage, and (k) skinfold body fat percentage. The dependent variable was the 1RM bench press performance.

Findings

All Subjects

When all variables were included in the regression analyses, the 10RM and hydrostatic lean body mass explained 93% of the total variance, and the equation had a standard error of estimate of 19.58 lb. The regression equation was 1RM = 1.12(10RM) + .34(HWLBM) - 6.95.

When all variables except hydrostatic lean body mass were included in the regression analysis, the 10RM and chest circumference, when combined, explained 93% of the total variance and the equation had a standard error of estimate of 19.59 lb. The regression equation was 1RM = 1.18(10RM) + .71(chest circumference) - 36.94.

When all variables except the 10RM were included in the regression analysis, hydrostatic lean body mass, skinfold ratio, and arm circumference combined to explain 73% of the total variance,and the equation had a standard error of estimate of 37.88 lb. The regression equation was 1RM = 1.32(HWLBM) + 2.88.01(SFRATIO) + 4.61(arm circumference) - 377.74.

When all variables except the 10RM and hydrostatic lean body mass were included in the regression analysis, skinfold lean body mass, weight, arm circumference, and chest circumference combined to explain 73% of the total variance, and the equation had a standard error of estimate of 38.17 lb. The regression equation was 1RM = 2.89(SFLBM) + -2.03(weight) + 6.10(arm circumference) + 2.00(chest circumference) - 259.43.

Males

When all variables were included in the regression analysis, the variables 10RM and weight together explained 88% of the total variance, and the equation had a standard error of estimate of 19.33 lb. The regression equation was 1RM = 1.16(10RM) + .37(weight) - 29.06.

When all variables except hydrostatic lean body mass were included in the regression analysis, the variables 10RM and weight together explained 88% of the total variance, and the equation had a standard error of estimate of 19.33 lb. The regression equation was 1RM = 1.16(10RM) + .37(weight) - 29.06.

When all variables except the 10RM were included in the regression analysis the variable hydrostatic lean body mass explained 30% of the total variance, and the equation had a standard error of estimate of 47.63 lb. The regression equation was 1RM = 1.93(HWLBM) - 62.92.

When all variables except the 10RM and hydrostatic lean body mass were included in the regression analysis the variable skinfold lean body mass explained 27% of the total variance, and the equation had a standard error of estimate of 48.61 lb. The regression equation was 1RM = 1.19(SFLBM) - 68.24.

Females

When all variables were included in the regression analysis, the variable 10RM explained 51% of the total variance, and the equation had a standard error of estimate of 19.72. The regression equation was 1RM = 1.44(10RM) + 7.83.

When all variables except hydrostatic lean body mass were included in the regression equation, the variable 10RM explained 51% of the total variance, and the equation had a standard error of estimate of 19.72. The regression equation was 1RM = 1.44(10RM) + 7.83

When all variables except the 10RM were included in the regression analysis, the variables hydrostatic body fat percentage and chest circumference explained 37% of the total variance, and the equation had a standard error of estimate equal to 22.72 lb. The regression equation was 1RM = -3.96(HWBF) + 3.22(chest circumference) - 80.06.

When all variables except the 10RM and hydrostatic lean body mass were included in the regression analysis none of the variables showed a significant relationship with the criterion measure, 1RM. No prediction equation was possible in this situation.

Conclusions

Based on the results of this study, the prediction equations developed were not of the accuracy needed for use in many situations. The equations tended to produce large standard errors of estimate and explained to little of the total variance. At the same time these prediction equations explained more of the variance and had smaller standard errors of estimate than reported in previous studies (Mayhew et al., 1991; Mayhew et al., 1993). The most accurate 1RM prediction equation occurred with the combined group, males and females. The variables 10RM and hydrostatic lean body mass, when combined, explained 93% of the variance with a standard error of estimate of 19.58 lb. However, because hydrostatic weighing tanks are not readily available, this is not the most practical equation. With hydrostatic lean body mass omitted, the 10RM and chest circumference variables were included in the equation. This equation explained 93% of the variance and had a slightly higher standard error of estimate, 19.59 lb. A standard error of estimate of 19.59 lb. means the prediction equation establishes the 1RM bench press performance with in a range of ± 19.59 lb. from the true 1RM, 68% of the time. When gender specific equations were calculated, the total explained variance was lower. For the males the best prediction equation included the variables, 10RM and weight. This equation explained 88% of the total variance and had a standard error of estimate of 19.33 lb. For the female prediction equation the variable 10RM explained 51% of the variance and had a standard error of estimate of 19.72 lb. This was the best 1RM prediction equation calculated for females. However, with a low explained variance and a large standard error of estimate there would be no situation where this equation would be applicable. The prediction equations listed above for males and the combined group could be used by a beginning lifter to set the initial exercise resistance for the bench press exercise. For the advanced lifter, the prediction equations did not provide the accuracy needed.

Recommendations

There is a need for further research that explores the use of anthropometric measures as predictors of the 1RM bench press exercise. Further research could focus on variables that would produce a more accurate prediction equation. A larger sample size should have been used if a gender-specific prediction equation was desired. The author postulates that the findings in this study are age specific and, if application is desired in older or younger individuals, research must be conducted sampling these populations.

Appendix A

Human Subjects Institutional Review Board Acceptance Form

Human Subjects Institutional Review Board

Kalamazoo, Michigan 49008-3899
616 387-8293

WESTERN MICHIGAN UNIVERSITY

Date: May, 9 1994

To: Jerry Thomas

From: Kevin Hollenbeck, Chair JT for K. Hollenbeck

Re: HSIRB Project Number 94-03-08

This letter will serve as confirmation that your research project entitled "Anthropometric measurements as accurate predictors of muscular strength represented by a one-repitition maximum in bench press and squat" has been **approved** under the full category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

You must seek reapproval for any changes in this design. You must also seek reapproval if the project extends beyond the termination date.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: May 9, 1995

xc: Zabic, HPER

Appendix B

Human Subjects Consent Form

College of Education
Department of Health, Physical
Education and Recreation

Kalamazoo, Michigan 49008-3871

WESTERN MICHIGAN UNIVERSITY

Principal Investigator:_________________________

Research Associate:____________________________

Informed Consent

I have been invited to participate in a research project entitled "The use anthropometric measures for the prediction of a one-repetition maximum lift in the bench press & squat weight lifting exercise." I understand that this research is intended to determine if an accurate method for predicting a one-repetition maximum is possible for the bench press and the squat using anthropometric measurements. I further understand that this study is a thesis project conducted by Nathan Kitchen and Jerry Thomas, graduate students in the department of Health, Physical Education & Recreation at Western Michigan University, Kalamazoo.

My agreement to participate indicates that I will attend two 1 hour group sessions with Nathan and Jerry. These sessions will take place in the Exercise Physiology Laboratory in the University Recreation Center, Gary Wing. The first session will involve anthropometric measurements including: height, weight, arm and leg measurements, chest circumference and depth, and percentage of body fat by skinfolds and hydrostatic weighing. The second session will involve a maximal lift (1RM, in the squat and bench press exercise.

I am aware that there may be some risk of injury, such as low back strain and muscle soreness. However appropriate measures will be taken to minimize these risks. All lifts will be proceeded by a warm-up and general stretch. Proper technique will be taught to each participant prior to each lift. Spotters will be used in all lifts, and participants will be required to wear a weight belt during each lift. All equipment incorporates safety features including adjustable safety stops to protect against injury while lifting. Appropriate emergency measures will be taken but no compensation and, or treatment will be provided by the project investigators. I also understand that I may terminate my involvement with this research for any reason at anytime.

I may benefit from my participation by knowing my percentage of body fat and level of strength. I may also evaluate my strength level in comparison with established norms. I may also increase my knowledge concerning the proper squat and bench lifting technique.

I am aware that all information and data pertaining to my participation is confidential. I will be assigned a n identification number, and no individual names will be printed on any paper or reports. The researcher will retain a master list containing the names of participants and corresponding identification number. At the end of data collection, the master list will be destroyed. All other data will be retained for a period of three years in a locked file controlled by the principle Investigator.

If I have any questions or concerns about this study I may contact either Jerry Thomas or Nathan Kitchen at 387-2689. or Dr. Zabik at 387-2705. I may also contact the chair of the Human Subjects Investigation Review Board or the Vice President of Research at 387-5926. My signature below indicates that I understand The purpose and requirements of the study and that I agree to participate.

Signature ______________________ Date __________

Appendix C

Subject Data Sheet

DATA RECORDING FORM

Subject's Name ______________________________Date ___________

Phone Number_____________ Subject ID ___________

Sex: Male_______ Female_________ Weight__________

CIRCUMFERENCE MEASUREMENTS

Chest __________cm.

Arm __________cm.

Wrist __________cm.

Midthigh __________cm.

Ankle __________cm.

1RM BENCH PRESS SQUAT

1RM __________lb. 1RM __________lb.

SKINFOLD MEASUREMENTS

Triceps (Males & Females) _____ ____ ____ _____

Chest (Males) _____ ____ ____ _____

Subscapula (Males) _____ ____ ____ _____

Abdomen (Females) _____ ____ ____ _____

Suprailium (Females) _____ ____ ____ _____

HYDROSTATIC WEIGHTING

Vital Capacity (VC) 1.__________ 2.________ 3.__________

Air temperature _____C Water Temperature ________C

Tare Weight _________

Trail 1.____ 2.____ 3.____ 4.____ 5.____

6.____ 7.____ 8.____ 9.____ 10.____

10RM BENCH PRESS SQUAT

10RM__________lb. 10RM__________lb.

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