PREDICTION EQUATIONS AS AN ALTERNATIVE TO 1-RM STRENGTH TESTING IN DIVISION I COLLEGE FOOTBALL PLAYERS

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By
Brian L. Schroeder

Thesis Committee:

Ron Hetzler, Chairperson
Iris Kimura
Jan Prins
Andrew Nichols

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ABSTRACT

The purpose of this investigation was to develop a new prediction equation for 1-RM bench press performance in Div. I college football players using both submaximal lifts and anthropometric variables. One repetition maximum (1-RM), 5-RM, reps at 225 lbs, and various anthropometric variables were collected on 85 Div. I college football players. Mean and SD were found for the following variables: height 182.3 cm ± 7.2; weight 102.0 kg ± 21.5; age 19.8 yrs ± 1.3; 1-RM 308.9 lbs ± 59.2; 5-RM 261.8 lbs ± 51.2; 225lb repetitions 14.1 reps ± 8.1; upper arm length 37.9 cm ± 2; CSA 125.5 cm^2 ± 24.8; and flexed arm 41.2 cm ± 4.2. Findings indicated that the performance variables accounted for the majority of the explained variance; however, anthropometric factors also made a meaningful contribution to the explanation of 1-RM bench press strength. The equation generated in this study produced an R^2 of 0.93 with a SEE ± 6.6 kg. Of ten previously published prediction equations investigated in this study, the equation developed in the current study was the only equation that did not significantly differ from actual 1-RM scores for a cross-validation sample of 31 subjects ($p = 0.37$). By combining anthropometric factors with performance variables, the current equation was able to predict 87% of individuals within ± 20 lbs of their actual 1-RM bench press performance. Therefore, it was concluded that the equation developed in this study is a valid means of estimating 1-RM bench press strength in Div I college football players.

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Introduction

Improving overall fitness levels and increasing the size and strength of muscles are two major objectives of Division I college football strength and conditioning programs. Both objectives can be accomplished through resistance training; however, resistance training requires a large amount of time and effort, which need to be justified by the results. Athletes and coaches alike have high expectations of noticeable strength gains. Accurate assessment is therefore needed to verify the effectiveness of various programs.

One repetition maximums (1-RM) are commonly used to evaluate training regimens in Division I college football programs (Ware, Clemens, Mayhew, Johnston, 1995). This procedure directly determines the maximum weight an individual can move once (but not twice) through a full range of motion. The 1-RM has been used to evaluate various types of exercises, trained and untrained individuals, and strength gains in both genders (Mayhew, Piper, Ware 1993; Mayhew, Ball, Ward, Hart, Arnold, 1991; Scanlan, Ballmann, Mayhew, Lantz, 1999). Its popularity is based on the ability of 1-RM testing to produce reliable results (Braith, Graves, Leggett, and Pollock, 1993). Although reliable, attempting a 1-RM lift requires a large amount of concentration and mental preparation (Ware, Clemens, Mayhew, Johnston, 1995) and may also involve some risk of injury. Injury rates when using 1-RM tests have not been reported in the literature; however, the potential for injury may be increased with this type of lift. Thus, many football coaches, conditioning specialists, and athletic trainers have begun to question the usefulness of the 1-RM in association with football playing potential or readiness (Ware, Clemens, Mayhew, Johnston, 1995).

A procedure that can reliably predict a 1-RM load without requiring the actual lift is appealing for testing athletes who are either unwilling to perform a 1-RM test or have a higher potential risk of injury. As a result, a number of prediction equations have been developed to estimate 1-RM from submaximal tests (Whisenant, Panton, East, Broeder, 2003; Mayhew et al., 1999; Brzycki, 1993; Mayhew, Ball, Arnold, Bowen, 1992; Epley, 1985; Lander, 1985; Lombardi, 1989; O'Conner, Simmons, O'Shea, 1989; Wathan, 1994). These equations range from multi-joint movements to single-joint movements (Ware, Clemens, Mayhew, Johnston, 1995; Nutter, Thorland, 1987), and use submaximal performance (Ware, Clemens, Mayhew, Johnston, 1995) or body dimensions (Mayhew, Ball, Ward, Hart, Arnold, 1991) in an attempt to estimate 1-RM strength.

Braith, Graves, Leggett, and Pollock (1993) noted that as the individual adapts to a training program the relationship between submaximal lifting and 1-RM strength changes. This finding suggests that prediction equations developed on untrained subjects may not be appropriate for use in trained individuals. Thus, caution should be used when interpreting estimations of 1-RM strength from submaximal prediction equations developed on subjects differing from the group of interest.

Another approach for predicting 1-RM strength has been developed from the use of anthropometric dimensions, such as flexed arm or chest circumference. It has been understood for some time that muscle responds to resistance training not only with an increase in strength but also with a considerable degree of hypertrophy. A 1991 study by Mayhew, Ball, Heart, & Arnold suggested that individuals with a "barrel" chest may have a decided advantage when attempting a maximal lift. Two later studies found correlations of $r = 0.87$ and $r = 0.83$ between various combinations of anthropometric dimensions and 1-RM bench press performance in Division II college football players (Mayhew, Piper, Ware, 1993; Mayhew, Piper, Ware, 1993a). In a cross validation of the Mayhew et al. 1991 anthropometric equation, a group of 84 male college students produced a multiple correlation of $r = 0.73$, with standard errors of estimate between predicted and actual bench press scores between 8.3 and 12.6 kg (Mayhew, Ball, Ward, Heart, & Arnold, 1991). These equations seem to have some utility; however, for anthropometric equations to be acceptable in identifying strength levels of athletes, a large percentage of individuals' predicted values must fall within a narrow margin of their actual 1-RM performance. Therefore, current equations using only anthropometric measures do not account for enough of the variance to be of practical use in estimating 1-RM values.

Greater accuracy may be achieved through the use of a submaximal performance tests combined with anthropometric measurements to estimate 1-RM strength. Currently only one study has been identified which combined both strength measures with anthropometric variables in a regression equation to estimate 1-RM bench press strength. Whisenant, Panton, East, and Broeder (2003) used height, repetitions to failure using 225lbs, and fat free mass to estimate 1-RM bench press values in Div. IAA football players ($R^2 = 0.933$, SEE of $\pm$ 7.5 kg, n = 69). The authors state that a possible limitation to their study was a relatively small sample size, and that generalization of their findings to other collegiate football populations may not be possible. No studies have been found to utilizing both strength measures combined with anthropometric variables to predict 1-RM bench press in Div. I college football players.

In summary, although the 1-RM test may be a reliable and valid means for assessing the maximal strength of an individual, it is not always the test of choice for a variety of reasons. Whatever the reason for avoiding 1-RM testing, prediction equations using submaximal multiples of a RM are available as an alternative means for evaluating 1-RM potential. However, because of the relatively large SEE these equations work better for predicting group strength than individual strength. It may be possible that including anthropometric measurements in the development of new prediction equations would increase the predictability of 1-RM strength for individuals. Therefore, the purpose of this investigation was to develop a new prediction equation for 1-RM bench press performance in Division I college football players using both submaximal lifts and anthropometric variables.

Methodology

Subjects

Subjects included 85 Division I football players from the University of Hawaii men's football team. Subjects ranged in age from 18 – 25 years, were in good physical health, and were experienced in performing the bench press. All players were measured prior to their winter conditioning period. Each subject was asked to complete a medical history form, physical activity readiness questionnaire (PAR-Q), and to provide written consent to participate. Subjects were asked to report to the laboratory on one occasion over a period of three weeks for anthropometric data collection. Subjects were then asked to perform the 5-RM, 1-RM, and 225 repetitions to fatigue bench press strength tests. The protocol used in the present study had been previously approved by the Institutional Review Board for studies involving human subjects.

Anthropometry

Trained examiners measured various dimensions thought to be related to the subjects' bench press ability. Skinfolds were measured using Harpenden calipers at the triceps, chest, suprailiac, abdominal, axial, calf, subscapula, supraspinale and thigh sights in duplicate, with the average at each site used in all calculations. If the two measurements varied by more than one millimeter, a third measurement was taken. Body composition was determined using the Jackson Pollock seven-site formula (Nieman, 1999). Body weight was measured with a Cardinal Detecto Certifier scale (model #442, Webb City, MO). Height for each subject was also recorded. Muscle circumferences were taken around a flexed arm, calf, and the chest at midexpiration, using a new plastic Gullick anthropometric measuring tape. Skeletal lengths of the arm, forearm, and biacromial width were obtained using a stainless steel anthropometric caliper. The drop distance, defined as the vertical distance the bench press bar traveled from full-arm extension to touch of the chest was measured using a wooden anthropometric caliper. Cross-sectional area (CSA) of the upper arm was estimated from upper arm circumference corrected for triceps skinfold using the following formula (Mayhew, Ball, Ward, Heart, & Arnold, 1991):

CSA (cm^2) = [Upper Arm Flexed Circumference (cm) - π (Triceps Skinfold (cm)/2]^2 / 4 * π.

Somatotype data for each subject was calculated using the Heath Carter anthropometric somatotype technique (MacDougall, Wenger, & Green, 1982).

Strength Testing

During the first week of data collection, subjects were tested for 5-RM bench press strength, followed by a 1-RM strength test one week later. A competitive powerlifting format was followed to determine the 5-RM and 1-RM bench press strength. After an individual warm-up using light weights, each subject performed a five-repetition or one-repetition lift with a weight he felt was near his maximum. Each lifter was given three to five attempts to perform a 5-RM or 1-RM. The subject began in a straight-arm position assisted by a spotter, and subsequently lowed the bar until it touched his chest. The bar was then immediately returned to a straight-arm position. If the lift was completed successfully, a 5-minute rest was given, weight was added to the bar, and another single or multiple repetition was attempted. The greatest amount of weight successfully lifted was considered the 5-RM or 1-RM. Five-minute rest intervals were given based on previous research indicating that 1-minute is sufficient for recovery between maximal bench press strength tests (Weir, Wagner & Housh, 1994). The reliability of this method has been reported to be greater than $r = 0.98$ (Invergo, Ball, & Looney, 1991; Rose, & Ball, 1992).

One week following the completion of the 1-RM test, each player was required to perform as many repetitions as possible using a 225-lb barbell. Following individual warm-ups, the player grasped the bar at the same position used during the 5-RM and 1-RM procedure. The bar was lowered each time and required to touch the chest without bouncing, and the arms were required to extend fully on each repetition. No more than a 2-second rest was allowed during an individual attempt of the test. The test was terminated when the subject could not complete a repetition with the proper form. The reliability of similar protocols have been reported to range from r = 0.80 to r = 0.97 (Invergo, Ball, & Looney, 1991; Rose, & Ball, 1992).

Cross-validation

Thirty-one subjects were recruited to participate in the cross-validation group. These subjects came from the same Div I college football program. Cross-validation subjects included new recruits and individuals who had not participated in the original study for various reasons (e.g. injury, schedule conflicts, etc.). Data were collected using the same protocol one year after the initial data collection. The cross-validation group was used to compare previously published prediction equations with the equation generated in the current study (see table 1).

Table 1
Previously developed prediction equations for 1-RM bench press used in the current study.

Author	Equation
Brzycki	1-RM = 100 * rep wt/(102.78 - 2.78 * reps)
Epley	1-RM = (1 + 0.0333 * reps) * rep wt
Lander	1-RM = 100 * rep wt/(101.3 - 2.67123 * reps)
Lombardi	1-RM = rep wt * (reps) ##.1
Mayhew et al. (1992)	1-RM = 100 * rep wt/(52.2 + 41.9 *exp[-0.055 *reps])
O'Conner et al.	1-RM = rep wt (1 + 0.025 * reps)
Wathan	1-RM = 100 * rep wt/(48.8 + 53.8 * exp[-0.075 * reps])
Mayhew et al. (1999)	1-RM = 226.7 + 7.1 (reps at 225 lb)
Whisenant et. al.	1-RM= 307.909 + 5.21367[reps(repetition weight lbs./FFW lbs.)] + (0.769843*FFW) + (-2.99795*Height inc.)

Exp means e^a, where e is math symbol for the number approx. 2.7181
whose natural logarithm is 1. The notation ## indicates exponentiation.
FFW represents Fat-free weight.
Equations derived from LeSuer et al. (1997), and Mayhew et al.(1999).

Prediction of 1-RM values

The appropriate values were entered into nine previously published 1-RM prediction equations and into the equation generated in the current study (see table 3). When using the equations requiring repetitions and weight other than 225 lb (Brzycki, 1993; Epley, 1995; Lander, 1985; Mayhew et al., 1992; Lombardi, 1989, O'Conner et al., 1989; and Wathan, 1994), the 5-RM values were used to predict 1-RM's. The 5-RM values were used rather than repetitions at 225 lbs based on reported error in prediction when endurance performance exceeds 10 repetitions (Mayhew et al. 1999).

Statistical Analysis

Descriptive statistics were generated using SAS. A regression equation to predict 1-RM from the 5-RM, 225 repetitions to failure, and anthropometric data was generated using the step-wise regression procedure to maximize R^2. Two sample t-test for means were used to test for demographic differences between the original group of subjects and the cross-validation group. Two sample paired t-tests for means were used to determine if there were significant differences between 1-RM's generated from the prediction equations and actual 1-RM. The Kolmogorov-Smirnov was used to test for normal distribution of the residuals in the cross-validation group. The alpha level was set at $p<0.05$.

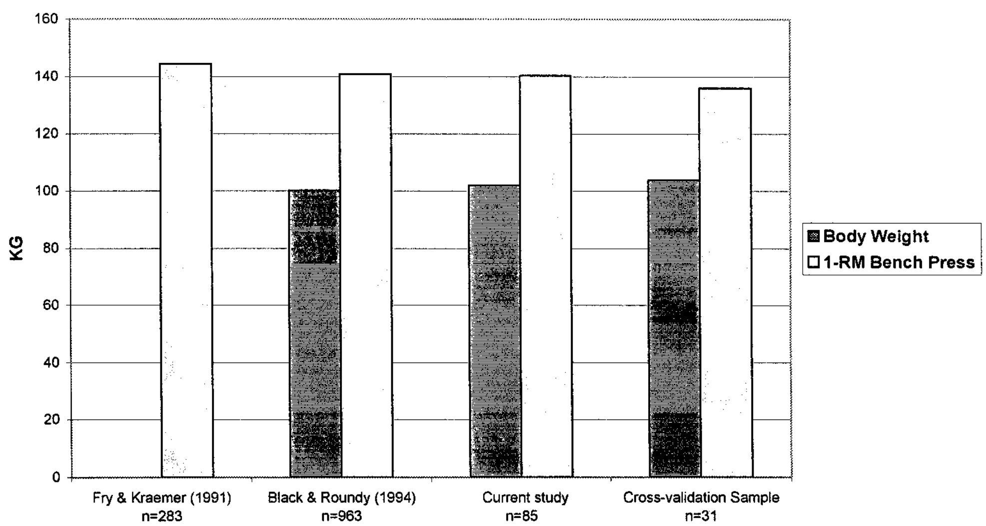
Results

Table 2 presents the mean, standard deviation, and range for all of the variables used to develop prediction equations in the present study. The mean 1-RM and 5-RM bench press were 140.4 ± 26.9 kg (308.9 ± 59.2 lb) and 119.0 ± 23.3 kg (261.9 ± 51.2 lb), respectively. The mean number of repetitions to fatigue with 102.3 kg (225 lb) was 14.1 ± 8.1 reps. The body weight of the subjects and 1-RM values obtained in the present study compared favorably with values previously reported for Division I college football players (Black and Roundy, 1994; Fry and Kraemer 1991) (see figure 1). Therefore, the subjects in the present study were considered representative of Division I college football players

Table 2
Physical characteristics of subjects used in the development of equation 1.

Variable	N	Mean	SD	Min	Max
Height cm	85	182.3	7.2	166.4	198.1
Weight kg	85	102.0	21.5	70.5	152.3
Flexed Arm cm	85	41.2	4.2	33.9	50.9
CSA (cm^2)	85	125.5	24.8	85.6	187.8
Chest Circumference cm	85	110.1	9.9	91.1	137.7
Calf Circumference cm	85	41.9	3.5	35.6	50.4
Upper Arm Length cm	85	37.9	2	32.8	43.5
Forearm Length cm	85	28.6	1.5	25.6	32.3
Shoulder Width cm	85	41.0	2.4	35	46.2
Elbow Width cm	85	7.7	0.6	6.4	9.7
Knee Width cm	85	10.2	0.7	9	11.9
Drop Distance cm	85	45.4	3.2	33.5	53.2
Sum of 7 Skinfolds	85	107.5	51.3	40	229.1
Body Density	85	1.1	0.01	1	1.1
% Fat	85	13.9	6.8	4.2	28.1
LBM kg	85	86.6	11.9	65.4	115.4
Endomorphy	85	2.6	1.2	0.9	5.9
Mesomorphy	85	7.4	1.7	2.5	11.4
Ectomorphy	85	0.8	0.8	0.1	3.1
5-RM lb	85	261.9	51.2	160	390
225 reps	85	14.1	8.1	0	38
1-RM lb	85	308.9	59.2	185	495

Figure 1
Average Body Weight and 1-RM Bench Press Scores of Current Study and Two Previous Studies using Div. I College Football Players.



The relationships between individual predictor variables and bench press performances are shown in Table 3. Correlations of 0.35 and above were significant at

$p<0.05$. Body weight was moderately but significantly related to 1-RM bench press performance ($r = 0.50$). Flexed arm and chest circumference were found to have higher significant correlations with 1-RM bench press strength $r = 0.79$, $r = 0.61$ respectively, with CSA (cm2) showing a high significant correlation of $r = 0.83$. Shoulder width ($r = 0.41$) and elbow width ($r = 0.56$) were found to have moderate correlations with 1-RM bench press strength. Lean body mass and %fat showed moderate to low correlations with 1-RM performance of $r = 0.55$ and $r = 0.35$ respectively. Somatotype descriptions found mesomorphy ($r = 0.53$) to be moderately correlated, ectomorphy ($r = -0.61$) to be negatively correlated with 1-RM bench press strength, and there was a low non-significant correlation for endomorphy ($r = 0.31$) and 1-RM. The physical performance variables showed the highest correlations with 1-RM bench press strength, resulting in correlations of $r = 0.93$ (5-RM) and $r = 0.94$ (225 reps).

Table 3
Correlations between 1-RM and individual predictor variables used in the development of equation 1.
n = 85

Variable	1-RM
Height cm	0.10
Weight kg	0.50*
Flexed Arm	0.79*
Cross Sectional Area (cm^2)	0.83*
Chest Circumference	0.61*
Calf Circumference	0.47*
Upper Arm Length	-0.06
Forearm Length	0.17
Shoulder Width	0.41*
Elbow Width	0.56*
Knee Width	0.34
Drop Distance	-0.07
Sum of 7 Skinfolds	0.34
Body Density	-0.34
% Fat	0.35*
Lean Body Mass kg	0.55*
Endomorphy	0.31
Mesomorphy	0.53*
Ectomorphy	-0.61*
5-RM	0.93*
225 reps	0.94*
* cr = 0.35 is significant at $p < 0.0001$	
1-RM = 1 repetition maximum	

Stepwise multiple regression analysis produced the following 1-RM bench press prediction equation using selected submaximal repetitions and structural dimensions:

$$1)\ \textit{1-RM(lb)} = 390.69668 + (1.66746 * \textit{CSA cm}^2) - (8.61112 * \textit{Flexed Arm}) - (2.70424 * \textit{Upper Arm Length}) + (0.43676 * \textit{5-RM}) + (3.67194 * \textit{Reps at 225})$$

This equation produced an R^2 of 0.93 between predicted and actual 1-RM bench press. When predicted values were correlated with actual 1-RM scores, they were found to be highly correlated ($r = 0.97$, SEE ± 6.8 kg) with 1-RM bench press.

Subjects in the cross-validation group were not significantly different in body weight, age, and 1-RM bench press when compared to subjects used to develop equation

1 (p>0.05) (see table 4). Data collected on the cross-validation group were used to predict 1-RM bench press strength using nine previously published prediction equations. T-tests for paired comparisons reviled that predicted 1-RM values were significantly different from actual 1-RM for each of the nine previously published equations; however, prediction of 1-RM bench press strength using equation 1 was not significantly different from the actual 1-RM (see table 5). Thus, equation 1 was found to be the only valid predictor of 1-RM bench press strength in Div. 1 college football players.

Table 4
Significant differences between subject variables from original and cross-validation samples.

Variables	Original Means	Cross-validation Means	t (Sig.)
Age (yrs)	19.8	19.5	0.144
Height (cm)	182.2	185.3	0.037
Weight (kg)	102.0	103.9	0.662
Upper Arm Length (cm)	37.9	37.7	0.678
5-RM (lbs)	261.8	243.2	0.082
1-RM (lbs)	308.9	299.2	0.432
225 reps (reps)	14.1	12.7	0.417

t-values significant at $p < 0.05$.
Original sample n = 85
Cross-validation sample n = 31

Table 5
Mean, SD, range of over / under prediction, mean differences, and probability of a significant t-value between predicted and actual 1-RM strength using cross-validation subject data.
n = 31

Author	Mean	SD	Max	Min	Mean Diff lb	t (Sig.)
1-RM Values	299.2	56.5				
Brzycki	273.7	54.6	5.0	-70.0	-25.5	0.000
Epley	283.4	56.5	14.6	-58.8	-15.8	0.000
Lander	276.6	55.2	7.9	-66.6	-22.6	0.000
Lombardi	285.7	57.0	16.9	-56.1	-13.5	0.001
Mayhew et al. (1992)	289.5	57.7	20.6	-51.8	-9.7	0.011
O'Conner et al.	273.6	54.6	5.0	-70.0	-25.6	0.000
Wathan	283.6	56.6	14.8	-58.6	-15.6	0.000
Mayhew et al. (1999)	316.9	62.8	70.2	-10.2	17.7	0.000
Whisenant et al.	311.0	58.5	54.1	-17.6	11.8	0.002
Equation (1)	296.8	56.2	31.3	-28.6	-2.3	0.374

Mean Diff lb = The mean difference between predicted & achieved 1-RM.
t-values significant at $p < 0.05$.

Table 6 presents the correlations, standard error of estimate, total error, and squared residuals for the cross validation subjects for each of the prediction equation's estimate of 1-RM and the actual value. Table 7 presents the comparison of the number of estimates falling within ± 10 and ± 20 pounds for each of the prediction equations. Equation 1 resulted in 52% of the subjects in the cross-validation group fell within ± 10 lbs and 87% fell within ± 20 lbs. Results of the Kolmogorov-Smirnov test indicated that the residuals obtained using equation 1 were normally distributed ($D = 0.134717$; $p>0.1500$).

Table 6
Squared residuals, correlations, standard error, and total error between prediction equations using cross-validation subject data.
n = 31

Author	Sqr Resid	Correlation	SEE kg	Total Error kg
Brzycki	31684.5	0.94	8.7	14.5
Epley	19530.1	0.94	9.0	11.4
Lander	27398.4	0.94	8.8	13.5
Lombardi	17506.0	0.94	9.1	10.8
Mayhew et al. (1992)	14988.6	0.94	9.2	10.0
O'Conner et al.	31727.3	0.94	8.7	14.5
Wathan	19345.5	0.94	9.0	11.4
Mayhew et al. (1999)	18689.1	0.96	7.8	11.2
Whisenant et al.	11776.0	0.96	7.3	8.9
Equation (1)	6453.9	0.97	6.6	6.6

SEE kg = Standard Error in Kilograms

Sqr Resid = Sum of Squared residuals for predicted minus actual.

Table 7
Comparison between equations for subjects within ± 10 and 20 lbs using data from the cross-validation sample.
n = 31

Author	# within ± 10 lb	% w/in ± 10 lb	# within ± 20 lb	% w/in ± 20 lb
Brzycki	7	23%	14	45%
Epley	12	39%	18	58%
Lander	12	39%	16	52%
Lombardi	11	35%	18	58%
Mayhew et al. (1992)	10	32%	20	65%
O'Conner et al.	7	23%	14	45%
Wathan	12	39%	18	58%
Mayhew et al. (1999)	11	35%	20	65%
Whisenant et al.	16	52%	24	77%
Schroeder (1)	16	52%	27	87%

Discussion

The most important finding of the present study was that a prediction equation using both anthropometric and submaximal strength measures produces accurate prediction of 1-RM bench press scores in Division I college football players. The current study was able to generate an equation accounting for 93% of the variance ($R^2 = 0.93$, SEE of ± 6.8 kg), by including both performance and anthropometric predictors,. The equation was crossvalidated using 31 different Division I college football players. For the cross-validation group the correlation for the predicted and actual 1-RM using equation 1 was $r = 0.97$ with a SEE ± 6.6 kg. Equation 1 slightly underpredicted 1-RM strength (-1.1 kg, -2.3 lb), but was not significantly different from the actual 1-RM ($p>0.05$).

Four previous studies have used football athletes as subjects when developing regression equations (Mayhew et al. 1999, Mayhew et al 1993, Chapman et al. 1998, and Whisenant et. al 2003). The studies by Chapman et al. 1998, and Mayhew et al. 1999 used 225 lb reps to fatigue to estimate 1-RM bench press and reported similar results ($R^2 = 0.92$, SEE of ± 4.9 kg and $R^2 = 0.92$, SEE of ± 6.4 kg, respectively). The other study by Mayhew et al. (1993) used anthropometric correlates with strength to develop an equation with an $R^2 = 0.76$, SEE ± 12.1 kg. Whisneant et al. 2003 reported $R^2 = 0.933$ with a SEE of ± 7.5 kg using a combination of reps to fatigue using 225 lb and basic anthropometric variables. When these equations were used with the cross-validation group in the present study, the predicted 1-RM values were significantly different than the actual 1-RM value ($p<0.05$) (see table 5).

In the present study the finding that performance variables (5-RM, and 225 reps) accounted for 90% of the variance confirms that individual performance on submaximal bench press tests is the major contributor to 1-RM strength. However, with the addition of anthropometric variables (arm CSA, upper arm length, and flexed arm circumference) the R^2 of this equation was increased to 0.93, suggesting that for Division I college football players, anthropometric measures provide a small but meaningful additional explanation of strength. It is not surprising that anthropometric measurements improve the ability to predict 1-RM strength. Mayhew, Piper, and Ware (1993) previously demonstrated that there was a strong relationship between regional muscle mass (CSA) and lifting performance. Factors such as upper arm muscle mass, and mechanical advantages and disadvantages of upper arm length were shown to influence 1-RM bench press performance of Division I college football players in the current study.

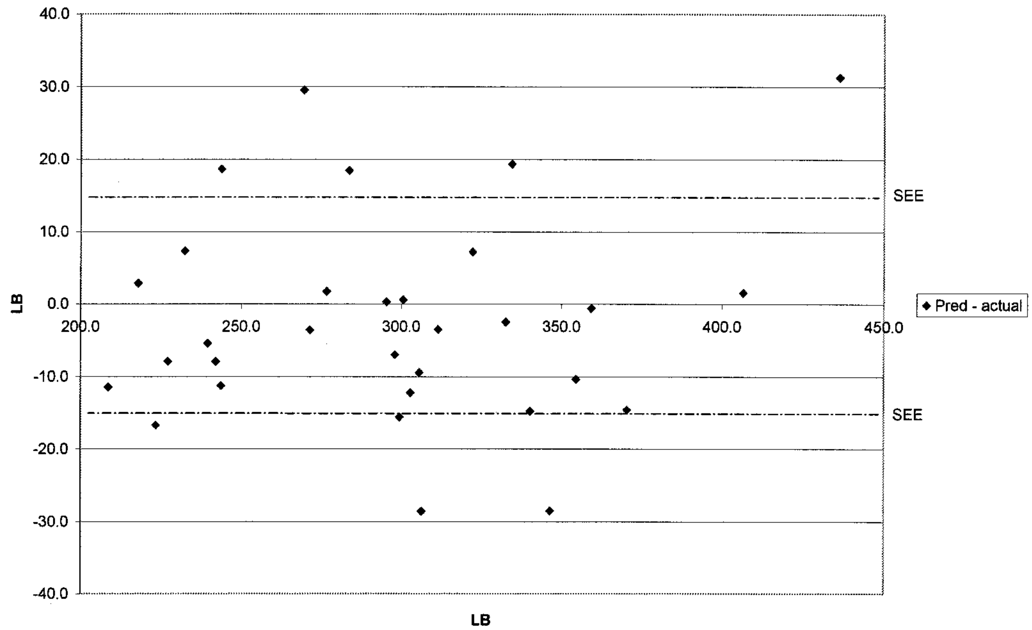
Although body type (physique) was not included in the regression equation, mesomorphy ($r = 0.53$) and ectomorphy ($r = -0.61$) were both significantly correlated to 1-RM bench press strength scores. These correlations suggest that individuals with a more stocky muscular body structure may perform better when tested for 1-RM bench press strength, when compared to individuals with a more lanky body structure. A similar observation was made by Mayhew, Piper, and Ware (1993). Whisenant, Panton, East, and Broeder (2003) had developed a prediction equation that included both fat free weight and height as significant predictors. Although fat free weight and height were not included in equation 1, upper arm length and CSA were selected as significant predictors. This may indicate that more specific anthropometric indicators than height and lean body mass may further reduce the error in prediction of 1-RM strength. Mayhew et al. (1993) had suggested the relationship of limb lengths to strength performance needs further investigation. The results of the present study support the need for further research in this area.

When nine previously developed 1-RM prediction equations (see table 1) were used to predict 1-RM bench press strength using data from the present study, the Brzycki (1993), Lander (1985), O'Conner et al. (1989), and Mayhew et. al. (1992) equations all significantly underestimate 1-RM strength by an average of –25.5 lb, -22.6 lb, –25.6, and –9.7 lbs respectively. The Epley (1985), Lombardi (1989), and Wathan (1994) equations were also found to significantly underestimate 1-RM strength by an average of, -15.8 lb, -13.5 lb, and –15.6 lb respectively. Mayhew et. al. (1999), and Whisenant et. al. (2003) equations were found to both significantly overestimate 1-RM strength by an average of 17.7 lb, and 11.8 lb respectively. Thus, previously published prediction equations do not appear to be useful for estimating strength in Div. I college football players.

Although, equation 1 was the only equation that resulted in non-significant differences between the actual and predicted strength scores, the SEE was similar to those generated by the nine previously developed equations (see table 6). Indicating that use of equation 1 to estimate individual strength must still be viewed with caution. This indicates that the best use of these equations would be to evaluate group differences.

The sum of the squared residuals [(1-RM – Predicted 1-RM)^2] of the nine previously developed equations were determined using the subjects in the present study to compare the accuracy of the equations (see table 7). The smallest value for the squared residuals indicated the best predictors. Analysis determined that equation 1 resulted in squared residual values that were almost half that of the next best prediction equation for the cross-validation group. SEE suggests that 68% of the predicted values for the cross-validation group fall within ± 6.8 kg (14.96 lb). When these equations were investigated to determine the percentage of individuals that were predicted within ± 10 lbs of actual 1-RM bench press strength, the current equation (1) predicted approximately 52% of the subjects within ± 10 lbs of their actual 1-RM, and 87% within ± 20 lbs (see table 7). Whisenant, Panton,, East, and Broeder (2003) had previously reported that the validity of various prediction equations based on 225 lb performance was dependant on the number of repetitions that could be performed. Therefore, they suggested using different prediction equations for subjects of different strength levels. In the present study, results of the Kolmogorov-Smirnov test showed that the residuals resulting from equation 1 were normally distributed, suggesting that the equation worked across the entire strength range for the cross-validation subjects (see figure 2). Ware, Clemens, Mayhew, and Jonhston (1995) state that the total error should be considered when evaluating prediction equations since it indicates the difference between predicted and actual 1-RM values, and should be comparable to the SEE. The SEE for predicted 1-RM strength scores using equation 1 was 6.6 kg with a total error of 6.6 kg for the cross-validation sample (see table 6).

Figure 2
Predicted minus actual 1-RM bench press strength for subjects in cross- validation group
(n = 31)



In summary, the findings indicated that the performance variables accounted for the majority of the explained variance; however, anthropometric factors also made a meaningful contribution to the explanation of 1-RM bench press strength in Division I college football players. Of the ten prediction equations investigated in this study, equation 1 was the only equation that did not significantly differ from actual 1-RM scores for the cross-validation sample. By combining anthropometric factors with performance variables, the current equation was able to predict 87% of individuals within ± 20 lbs of their actual 1-RM bench press performance. It was concluded that equation 1 is a valid means to estimate 1-RM bench press strength for Div I college football players.

Review of Literature

Repetitions

Hoeger, Hopkins, Barette, and Hale (1990) investigated the average number of repetitions that trained males, and untrained and trained females could perform at 40, 60, and 80 percent of their 1-RM bench press. Twenty-five trained male subjects, 40 untrained female subjects, and 26 trained female subjects were used in their study. Physical and performance data on height, weight, age, percent body fat, and 1-RM bench were collected on the same day. The 1-RM was determined through the trial and error method until a weight that the individual could do once but not twice was found. All bench press testing was done using constant resistance on a 16-station Universal Gym apparatus. Data for the repetitions performed at 40, 60, and 80% of 1-RM were collected on separate days, over a period of four to eight weeks, with a minimum of one-week between sessions. Results determined that the analysis of 1-RM and the average number of repetitions performed by untrained and trained males, and untrained and trained females at the selected percent 1-RM for the bench press were: 34.9 $\pm$ 8.8 reps at 40%, 38.8 $\pm$ 8.2 reps at 40%, 19.7 $\pm$ 4.9 at 60%, 22.6 $\pm$ 4.4 at 60%, 9.8 $\pm$ 3.6 reps at 80%, 12.2 $\pm$ 2.87 at 80%; 20.3 $\pm$ 8.2 at 60%, 27.9 $\pm$ 7.9 at 60%, 10.3 $\pm$ 4.2 at 80%, and 14.3 $\pm$ 4.4 at 80% respectively. Repetition data at 40% of 1-RM for females in their study was unobtainable due to resistance limitations on the Universal Gym equipment. Significant differences were found ($p < 0.05$) in the number of reps that males and females performed at the selected % 1-RMs. When comparing untrained and trained males, no significant difference ($p < 0.05$) was found for any percent 1-RM for the bench press.

Concluding that number of repetitions performed in the machine bench press at selected percent 1-RM are not the same between genders.

Rose and Ball (1992) investigated the relationship between absolute muscular endurance and the maximum weight that could be lifted in a bench press exercise. Their study used 84 normal healthy untrained females between the ages of 18 and 25. Data was collected during 2 sessions separated by 24 to 72 hours. During the first session, subjects were measured for height, weight, 1-RM bench press, and absolute muscular endurance using either 15.9 kg or 20.4 kg. The second session was used to measure absolute muscular endurance using the weight not used during the first session. Absolute muscular endurance was assessed using the YMCA bench press test and a modified version of the YMCA bench press test. In the modified test, the load lifted was increased form 15.9 kg to 20.4 kg. Results of their study found that bench press 1-RM of college women can be accurately predicted from tests of absolute muscular endurance. The YMCA bench press test for women, using a load of 15.9 kg, accounted for 63 percent of the variance (SEE = 3.34 kg). The absolute endurance test, which used a load of 20.4 kg, accounted for 68 percent of the variance (SEE = 3.27 kg). In both cases, the common variance between bench press 1-RM and absolute muscular endurance increased slightly when adjusted for body weight: 66 percent (SEE = 3.27), and 72 percent (SEE = 2.95 kg). Therefore, the results of their study show that a submaximal absolute endurance test can effectively predict maximal bench press strength in untrained college age women. Based on the results of their regression analysis, the best prediction of bench press was found using the equation: bench press = (0.571 * number of repetitions) + (0.142 * body weight) + 20.10.

Mayhew, Ball, Arnold, & Bowen (1992) investigated the accuracy of using relative muscular endurance performance to estimate 1-RM bench press strength in college men and women. College males (n=184) and females (n=251) enrolled in a fitness class agreed to participate in the study. The subjects were tested at the conclusion of a 14-week fitness course, consisting of 20 minutes of aerobic exercise and 20 minutes of resistance training using both free weights and Nautilus equipment. Both free weights and Nautilus users stayed at 10 to 12 repetitions for the entire 14 weeks of training. The initial bench press weight was subjectively chosen based on previous training history to allow the completion of four to five repetitions. After one to two minutes of rest 2.3 to 4.5kg were added and the subject performed one repetition. This procedure was repeated until the subject could not lift the weight. The highest weight lifted successfully was recorded as the 1-RM, and was usually determined within 4 to 6 attempts. Relative endurance was tested within three to five days after the 1-RM test. A specially designed computer program randomly assigned a relative endurance load for each subject ranging from 55 to 95 percent of the 1-RM, which was designated the endurance repetition weight. After a warm-up the subject performed as many correct repetitions of the bench press as possible in one minute with the designated repetition weight. In order to determine the broad application of the prediction technique, several cross-validation groups were selected. Group one was composed of 70 men and 101 women randomly selected from the subsequent semester of the same fitness class. A second sample was composed of 25 high school male athletes and 74 high school male non-athletes. A third group was composed of 56 first-year players from a NCAA Division II college football team. Results indicated that the relationship between percent 1-RM and reps were exponential for both men and women. The curves were found not to be significantly different ($p<0.05$) in slope or intercept, therefore the data for men and women were combined to produce the following exponential regression equation: $\%1\text{-RM} = 52.2 + 41.9e^{-0.055reps}$ ($r = 0.80$, SEE = $\pm$ 6.4). The predicted 1-RM percent was used to estimate the 1-RM using the following formula: 1-RM bench = rep weight / (predicted percent 1-RM / 100). When this formula was applied to the original sample the correlation between predicted and actual bench press was $r = 0.98$ (SEE = $\pm$ 4.8 kg). When the above equations were applied to a cross validation group undergoing the same training program the correlations between predicted and actual 1-RM for both men and women were $r = 0.96$ (SEE = $\pm$ 5.7 kg), and $r = 0.90$ (SEE = 0.3.6 kg) respectively. Using the adolescent samples the correlation coefficients between the predicted and actual 1-RM for the athletes and non-athletes were $r = 0.97$ (SEE = $\pm$ 4.1 kg) and $r = 0.95$ (SEE = $\pm$ 5.8 kg) respectively. When the prediction equations were applied to the college football sample the correlation between predicted and actual 1-RM was $r = 0.95$, SEE = $\pm$ 5.0 kg. Therefore, based on their findings the authors concluded that the number of repetitions completed in one minute with a less than 1-RM load can be used to estimate accurately the 1-RM bench press in a wide variety of subjects.

Based on previous research Brzycki (1993) calculated a mathematical equation for predicting a 1-RM bench press based upon reps to fatigue: 1-RM = Weight lifted /

1.0278 – 0.0278 * number of repetitions performed. Brzycki determined that the relationship was not quite linear beyond 10 reps, and the formula was only valid if reps to failure are less than 10.

Mayhew, Prinster, Ware, Zimmer, Arabas, and Bemben (1995) set out to determine not only the differences in present repetition bench press max prediction equations, but also the various results those equations may yield for groups varying in age and training level. To accomplish this the investigators used a total of 220 male volunteers consisting of various age and training levels. The different groups consisted of 35 untrained college males, 28 college males who underwent eight weeks of resistance training, 21 Division II college wrestlers, 22 Division II college soccer players, 51 Division II college football players, 35 high school boys enrolled in an eight week weight training class, and 24 middle-aged men participating in ten weeks of resistance training. 1-RM bench press scores were recorded for all groups, along with endurance repetitions. The data was then used to compare prediction differences for six different equations. The investigators looked at overall differences between equations, along with group and number of endurance repetitions completed differences. After obtaining the statistical information of the study the investigators determined that all the equations demonstrated highly correlated results. However, it was also noted that for practical use interpretations should be taken with some degree of caution. The findings did indicate overall high correlations, but it is suggested that the possibility of large errors within individual scores may exist. Findings also indicated that overall prediction equations might be better when ten or fewer endurance repetitions were performed. The authors also determined which equations performed better in relation to number of endurance repetitions and actual 1-RM bench press. For endurance repetitions performed under 10 the Brzycki equation (r=0.98) appeared to dimonstraight the most accurate results. However, for those individuals who performed over 10 endurance repetitions the study found that an average of the Mayhew et al. and Epley equations (r=0.97) provided the most accurate results.

Ware, Clemens, Mayhew, and Johnston (1995) investigated the accuracy of using relative muscular endurance performance to estimate one-repetition maximum (1-RM) bench press in college football players. In order complete the study forty-five Division II college football players were used. The subjects had undergone an extensive modified periodized resistance training program that lasted for 12 weeks. At the culmination of the 12 week training program subjects were tested for 1-RM bench press strength. Prior to testing, the subjects were allowed several warm-up sets using a weight of there choice. The initial 1-RM attempt weight was chosen subjectively based on previous training history, if successful weight was added and the procedure continued until a weight the subject could not successfully lift was reached. The highest weight successfully lifted was recorded as the 1-RM, and was usually reached within three to five attempts. During the week prior to 1-RM testing each subject performed repetitions-to-failure in the bench press. As a guideline, subjects used a weight that was approximately 70% of their probable 1-RM. After a brief warm-up, the subjects performed as many correct repetitions to failure as possible. After completion of both submaximal and 1-RM testing, submaximal scores were predicted for the bench press using four different prediction equations (Brzycki, Epley, Lander, Mayhew et al.). Results found that in the bench press the Mayhew et al. equation significantly underestimated 1-RM by an average of –3.1 kg (±7.7) and had a correlation of r =0.91 between predicted and actual performance. The Epley, Lander, and Brzycki equations were found to overestimate the predicted 1-RM by 4.80 kg (±8.2), 14.1 kg (±12.0), and 14.2 kg (±12.4), with correlations of r =0.91, r=0.86, and r=0.85 respectively. Therefore, in conclusion the investigators determined that higher repetitions-to-failure do not provide an accurate basis for judging strength levels in the bench press among resistance trained athletes.

Morales and Sobonya (1996) investigated the best predictors of 1-RM strength for the bench press from submaximal repetition loads ranging from 70% to 95% of actual 1-RM. Subjects participating in their study were made up of 16 varsity football players, and 7 track and field throwers. All subjects competed at the Div 1-A level. Subjects were tested for 1-RM bench press strength on the first of four testing days. On the remanding testing sessions subjects were tested for their maximal number of reps at loads equal to 70, 75, 80, 85, 90, and 95% of their 1-RM. Submaximal repetitions were tested in pairs, with 2 days separating the testing sessions. Results indicated that the best predictor for the bench press was the number of repetitions performed at 95% of the individuals 1-RM, accounting for 11.6% of the variance. Results also indicated that the mean number of repetitions performed at the selected % 1-RMs did not differ considerable from those established in previous prediction charts. Therefore, it was the conclusion of the authors that in order to get the most accurate prediction of the bench press 1-RM attempts with 95% should be made.

LeSuer, McCormick, Mayhew, Wesserstein, and Arnold (1997) examined the accuracy of the predicting formulas using reps to fatigue in estimating 1-RM bench press strength. Sixty-seven untrained college students (40 males, 27 females) enrolled in a weight lifting class participated in the study. During the fist four class periods subjects were given instructions as to the proper lifting technique for the bench press. As the subjects became familiar with the techniques, they selected a weight to lift for the 1-RM test and a weight that would fatigue them in 10 or fewer repetitions for the bench press. Subjects were randomly assigned to 1 of 2 groups. Those in group 1 were tested for the 1-RM then allowed 10 min rest before testing repetitions to fatigue. Those in group 2 were tested for repetitions to fatigue first then allowed 10 min rest before being tested for the 1-RM. Seven formulas were used to predict 1-RM bench press strength (Brzycki, Lander, Epley, Lombardi, Mayhew et al., O'Conner et al., Wathan). Results of their study determined that all correlation coefficients comparing repetition to fatigue scores and 1-RM performance were significant and exceeded $r = 0.95$. When evaluating the formulas for bench press performance, only the Mayhew et al. and Wathan formulas predicted 1-RM values that did not differ significantly from the achieved 1-RM values. The other formulas significantly underestimated 1-RM performance by an average of 2.2 to 5.4 lbs. Therefore, the findings of their study revealed that all correlation coefficients between predicted and achieved 1-RM lifts were high; however, the average difference between achieved and predicted weights was significantly different from zero in all but 2 equations. Concluding that the Mayhew et al. and Wathan equations proved to be the better predictors of the bench press, with the trend in these types of studies resulting in underestimation of the bench press by 1 to 5 lbs.

Chapman, Whitehead, and Binkert (1998) examined the validity of the 225-lb bench press reps to fatigue test as a submaximal estimate of the 1-RM bench press performance of college football players. Subjects included 98 NCAA Division II football players, with at least 8-months experience in strength and conditioning. Data was collected during spring training after 11- weeks of winter lifting. Each subject was assigned to 1 of 2 groups (A or B), and did either a 225-lb repetition test or a 1-RM bench press test first. Three days were given between each test. Results indicated that the 225-lb bench press reps to fatigue test was highly correlated with the 1-RM bench press (r = 0.96). Regression analysis revealed that 92% of the 1-RM bench press variance was accounted for by the 225-lb bench press reps to fatigue test (R^2 = 0.92, SE of $\pm$ 4.9 kg). Analysis by participants' years of experience were found to give the following R^2 results: redshirt freshman = 0.90, freshman = 0.94, sophomores = 0.90, juniors = 0.94, less than 1 year experience = 0.93, and greater than 1 year experience = 0.90. Analysis of repetitions to fatigue gave the following R2 results: 0 to 10 reps = 0.85, 11 to 21 reps = 0.76. Therefore, based on their findings the investigators concluded that the 225-lb reps to fatigue test is a valid estimation 1-RM bench press strength. However, prediction of the 1-RM bench press performance from the 225-lb reps to fatigue test seems to be greater when 10 or fewer reps are performed.

Mayhew et al. (1999) investigated the relationship between reps completed with an absolute load of 225-lbs and the 1-RM bench press in college football players at different levels of competition. Subjects include one hundred forty-two college football players from 3 NCAA universities. The validation sample was composed of 52 Division 1AA players, 41 Division II regular players, and 21 Division II red-shirt freshmen. A cross-validation sample was randomly selected from the original sample and was composed of 17 Division IAA players, 7 Division II regular players, and 4 Division II red-shirt players. The players were measured at the conclusion of their winter conditioning period after resistance training for a minimum of 8 weeks. Subjects were tested for their 1-RM bench press strength, and within 1 week before or after completing the 1-RM test, each player was required to perform as many repetitions as possible using a 225-lb barbell. Results indicated that body weight was moderately but significantly related to 1-RM and negatively related to %1-RM (225lb / 1-RM X 100). Repetitions completed with an absolute load of 225-lb were highly correlated with 1-RM bench pres ($r = 0.96$) and produced the following linear prediction equation: 1-RM (lb) = 226.7 + 7.1 (repetitions at 225 lb). The cross-validation sample was not significantly different from the original sample, and when the linear prediction equation was applied to the cross-validation sample, the predicted 1-RM bench press was highly correlated with ($r = 0.96$) and was not significantly different from ($t = 0.46$) the actual 1-RM. The predicted 1-RM bench press represented an average overestimation in their cross-validation group of 1.1 lb (SD = 12.5 lb) compared with the actual 1-RM. Twenty-two (78.6%) of the predicted cross-validation groups 1-RM values fell within $\pm$ 1 SEE of the actual 1-RM. Furthermore, 19 players from the cross-validation group (67.9%) had predicted 1-RM values within $\pm$ 10 lb of their actual 1-RM performance. The 95% confidence interval on the difference scores (predicted 1-RM – actual 1-RM) indicated that 26 (92.9%) of the cross-validation groups predicted 1-RM values were between 23.6 lb below to 25.8 lb above their actual 1-RM. On players in the cross-validation group who completed 10 or fewer repetitions (n = 19), the difference between predicted and actual 1-RM produced an average difference ranging from 6.3 lb below to 5.5 lb above actual 1-RM values. For the players who completed more than 10 repetitions (n = 9), the difference between predicted and actual 1-RM produced and average overestimation of 4.2 lb, but the SD increased to 13.5 lb. The 95% confidence interval on the difference ranged from 6.1 lb below to 14.5 lb above actual 1-RM values. Therefore, since 67.9% of the cross-validation players had their 1-RM accurately predicted within 10 lb of their actual 1-RM and only 10.7% had an error greater than 20 lb, the NFL-225 test appears to be an acceptable technique for determining strength levels for most college football players.

Anthropometric

Nutter and Thorland (1987) investigated the relative importance of body size and composition as determinates of individual differences in isokinetic leg extensor strength in young adult males performing at slow, moderate, and fast speeds. Subjects included 31 males aged 19-29 years not participating in any organized or regulated weight training programs. Measurements included height and limb length measurements, anterior thigh skinfold, thigh circumference, thigh volume, and body composition from underwater weighing. Leg extension strength was measured using a Cybex II isokinetic dynamometer. Each subject performed three maximal effort trials at speeds of 60°, 180°, and 240°/sec, going from slowest to fastest speed. Forty-five seconds of rest were given between each testing speed. Results indicted that at all three speeds, both lean body weight and body weight accounted for similar proportions of the variance in peak torque values. Thigh circumference and thigh volume were also found to be moderately correlated with peak torques at the three respective speeds. Lean body weight was also determined to be a significant predictor of peak torque at 60° and 180°/sec, with thigh volume being a significant predictor at 240°/sec. Therefore, the investigators concluded that low to moderate associations were found with anthropometric measurements and isokinetic leg extension strength.

The influence structural dimensions may have on strength performance may be useful to individuals evaluating strength from such exercises as the bench press. If structural dimensions are related to strength performance, then strength tests such as the bench press may not solely measure muscle strength and may reflect an individual's structural predisposition for success. Therefore, Mayhew, Ball, Ward, Hart, and Arnold (1991) sought to determine relationships between structural dimensions and bench press performance in collage males. One hundred and seventy males enrolled in a fitness class served as subjects for this study, with strength measurements following 14 weeks of strength and aerobic endurance training. Anthropometric dimensions included upper arm and chest circumferences, upper and lower arm lengths, shoulder and hip widths, % fat, and height. Arm muscle cross-sectional area was calculated from upper arm circumference correlated for triceps skinfold. Drop distance was measured from the bar to the pectoral muscles. Multiple regression analysis selected upper arm cross-sectional area, %fat, and chest circumference as the best items to predict bench press strength (R = 0.83; SEE = 11.6 kg). Cross-validation of the prediction equation on a similar sample of 89 males produced an r = 0.74 between predicted and actual bench press. In a second cross validation sample of 57 males who had trained more extensively, the correlation between predicted and actual bench press was r = 0.57. The prediction equations significantly underestimated bench press performance in the more extensively weight trained subjects. The results of the study suggest that bench press performance is related to structural dimensions in males and that extensive strength training may alter the relationship.

Basic lifts such as bench press, squat, and deadlift are used in the practical setting to assess the strength levels of athletes. Previous research indicates that strength is related to muscle size in isolated one-joint movements, but few studies have considered multi-joint movements such as those listed above. Highly experienced athletes make good subjects for investigation into multi-joint movements due their reduced neural inhibition controlling the amount of weight lifted. These types of individuals provide a valuable source to investigate the relationships of body size and build to strength performance. Therefore, Mayhew, Piper, and Ware (1993) sought to determine the relationship between anthropometric dimensions and strength performance in the bench press, squat, and deadlift in a group of resistance trained athletes. Fifty-eight college football players were measured for 1-RM bench press, squat, deadlift, and eleven anthropometric dimensions following a ten week strength training program. Results indicated that arm circumferences, arm muscle cross-sectional area, and thigh circumferences yielded the highest relationships to lifting performance. Multiple regression analysis selected arm size and %fat as variables common to the prediction of all three lifts. It was determined by comparing the predictions of the three lifts, that the fewer joints and muscle groups involved in a lift, the greater the predictive accuracy would be using structural dimensions. It was concluded that physical dimensions play a role in the determining strength performance in resistance-trained athletes.

Mayhew, Piper, and Ware (1993) sought to determine the relationship between selected structural dimensions and strength performance in a group of resistance trained athletes. To accomplish this seventy-two college football players volunteered to be measured following their winter conditioning program. Anthropometric dimensions included height, body mass, two muscle circumferences, four skeletal lengths, and five skinfolds. Standing and sitting heights were also determined, along with leg length estimated as the difference between standing height and sitting height. Arm circumference, and chest circumference were measured in triplicate with the average used for analysis. Skeletal dimensions included arm and forearm lengths, and barbell drop distance during the bench press. Skinfolds were measured in triplicate at the triceps, subscapular, suprailiac, abdominal, and thigh sites, with body density estimated from the average of a general equation developed for athletes and a football-specific equation. Body density was converted to % fat using the siri formula. Strength testing included 1-RM's for the bench press, squat, and deadlift. Multiple regression analysis selected arm circumference, and % fat as predictors of lifting performance in all three lifting categories, with other predictors varying from lift to lift. Overall conclusions indicated body mass as the major determinate of the absolute amount of weight and athlete is capable of lifting in the bench, squat, and deadlift. Among athletes of similar body mass, local muscle mass and limb dimensions may reflect a structural limitation on weightlifting potential. And finally that structural dimensions are more indicative of weightlifting performance when the lift involves fewer joints and muscle groups.

Previous research has indicated a strong relationship between anthropometric dimensions and strength performance in males; however, there have been few investigations into this type of relationship in females. Therefore, the study of Scanlan, Ballmann, Mayhew, and Lantz (1999) sought to investigate the relationship between anthropometric dimensions and 1-RM bench press in untrained females. If significant correlations do exist between anthropometric dimensions and bench press in females, strength potential could be identified without requiring an exercise model to do so. Potential for injury could be avoided by predicting 1-RM potential without the handling of heavy loads experienced in 1-RM testing. One hundred and thirteen untrained college females volunteered for this investigation. Eighteen measured and seven derived anthropometric variables to predict 1-RM bench press were gathered for this study, along with five skinfolds, five circumferences, and six skeletal widths. Derived measurements included body mass index, percent fat, fat-free mass, flexed arm cross-sectional area, shoulder width to hip width ratio, androgyny index, and somatotype. Results showed the strongest correlations to bench press were arm cross sectional area ($r=0.45$), flexed arm circumference ($r=0.45$), mesomorphy ($r=0.44$), and forearm circumference ($r=0.42$). Multiple regression analysis to predict bench press revealed a disappointing $R=0.58$ with a SEE= ± 5.6 kg. Therefore the investigators concluded that prediction from anthropometric dimensions in untrained females dose not appear to be practical or accurate.

Methods

Braith, Graves, Leggett, and Pollock (1993) investigated the validity of a dynamic seven to 10 repetition maximum test to estimate maximal knee extension strength in untrained and trained subjects. Thirty-three men and 25 women were randomly assigned to a group that trained two or three times a week for 18 weeks, or a control group. The training group improved their 1-RM and 7-10 RM strength while the control group did not change. A linear regression equation was produced after training resulting in an R^2 = 0.91 with a standard estimate of error .9 kg. Results indicated that a test consisting of 7-10 repetitions performed to exhaustion can accurately predict 1-RM knee extension strength. However resistance training alters the relationship between maximal and submaximal strength, and thus the level of training is an important consideration when estimating 1-RM strength from a multiple repletion test performed to volitional fatigue.

Weir, Wagner, and Housh (1994) examined the effect of rest interval length on repeated on-repetition maximum bench press performance. Sixteen male college students who were experienced in the bench press volunteered for their study. On the first day subjects in their study were tested for 1-RM strength. During the next four testing sessions, subjects were tested for 1-RM strength two times, with the rest interval lengths being 1, 3, 5, or 10 minutes. The results of their study found no significant difference in the ability to repeat a successful maximal bench press based on the rest interval lengths tested. Indicating that 1-min rest intervals are sufficient for recovery between maximal strength tests.

Invergo, Ball, and Looney (1991) investigated the effectiveness of push-ups and absolute muscular endurance (YMCA bench press test) for predicting the maximal weight that can be lifted in the bench press exercise. Subjects include 144 untrained to moderately-trained men ages 18-34. Within 15 days, each subject performed a one-repetition maximum bench press with free weights, push-ups timed for 60 seconds and the YMCA bench press test (a test of absolute muscular endurance). Results of a multiple regression analysis revealed that bench press absolute endurance was more effective for predicting bench press strength with $R^2 = 0.86$, and SEE = 6.03 kg. Push-ups were found to account for only 31% of the variance with a SEE = 13.33. A cross-validation (n = 48) of the prediction equation using bench press absolute endurance accounted for 91% of the variance (SEE = 4.49 kg) between the measured and predicted bench press strength. Suggesting that absolute muscular endurance in some cases may provide a feasible alternative to the one-repetition maximum in the assessment of maximal lifting capacity.

Fry and Kraemer (1991) investigated the physical performance characteristics of American collegiate football players from Division I, Division II, and Division III levels of competition. Nineteen collegiate football programs were surveyed for a variety of athlete performances including the 1-RM bench press. Performances for the entire sample for the 1-RM bench press revealed a mean value of 136.9 with a standard deviation of $\pm$ 25.8 kg. In general, the bench press was one of the performance variables investigated in their study that was determined to effectively differentiate between divisions of play as well as playing abilities. The data presented in their study provides helpful norms for strength and conditioning professionals.

Black and Roundy (1994) compared starters and non-starters on the predictor variables of body weight, and bench press. Results indicated that for 1,018 Division I football players mean body weight was determined to be 100.2 kg, with a mean 1-RM bench press of 140.8 kg for 963 football players. The data presented in their study provides helpful norms for strength and conditioning professionals.

Appendix A: Subject Forms

CHS 11/00 CHS #______________

Application for New Approval of a Study Involving Human Subjects
University of Hawai'i, Committee on Human Studies (CHS)
Spalding Hall 252B, 2540 Maile Way, Honolulu, Hawai'i 96822
Telephone: (808) 956-5007

Date: 10/3/2001

PI (name & title): Brian Schroeder Master's Graduate Student Exercise Science

Email: brian.schroeder2@gte.net Phone: 808-942-0980

Department: Kinesiology & Leisure Science

[ ] Faculty or Staff [X] Student - name of supervising professor: Ronald Hetzler Ph.D.

Training in Human Subject Protection: When, where, & what? ______________

Project Title: Prediction Equations as an Alternative to !-RM Strength Testing

Proposed Sponsoring Agency: N/A

Start Date: Nov. 2001

Complete Agency address: N/A

Proposal Submitted to ORS: [X] No [ ] Yes, when? N/A

Proposal #: (if known) N/A

1. Summarize your proposed research. Outline objectives and methods.

   The purpose of this investigation is to develop a bench press prediction equation combining submaximal repetitions with anthropometric measurements, and to recognize anthropometric commonalities amongst prediction outliers. Both anthropometic dimensions and strength testing will be conducted in order to investigate these objectives. Skinfolds will be measured at the triceps, chest, suprailiac, abdominal, axial, calf, subscapula, supraspinale and thigh sights in triplicate. Muscle circumferences will be taken around a flexed arm, calf, and the chest at midexpiration. Skeletal lengths will include the length of the arm, forearm, and biacromial width. Distance the bench press bar had to travel from full-arm extension to touch the chest will be measured as the drop distance. Height and weight will also be recorded for each individual. Bench press strength will be determand using a competitive powerlifting format. After an individual warm-up, each subject will perform a one-repetition or three to five repetition lift with a weight he felt was near his maximum. Each lifter will be given at least three attempts to perform ether a 1RM or 3 – 5 RM lift. Subject will begin in a straight-arm position, assisted by a spotter and subsequently lower the bar until touching the chest. It will be immediately returned to a straight-arm position. If the lift is completed successfully, a 5-minute rest will be given, weight will be added to the bar, and another single or multiple repetition lift will be attempted. The greatest amount of weight successfully lifted will be recorded. The objectives are: To develop a bench press prediction equation that has a higher degree of accuracy, and to identify individuals who may have a predisposition to inaccurate predictions due to body type. For a more detailed explanation, see attached proposal.

2. Summarize all involvement of humans in this project (who, how many, age, sex, length of involvement, frequency, etc.) and the procedures they will be exposed to. Attach survey instrument, if applicable.

Subjects in the present study will be recruited from the University of Hawaii men's football team. The subjects (n = 70) will range in age from 19 – 30 years. Subjects will be in good physical health and will be experienced in performing the bench press. Subjects will be asked to report to the KLS Teaching Laboratory (room 100 Stan Sheriff Center) on two occasions at least 48 hours but not more than one week apart. On the first day the subjects will be required to complete a Medical History Form and the PAR-Q prior to testing. Subjects will also be required to give informed consent prior to participation. Results will be kept confidential, and subject data will be coded. On the first day, anthropometric data will be collected and the subjects will then be asked to perform either a 3 to 5 RM or a 1RM, assigned in a counterbalanced random order. On the second day the subjects in this study will be accessed for either the 3 to 5RM or the 1RM bench press. The anthropometric variables included will be skinfolds, muscle circumferences, and skeletal lengths. For a more detailed explanation, see attached proposal. All forms are included.

Check whether any subject of your research will be selected from the following categories:

[ ] Minors [ ] Pregnant Women [ ] Mentally Disabled [ ] Fetuses

[ ] Abortuses [ ] Physically Disabled [ ] Prisoners [X] N/A

3. Research involving humans often exposes the subjects to risks: For the purpose of this application, "risk" is defined as exposure of any person to the possibility of injury, including physical, psychological, or social injury, as a consequence of participation as a subject in any research, development, or related activity which departs from the application of those established and accepted methods necessary to meet his needs, or which increases the ordinary risks of daily life, including the recognized risks inherent in a chosen occupation or field or service.

a. Check all the risks to human subjects that apply to your project:

[X] Physical trauma or pain	[ ] Deception	[ ] Experimental diagnostic procedures
[ ] Side effects of medications	[ ] Contraction of disease	[ ] Experimental treatment procedures
[ ] Contraction of disease	[ ] Worsening of illness	[ ] Loss of privacy
[ ] Psychological pain	[ ] Loss of legal rights	[ ] Other – explain

b. Check procedures that will be used to protect human participants from risks:

[X] M.D. or other appropriately trained individuals in attendance
[ ] Sterile equipment
[ ] Precautions in use of stressor or emotional material (explain below)
[ ] When deception used, subjects fully informed as to nature of research at feasible time (explain below)
[ ] Procedures to minimize changes in self-concept (explain below)
[X] Confideniality of subjects maintained via code numbers and protected files
[X] Anonymity - no personally identifiable information collected
[ ] Others-- explain

c. Has provision been made to assure that Human Subjects will be indemnified for expenses incurred as a direct or indirect result of participating in this research?

[ ] Not applicable
[X] No - The following language should appear in the written consent form:
I understand that if I am injured in the course of this research procedure, I alone may be responsible for the costs of treating my injuries.
[ ] YES, explain:

d. Are there non-therapeutic tests that the research subjects may be required to pay for?

[X] Not applicable
[ ] No
[ ] Yes - explain below. The following language should appear in the written consent form:

I understand that I may be responsible for the costs of procedures that are solely part of the research project.

4. Describe mechanism for safety monitoring: How will you detect if greater harm is accruing to your subjects than you anticipated? What will you do if such increased risk is detected?

Minimal risk is anticipated in the course of this study. Only subjects experienced in the bench press will be allowed to participate in the study. The proposed procedure is designed to test within the subject's strength ability. Throughout the bench press testing procedures the investigators will frequently ask the subjects if they feel comfortable to continue. Any subject experiencing unbearable comfort or unease shall be allowed to withdraw immediately from the study without bias. In the event of an emergency both the primary investigator and supervising professor are trained in CPR and will call immediately for an ambulance.

5. Briefly describe the benefits that will accrue to each human subject or to mankind in general, as a result of the individual's participation in this project, so that the committee can access the risk benefit/ratio.

The subjects will gain a better understanding of their own bench press strength and body composition. Subjects will also be given their estimated 1-RM values upon request. The investigation in general will be aimed at developing a bench press prediction equation that can estimate 1-RM values with a greater amount of accuracy than the current equations, along with identifying individuals that may not be suited for this type of estimation procedure. This study will provide coaches, personal trainers, and physical therapists with another and possibly better prediction equation to determine 1-RM, along with possible subject predisposition to inaccurate estimation.

6. **Participation must be voluntary: the participants cannot waive legal Rights, and must be able to withdraw at any time without prejudice.** Indicate how you will obtain informed consent:

[X] Subject (or Parent/Guardian) reads complete consent form & signs ('written' form)
[ ] Oral briefings by PI or project personnel, with simple consent form ('oral' form). Explain below the reason(s) why a written consent form is not used
[ ] Other- explain

7. Are there any other local IRB's reviewing this proposal? [X] No [ ] Yes, Location: ____

I affirm:

(i) that the attached drug sheet(s) submitted to CHS for this project have been checked and confirmed to be accurate and current. If changes in a CHS-approved drug sheet have been made to insure accuracy and currency these changes have been listed on the attached, and

(ii) that the above and any attachments are a true and accurate statement of the proposed research and of any and all risks to human subjects.

Signed: ______________________ Date: _______

Principal Investigator

Signed: ______________________ Date: _______

Supervising Professor (required if PI is a student)
Date of Human Subject Protection Training: ____________

Submit the ORIGINAL plus 12 copies of this form with the following attachments:

Three (3) copies of proposal
Thirteen (13) copies of all consent forms
Thirteen (13) copies of any other information to be read or presented to the participants
Thirteen (13) copies of verbal information to be given if short form is used
Thirteen (13) copies of the survey instrument
(Please consult with the CHS staff if providing the survey instrument is a problem.)

AGREEMENT TO PARTICIPATE IN

Prediction Equations as an Alternative to 1-RM Testing

Principal Investigator: Brian Schroeder, Graduate Student
2218 Lime Street Apt. 4
Honolulu, HI 96826
Phone: 808-942-0980
e-mail: brian.schroeder2@gte.net

Faculty Advisor: Ronald Hetzler, Ph.D.
Kinesiology and Leisure Science
College of Education
University of Hawaii at Manoa
Honolulu, HI 96826
Phone: 808-956-3802
e-mail: hetzler@hawaii.edu

The purpose of this research study is to investigate the effectiveness of current bench press prediction equations as they relate to body type, and to develop an equation based on both submaximal performance and anthropometric dimensions. This equation will allow for the estimation of 1-RM bench press performance based on 3 to 5-RM performances. For use in this study, 1-RM and 3 to 5-RM is defined as the maximum amount of weight that you can successfully lift through a full range of motion. You will be asked to meet in the KLS Teaching Laboratory (room 100 Stan Sheriff Center) with the principal investigator on two occasions at least 48 hours but not more than one week apart. On the first day you will be asked to complete a Medical History Form and PAR-Q prior to testing. You will also be asked to give informed consent prior to participation. Subject participation in this study is estimated to be around 70, so your patience and participation is greatly appreciated.

On the first day, anthropometric data will be collected and you will be asked to perform either a 3 to 5 RM or a 1 RM bench press. The anthropometric data will include skinfolds, muscle circumferences, skeletal lengths, along with height and weight. The bench press will follow a competitive powerlifting format. You will be asked to warm-up on your own followed by a 1-RM or 3 to 5-RM test. You will be required to lower the bar until it touches your chest and return the bar to a straight-arm position. Spotters will be allowed to give you a lift off, but are not allowed to assist you during the lift if it is to be considered successful. If your lift is considered successful a 5-minute rest will be given, weight added to the bar, and another single to multiple repetition will be allowed. The greatest amount of weight successfully lifted will be considered your 1-RM or 3 to 5-RM. On the second day you will be asked to perform either a 3 to 5-RM or a 1-RM test depending on which one you participated in on the first day. The expected duration of the first day will be approximately 90 minutes, with the second day lasting approximately 45 minutes.

All data collected during this investigation will be confidential. The researchers and you will be the only persons with access to any of your recorded values, and your name or identity will not be shown or indicated on any report of this data. This study is strictly voluntary and you are allowed to withdraw at anytime during the investigation without prejudice.

By participating in this research study will gain a better understanding of your own bench press strength and body composition. You will also be given your estimated 1-RM values upon request. Your participation in general will aid in developing a bench press prediction equation that can estimate 1-RM values with a greater amount of accuracy than the current equations, along with identifying individuals that may not be suited for this type of estimation procedure. Therefore, with you participation we may be able provide coaches, personal trainers, and physical therapists with another and possibly better prediction equation to determine 1-RM.

Because of the level of physical activity involved in this investigation, there is always the risk of injury. Although very remote, in the event of any physical injury only immediate and essential medical treatment will be available. You should understand that if you are injured during the course of this research procedure, you alone may be responsible for the costs of treating your injuries.

I certify that I have read and that I understand the foregoing, that I have been given satisfactory answers to my inquiries concerning project procedures and other matters and that I have been advised that I am free to withdraw my consent and to discontinue participation in the project or activity at any time without prejudice.

I herewith give my consent to participate in this project with the understanding that such consent does not waive any of my legal rights, nor does it release the principal investigator or the institution or any employee or agent thereof from liability for negligence.

Signature of Participant: ________________________________ Date:__________

Signature of Investigator: ________________________________ Date:__________

If you cannot obtain satisfactory answers to your questions or have comments or complaints about your treatment in this study, contact: Committee of Human Studies, University of Hawaii, 2540 Maile Way, Honolulu, Hawaii 96822. Phone: (808)956-5007

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

	Please Circle One	
1. Has your doctor ever said you have heart trouble?	YES	NO
2. Do you have pains in your heart or chest?	YES	NO
3. Do you ever feel faint or have spells of severe dizziness?	YES	NO
4. Has your doctor ever said your blood pressure was too high?	YES	NO
5. Has you doctor ever said you have a bone or joint problem that has been aggravated or might be made worse by exercise?	YES	NO
6. Is there good physical reason not mentioned here why you should not follow an exercise program?	YES	NO
7. Are you between the ages of 18 and 30?	YES	NO

____________________ ____________________ __________

Signature of Participant Witness Date

Appendix B: Subject Data

Subject Data for Position, Age, Hight, Weight

Subject #	Pos	Age	Hight inc.	Hight cm	Weight lb	Weight KG
1	ol	20	72.0	182.9	302	137.3
2	wr	18	67.5	171.5	160	72.7
3	dl	19	72.6	184.5	247	112.3
4	lb	20	73.0	185.4	202	91.8
5	lb	20	72.0	182.9	219	99.5
6	ol	21	77.5	196.9	292	132.7
7	k	20	71.4	181.3	209	95.0
8	lb	20	70.6	179.4	234	106.4
9	rb	18	66.0	167.6	155	70.5
10	db	21	69.0	175.3	193	87.7
11	lb	19	69.5	176.5	214	97.3
12	rb	19	65.5	166.4	180	81.8
13	db	19	71.5	181.6	168	76.4
14	lb	22	72.1	183.1	245	111.4
15	db	22	75.5	191.8	196	89.1
16	lb	19	73.6	187.0	245	111.4
17	lb	21	74.0	188.0	235	106.8
18	wr	20	66.4	168.7	160	72.7
19	dl	21	74.8	190.0	262	119.1
20	db	20	69.0	175.3	188	85.5
21	lb	19	69.6	176.8	215	97.7
22	rb	18	71.4	181.4	222	100.9
23	dl	18	75.4	191.5	241	109.5
24	ol	21	78.0	198.1	321	145.9
25	ol	19	73.5	186.7	293	133.2
26	ol	19	77.5	196.9	312	141.8
27	db	19	69.6	176.8	184	83.6
28	lb	25	71.0	180.3	241	109.5
29	ol	18	72.4	183.9	268	121.8
30	lb	20	72.3	183.6	241	109.5
31	rb	18	69.5	176.5	263	119.5
32	ol	21	74.1	188.2	309	140.5
33	wr	21	73.0	185.4	192	87.3
34	db	21	71.8	182.4	186	84.5
35	rb	21	71.5	181.6	230	104.5
36	lb	18	69.4	176.3	202	91.8
37	lb	18	71.1	180.6	202	91.8
38	wr	20	67.0	170.2	155	70.5
39	db	19	70.0	177.8	174	79.1
40	db	19	71.3	181.1	168	76.4
41	ol	21	76.3	193.8	305	138.6
42	ol	20	77.0	195.6	294	133.6
43	wr	18	68.5	174.0	197	89.5
44	ol	20	73.0	185.4	335	152.3
45	ol	21	74.8	190.0	323	146.8
46	lb	18	75.0	190.5	239	108.6

Subject Data for Position, Age, Hight, Weight

47	db	20	72.0	182.9	222	100.9
48	ol	19	72.3	183.6	272	123.6
49	rb	22	71.1	180.6	214	97.3
50	wr	19	69.5	176.5	182	82.7
51	rb	19	70.1	178.1	208	94.5
52	db	18	70.0	177.8	196	89.1
53	db	20	73.5	186.7	204	92.7
54	ol	21	74.1	188.2	300	136.4
55	k	22	72.5	184.2	208	94.5
56	db	21	73.0	185.4	188	85.5
57	rb	21	70.5	179.1	219	99.5
58	rb	21	70.3	178.6	217	98.6
59	lb	19	70.8	179.8	220	100.0
60	ol	19	74.5	189.2	335	152.3
61	db	20	68.5	174.0	176	80.0
62	wr	19	71.6	181.9	174	79.1
63	lb	20	71.3	181.1	220	100.0
64	wr	19	67.4	171.2	183	83.2
65	db	20	68.8	174.8	186	84.5
66	db	20	68.5	174.0	175	79.5
67	qb	19	77.5	196.9	240	109.1
68	wr	21	69.3	176.0	165	75.0
69	wr	18	76.3	193.8	198	90.0
70	lb	20	71.8	182.4	214	97.3
71	dl	21	70.8	179.8	298	135.5
72	ol	19	76.5	194.3	328	149.1
73	db	19	68.3	173.4	179	81.4
74	wr	19	74.5	189.2	193	87.7
75	lb	22	71.6	181.9	232	105.5
76	wr	19	73.8	187.5	229	104.1
77	dl	21	72.8	184.9	259	117.7
78	lb	18	69.5	176.5	236	107.3
79	wr	19	69.3	176.0	172	78.2
80	wr	20	67.0	170.2	205	93.2
81	wr	21	70.0	177.8	183	83.2
82	qb	20	72.0	182.9	188	85.5
83	qb	21	75.8	192.5	216	98.2
84	db	20	69.3	175.9	195	88.6
85	lb	22	72.5	184.2	224	101.8
Mean		19.8	71.7	182.2	224	102.0
Median		20	71.6	181.9	215	97.7
Mode		19	72.0	182.9	202	91.8
Standard Deviation		1.3	2.9	7.2	47	21.5
Minimum		18	65.5	166.4	155	70.5
Maximum		25	78.0	198.1	335	152.3
Count		85	85.0	85.0	85	85.0

Subject Data for Arm Length, Forarm Length, Shoulder Width

Subject #	Arm length1	Arm length2	Arm length3	Arm length Average	Forarm length 1	Forarm length 2	Forarm length 3	Forarm length Average	Shoulder width 1	Shoulder width 2	Shoulder width 3	Shoulder width Average
1	39.5	39.8		39.7	28.7	29.2		29.0	45.7	45.3		45.5
2	35.8	35.8		35.8	26.5	26.2		26.4	36.1	36.9		36.5
3	37.5	37.0		37.3	29.4	29.2		29.3	41.7	40.5		41.1
4	39.5	39.0		39.3	27.4	27.7		27.6	41.9	42.5		42.2
5	40.4	41.2		40.8	30.3	30.2		30.3	34.7	35.2		35.0
6	38.0	38.6		38.3	29.0	29.5		29.3	45.9	46.0		46.0
7	37.2	37.1		37.2	28.3	28.4		28.4	42.5	42.8		42.7
8	37.0	36.9		37.0	28.0	27.9		28.0	40.0	39.7		39.9
9	34.3	34.7		34.5	26.7	27.1		26.9	35.1	35.0		35.1
10	37.4	37.4		37.4	29.1	29.2		29.2	38.0	38.5		38.3
11	35.4	35.3		35.4	26.9	26.4		26.7	40.0	40.1		40.1
12	34.7	34.5		34.6	26.4	26.5		26.5	38.4	38.5		38.5
13	37.2	37.6		37.4	29.6	29.6		29.6	39.5	40.1		39.8
14	38.1	37.5		37.8	28.0	28.4		28.2	39.5	40.6	40.0	40.0
15	40.1	40.5		40.3	29.5	29.4		29.5	43.6	43.6		43.6
16	39.4	39.1		39.3	29.9	30.1		30.0	40.5	40.5		40.5
17	37.8	36.7	36.5	37.0	28.1	27.7		27.9	42.0	41.4		41.7
18	36.1	36.0		36.1	27.5	27.1		27.3	37.5	36.1	37.0	36.9
19	40.1	40.0		40.1	29.5	29.8		29.7	42.5	44.3	42.2	43.0
20	36.9	36.5		36.7	27.4	27.6	27.1	27.4	37.5	38.5		38.0
21	37.6	37.5		37.6	28.0	28.0		28.0	40.0	40.5		40.3
22	38.0	37.6		37.8	30.2	29.5		29.9	41.2	40.7		41.0
23	40.4	40.5		40.5	31.8	29.5	29.3	30.2	40.4	40.4		40.4
24	40.9	40.4		40.7	30.7	30.5		30.6	45.0	44.4		44.7
25	41.5	41.9		41.7	32.3	32.2		32.3	40.3	41.7	41.8	41.3
26	41.5	40.5		41.0	30.0	30.5		30.3	44.5	44.4		44.5
27	39.2	39.8		39.5	29.0	29.3		29.2	38.2	38.3		38.3
28	35.5	37.1	37.8	36.8	28.9	29.2		29.1	41.2	40.6		40.9
29	40.4	39.0		39.7	29.5	28.7		29.1	41.7	41.8		41.8
30	37.6	37.6		37.6	28.0	27.5		27.8	41.5	40.3	40.4	40.7
31	38.0	37.9		38.0	26.8	26.5		26.7	41.3	41.4		41.4
32	41.0	40.7		40.9	30.0	31.0		30.5	44.0	43.7		43.9
33	37.7	37.0		37.4	28.6	28.5		28.6	41.7	41.6		41.7
34	36.9			36.9	27.4			27.4	39.3			39.3
35	41.6	41.1		41.4	29.7	29.7		29.7	44.2	43.2		43.7
36	35.2	35.2		35.2	27.0	27.2		27.1	38.5	38.6		38.6
37	39.0	38.7		38.9	28.3	27.5		27.9	40.7	41.5		41.1
38	34.0	34.5		34.3	28.2	28.0		28.1	39.1	39.1		39.1
39	38.7	38.7		38.7	29.7	29.0		29.4	39.6	39.5		39.6
40	36.2	36.0		36.1	29.0	28.5		28.8	39.2	40.0		39.6
41	38.0	38.1		38.1	30.0	29.8		29.9	44.0	43.2		43.6
42	39.5	39.0		39.3	30.3	30.5		30.4	46.3	46.0		46.2
43	36.5	36.8		36.7	26.5	26.8		26.7	40.2	39.5		39.9
44	40.0	39.2		39.6	31.1	31.4		31.3	46.0	45.5		45.8
45	38.5	38.9		38.7	30.0	30.0		30.0	45.1	44.8		45.0
46	39.0	39.0		39.0	28.6	28.5		28.6	40.6	40.5		40.6
47	38.1	38.1		38.1	28.4	28.5		28.5	40.9	40.3		40.6
48	38.7	38.2		38.5	27.6	27.2		27.4	44.2	45.0		44.6
49	37.5	38.2		37.9	28.5	28.2		28.4	41.0	41.5		41.3
50	35.1	35.4		35.3	28.0	27.4		27.7	39.4	39.0		39.2
51	37.4	38.0		37.7	27.6	28.0		27.8	41.1	42.0		41.6
52	37.2	37.0		37.1	27.6	28.1		27.9	41.5	41.7		41.6
53	40.3	40.1		40.2	30.6	30.5		30.6	40.2	40.3		40.3
54	37.5	37.0		37.3	30.4	30.0		30.2	43.4	41.8	43.0	42.7
55	40.8	40.4		40.6	27.9	27.9		27.9	37.5	39.3	38.5	38.4
56	38.0	38.4		38.2	28.7	28.6		28.7	38.5	40.0	39.5	39.3
57	38.0	37.5		37.8	28.3	27.5		27.9	42.0	41.4		41.7
58	37.6	37.2		37.4	28.6	29.1		28.9	40.5	38.5	41.1	40.0
59	37.7	38.0		37.9	28.7	28.5		28.6	40.1	41.0		40.6
60	41.2	41.2		41.2	31.4	31.1		31.3	44.0	43.8		43.9
61	36.4	36.4		36.4	27.4	27.2		27.3	41.7	42.0		41.9
62	38.4	37.8		38.1	27.1	26.8		27.0	38.5	39.4		39.0
63	37.8	37.6		37.7	28.5	28.1		28.3	38.8	39.5		39.2
64	35.1	35.0		35.1	25.5	26.1		25.8	40.5	40.5		40.5
65	35.1	36.4	36.0	35.8	26.1	26.4		26.3	40.2	40.1		40.2
66	36.0	35.9		36.0	25.4	25.8		25.6	40.7	40.0		40.4
67	41.6	41.6		41.6	29.8	29.6		29.7	43.9	44.1		44.0
68	35.7	36.7		36.2	27.0	26.8		26.9	39.1	38.5		38.8
69	42.0	40.0	40.2	40.7	31.6	31.5		31.6	39.2	40.1		39.7
70	39.5	38.9	39.0	39.1	29.6	29.6		29.6	43.0	42.8		42.9
71	35.1	35.2		35.2	30.1	30.3		30.2	45.5	45.0	44.6	45.0
72	43.5	43.4		43.5	31.5	31.6		31.6	45.4	45.9		45.7
73	34.6	35.0		34.8	26.5	27.0		26.8	38.7	38.7		38.7
74	38.3	38.4		38.4	29.3	29.2		29.3	39.1	38.5		38.8
75	36.5	36.9		36.7	28.0	28.2		28.1	43.4	42.6		43.0
76	38.1	38.3		38.2	26.5	26.3		26.4	40.7	40.6		40.7
77	37.6	37.8		37.7	28.1	28.2		28.2	40.0	37.6	39.8	39.1
78	36.0	36.0		36.0	28.4	28.5		28.5	43.5	41.9	43.6	43.0
79	37.1	37.0		37.1	25.8	25.5		25.7	40.5	39.4		40.0
80	37.2	37.0		37.1	27.7	27.3		27.5	40.6	40.6		40.6
81	32.6	33.0		32.8	29.4	29.5		29.5	39.1	38.6		38.9
82	37.4	36.4	36.4	36.7	28.5	28.5		28.5	37.6	38.5	38.7	38.3
83	38.9	38.8		38.9	29.0	29.4		29.2	40.1	40.0		40.1
84	38.0	38.2		38.1	29.7	29.0		29.4	41.0	41.5		41.3
85	36.3	36.2		36.3	27.5	27.5		27.5	42.3	40.7	41.7	41.6
Mean	37.9	37.9	37.7	37.9	28.6	28.6	28.2	28.6	41.0	41.0	40.9	41.0
Median	37.8	37.7	37.2	37.8	28.5	28.5	28.2	28.5	40.6	40.6	40.8	40.6
Mode	38.0	37.0	#N/A	39.3	28.0	28.5	#N/A	27.9	41.7	38.5	#N/A	43.0
Standard Deviation	2.1	1.9	1.7	2.0	1.5	1.5	1.6	1.5	2.5	2.4	2.1	2.4
Minimum	32.6	33.0	36.0	32.8	25.4	25.5	27.1	25.6	34.7	35.0	37.0	35.0
Maximum	43.5	43.4	40.2	43.5	32.3	32.2	29.3	32.3	46.3	46.0	44.6	46.2
Count	85	85	85	85	85	85	85	85	85	85	85	85

Subject Data for Elbow and Knee width

Subject #	Elbow width 1	Elbow width 2	Elbow width 3	Elbow width Average	Knee width 1	Knee width 2	Knee width 3	Knee width Average
1	8.3	8.1		8.2	12.1	11.7		11.9
2	6.2	6.6		6.4	9.3	9.2		9.3
3	8.6	8.7		8.7	10.6	10.2	10.0	10.3
4	7.5	7.5		7.5	10.5	10.3		10.4
5	7.4	7.5		7.5	10.0	9.8		9.9
6	8.0	8.2		8.1	11.8	11.8		11.8
7	7.5	7.4		7.5	10.4	10.6		10.5
8	8.1	8.2		8.2	10.6	10.6		10.6
9	7.0	7.0		7.0	9.6	9.6		9.6
10	7.5	7.6		7.6	9.5	9.6		9.6
11	7.4	7.2		7.3	9.8	9.8		9.8
12	7.2	7.7	7.2	7.4	9.4	9.4		9.4
13	7.4	7.3		7.4	9.6	9.7		9.7
14	7.8	7.7		7.8	9.8	9.5	9.5	9.6
15	7.5	7.6		7.6	9.5	9.5		9.5
16	7.8	7.6		7.7	10.6	10.2	9.8	10.2
17	7.7	7.5		7.6	10.9	11.1		11.0
18	6.9	7.2		7.1	9.1	9.1		9.1
19	8.4	8.2		8.3	10.2	10.1		10.2
20	7.0	7.1		7.1	9.3	9.2		9.3
21	8.1	7.9		8.0	9.9	9.7		9.8
22	7.6	7.5		7.6	10.7	10.5		10.6
23	7.7	7.7		7.7	10.6	10.7		10.7
24	7.3	7.8		7.6	11.0	10.9		11.0
25	8.2	8.1		8.2	10.7	10.6		10.7
26	7.8	8.1		8.0	10.8	10.6		10.7
27	7.1	6.9		7.0	9.6	9.4		9.5
28	7.7	7.2	7.4	7.4	11.0	10.9		11.0
29	8.5	8.1		8.3	10.7	10.7		10.7
30	8.1	8.1		8.1	10.9	10.8		10.9
31	7.8	7.7		7.8	11.4	11.7		11.6
32	7.9	8.6		8.3	11.0	10.8		10.9
33	7.0	7.1		7.1	9.5	9.4		9.5
34	7.1	7.3		7.2	9.9	9.7		9.8
35	8.1	8.2		8.2	10.7	10.9		10.8
36	7.7	7.7		7.7	10.3	10.3		10.3
37	7.6	7.3	7.3	7.4	10.4	10.3		10.4
38	6.6	6.4		6.5	9.5	9.6		9.6
39	7.6	7.6		7.6	9.4	9.4		9.4
40	7.1	6.9		7.0	9.4	9.3		9.4
41	8.0	8.0		8.0	11.4	11.5		11.5
42	8.6	8.3		8.5	11.2	10.9		11.1
43	7.1	7.1		7.1	9.6	9.6		9.6
44	8.8	8.8		8.8	11.2	11.3		11.3
45	8.2	8.3		8.3	11.9	11.6	11.5	11.7
46	8.1	7.8		8.0	10.9	11.0		11.0
47	7.8	8.1		8.0	10.8	10.4		10.6
48	8.0	7.5	7.3	7.6	10.3	10.4		10.4
49	7.6	7.4		7.5	10.0	9.7		9.9
50	7.2	7.2		7.2	9.7	9.4		9.6
51	8.0	8.3		8.2	10.9	10.7		10.8
52	7.5	7.8		7.7	9.6	9.4		9.5
53	7.4	7.4		7.4	9.6	9.8		9.7
54	9.0	8.8		8.9	11.1	11.3		11.2
55	7.7	7.7		7.7	10.2	10.2		10.2
56	7.2	7.5		7.4	9.7	9.6		9.7
57	7.7	7.8		7.8	10.8	10.4	10.5	10.6
58	7.3	7.8	7.9	7.7	9.9	10.2		10.1
59	7.8	7.9		7.9	9.5	9.4		9.5
60	9.0	9.0		9.0	11.7	11.7		11.7

Subject Data for Elbow and Knee width

61	7.1	7.2		7.2	10.1	9.8		10.0
62	6.9	7.1		7.0	9.6	9.5		9.6
63	7.5	7.6		7.6	11.3	11.0		11.2
64	7.2	7.0		7.1	9.3	8.9		9.1
65	7.4	7.2		7.3	9.7	9.5		9.6
66	7.3	7.3		7.3	9.7	9.5		9.6
67	8.1	8.1		8.1	10.4	11.5	11.7	11.2
68	7.0	6.9		7.0	9.0	9.1		9.1
69	7.4	7.3		7.4	10.0	9.8		9.9
70	7.4	7.6		7.5	10.1	9.9		10.0
71	9.7	9.6		9.7	11.3	11.1		11.2
72	8.2	8.7	8.5	8.5	11.0	11.6	11.0	11.2
73	7.1	7.2		7.2	9.3	9.2		9.3
74	6.9	6.9		6.9	9.0	9.0		9.0
75	7.6	7.3		7.5	10.7	10.7		10.7
76	7.5	7.3		7.4	9.6	9.6		9.6
77	8.0	7.9		8.0	11.1	11.0		11.1
78	7.8	7.6		7.7	10.0	10.1		10.1
79	6.9	7.2		7.1	9.8	9.8		9.8
80	7.4	7.8	7.6	7.6	9.5	9.6		9.6
81	7.9	7.3	7.3	7.5	9.3	9.4		9.4
82	7.8	7.8		7.8	10.0	10.1		10.1
83	8.1	8.0		8.1	10.6	10.4		10.5
84	7.4	7.6		7.5	9.9	9.8		9.9
85	8.1	8.0		8.1	10.8	10.7		10.8
Mean	7.7	7.7	7.6	7.7	10.2	10.2	10.6	10.2
Median	7.6	7.6	7.4	7.6	10.1	10.1	10.5	10.1
Mode	7.4	7.6	7.3	7.5	9.6	9.4	#N/A	9.6
Standard Deviation	0.6	0.6	0.4	0.5	0.7	0.8	0.9	0.7
Minimum	6.2	6.4	7.2	6.4	9.0	8.9	9.5	9.0
Maximum	9.7	9.6	8.5	9.7	12.1	11.8	11.7	11.9
Count	85	85	85	85	85	85	85	85

Subject Data for Flexed Arm and Chest Circumference

Subject #	Flexed Arm 1	Flexed Arm 2	Flesed Arm 3	Flexed Arm Average	Flexed Arm in.	Chest Circumference 1	Chest Circumference 2	Chest Circumference 3	Chest Circumference
1	50.0	49.3	50.0	49.8	19.6	127.9	123.0	124.7	125.2
2	36.5	36.4		36.5	14.4	98.8	99.1	101.2	99.7
3	47.9	48.3		48.1	18.9	112.4	114.6	112.7	113.2
4	39.8	39.8		39.8	15.7	102.3	103.8	103.5	103.2
5	38.5	38.6		38.6	15.2	105.6	106.0		105.8
6	47.2	46.8		47.0	18.5	130.0	127.5	126.0	127.8
7	43.7	43.8		43.8	17.2	110.7	109.0	107.4	109.0
8	44.4	44.1		44.3	17.4	117.1	116.6	115.5	116.4
9	34.0	34.2		34.1	13.4	95.2	94.5		94.9
10	41.8	41.4		41.6	16.4	105.2	106.6	106.4	106.1
11	42.6	42.0		42.3	16.7	109.8	108.8	107.8	108.8
12	38.0	38.4		38.2	15.0	104.2	104.9		104.6
13	36.0	35.9		36.0	14.2	98.7	98.2		98.5
14	46.7	46.0		46.4	18.2	117.8	115.6	123.5	119.0
15	34.9	34.8		34.9	13.7	104.3	104.3		104.3
16	42.8	42.9		42.9	16.9	116.8	115.8	113.6	115.4
17	41.0	41.2		41.1	16.2	108.5	108.7		108.6
18	37.8	37.5		37.7	14.8	94.0	89.5	89.9	91.1
19	47.4	46.4		46.9	18.5	116.2	114.9		115.6
20	37.4	37.4		37.4	14.7	105.7	104.1	103.8	104.5
21	42.3	42.5		42.4	16.7	114.0	111.3	112.2	112.5
22	38.1	38.4		38.3	15.1	107.3	106.7		107.0
23	39.3	40.1		39.7	15.6	115.5	116.0		115.8
24	43.5	43.3		43.4	17.1	134.5	131.8	130.5	132.3
25	40.3	39.5	40.7	40.2	15.8	123.6	123.6		123.6
26	45.0	45.4		45.2	17.8	128.6	128.8		128.7
27	36.7	36.6		36.7	14.4	102.5	104.4	104.5	103.8
28	45.2	44.9		45.1	17.7	112.4	109.5	109.6	110.5
29	44.5	44.1		44.3	17.4	117.5	117.8		117.7
30	38.7	39.7		39.2	15.4	103.5	103.8		103.7
31	42.9	42.9		42.9	16.9	113.7	113.3		113.5
32	48.3	47.6		48.0	18.9	128.9	129.2		129.1
33	36.8	37.1		37.0	14.5	98.1	98.4		98.3
34	38.1	38.4		38.3	15.1	104.8	104.8		104.8
35	39.6	39.8		39.7	15.6	111.7	113.9	112.9	112.8
36	36.8	37.8	37.5	37.4	14.7	103.5	104.5		104.0
37	40.1	40.2		40.2	15.8	105.5	107.3	104.6	105.8
38	34.0	33.7		33.9	13.3	97.8	98.1		98.0
39	37.5	37.4		37.5	14.7	99.2	101.7	102.8	101.2
40	34.3	37.1	34.3	35.2	13.9	95.3	97.5	97.8	96.9
41	46.5	46.5		46.5	18.3	126.5	124.9	124.9	125.4
42	47.8	47.8		47.8	18.8	119.4	117.6	118.8	118.6
43	37.9	37.4		37.7	14.8	105.5	104.9		105.2
44	47.5	47.0		47.3	18.6	136.5	138.5	138.0	137.7
45	49.2	49.8		49.5	19.5	128.9	130.8	131.4	130.4
46	41.5	41.2		41.4	16.3	107.8	107.6		107.7
47	40.9	40.9		40.9	16.1	108.6	113.7	112.4	111.6
48	46.0	46.0		46.0	18.1	124.5	125.4	124.0	124.6
49	38.5	38.6		38.6	15.2	109.0	109.6		109.3
50	37.2	38.5	38.5	38.1	15.0	104.2	100.8	102.1	102.4
51	40.9	41.3	41.2	41.1	16.2	106.6	107.5	107.6	107.2
52	42.2	42.0		42.1	16.6	106.5	107.9	106.5	107.0
53	40.5	40.2		40.4	15.9	107.8	105.2	108.9	107.3
54	48.6	48.3		48.5	19.1	124.8	124.8		124.8
55	39.3	39.8	39.6	39.6	15.6	111.2	109.7	111.1	110.7
56	36.8	36.5		36.7	14.4	102.3	101.3		101.8
57	42.2	42.2		42.2	16.6	106.9	111.8	107.6	108.8
58	43.2	43.2		43.2	17.0	111.8	110.2	110.2	110.7
59	41.6	41.6		41.6	16.4	113.3	116.5	115.3	115.0
60	47.9	48.0		48.0	18.9	125.5	124.5	123.5	124.5
61	37.8	37.9		37.9	14.9	101.8	101.0	100.8	101.2
62	38.5	38.6		38.6	15.2	101.5	103.2	102.0	102.2
63	41.9	42.0		42.0	16.5	103.5	102.2	103.0	102.9
64	40.4	41.2		40.8	16.1	106.7	109.7	107.8	108.1
65	39.0	38.8		38.9	15.3	101.4	99.1	98.5	99.7
66	38.8	39.0		38.9	15.3	103.8	102.0	101.3	102.4

Subject Data for Flexed Arm and Chest Circumference

67	38.0	38.2		38.1	15.0	104.8	107.4	107.3	106.5
68	36.0	36.0		36.0	14.2	98.4	99.0	98.3	98.6
69	35.2	35.2		35.2	13.9	94.0	92.4		93.2
70	40.7	40.7		40.7	16.0	108.4	110.5	108.8	109.2
71	51.0	50.8		50.9	20.0	125.9	125.5		125.7
72	47.5	47.5		47.5	18.7	126.5	126.8		126.7
73	38.4	38.6		38.5	15.2	99.8	96.6		98.2
74	37.1	37.0		37.1	14.6	105.6	107.2	106.0	106.3
75	43.8	43.2	43.2	43.4	17.1	114.0	114.9	115.6	114.8
76	36.9	36.5		36.7	14.4	110.6	109.0	110.4	110.0
77	47.6	47.6		47.6	18.7	117.5	117.8		117.7
78	43.5	43.5		43.5	17.1	108.9	111.8	110.5	110.4
79	35.6	35.4		35.5	14.0	98.6	98.6		98.6
80	40.0	40.1		40.1	15.8	108.8	108.0	109.4	108.7
81	40.6	40.6		40.6	16.0	98.7	99.4		99.1
82	36.5	36.9		36.7	14.4	101.4	101.4		101.4
83	42.1	42.2		42.2	16.6	111.4	109.8	110.0	110.4
84	42.9	42.9		42.9	16.9	107.6	111.4	111.8	110.3
85	43.8	43.8		43.8	17.2	114.3	115.6		115.0
Mean	41.2	41.2	40.6	41.2	16.2	110.1	110.1	110.7	110.1
Median	40.6	40.7	40.2	40.7	16.0	107.8	108.8	109.2	108.7
Mode	38.5	38.6	#N/A	38.6	15.2	103.5	99.1	107.8	105.8
Standard Deviation	4.2	4.1	4.6	4.2	1.6	10.0	9.9	9.5	9.9
Minimum	34.0	33.7	34.3	33.9	13.3	94.0	89.5	89.9	91.1
Maximum	51.0	50.8	50.0	50.9	20.0	136.5	138.5	138.0	137.7
Count	85	85	85	85	85	85	85	85	85

Subject Data for Calf Circumference, and Drop Distance

Subject #	Calf 1	Calf 2	Calf 3	Calf Average	Calf in.	Drop Distance 1	Drop Distance 2	Drop Distance 3	Drop Distance Average
1	48.8	48.8		48.8	19.2	45.0	45.2		45.1
2	36.5	36.8		36.7	14.4	37.4	40.0		38.7
3	41.9	41.9		41.9	16.5	44.9	43.9	48.5	45.8
4	41.2	41.2		41.2	16.2	45.6	46.7	46.1	46.1
5	39.9	39.6		39.8	15.6	48.1	47.5		47.8
6	48.2	48.5		48.4	19.0	44.6	43.5	43.1	43.7
7	41.2	41.5		41.4	16.3	47.1	47.4		47.3
8	44.3	44.0		44.2	17.4	47.0	45.7	46.0	46.2
9	36.4	36.8		36.6	14.4	42.9	43.8	44.0	43.6
10	39.9	39.4		39.7	15.6	45.1	45.2		45.2
11	40.5	40.7		40.6	16.0	36.5	37.2		36.9
12	41.4	41.0		41.2	16.2	40.3	41.0		40.7
13	37.6	37.9		37.8	14.9	49.8	51.2	48.7	49.9
14	41.6	42.5		42.1	16.6	44.0	44.7	45.5	44.7
15	40.6	41.3	41.0	41.0	16.1	49.6	47.9	49.5	49.0
16	41.0	40.8		40.9	16.1	47.0	48.2	48.4	47.9
17	44.1	44.0		44.1	17.3	45.1	46.1	43.3	44.8
18	39.1	39.1		39.1	15.4	43.0	46.2	47.6	45.6
19	40.6	41.0		40.8	16.1	46.0	48.5	48.3	47.6
20	39.9	40.0		40.0	15.7	46.4	40.5	46.7	44.5
21	40.0	40.2		40.1	15.8	47.2	48.0		47.6
22	41.9	41.9		41.9	16.5	46.1	46.9	48.1	47.0
23	43.4	43.2		43.3	17.0	45.9	47.2	46.2	46.4
24	45.9	46.0		46.0	18.1	47.1	50.0	49.3	48.8
25	46.3	46.6		46.5	18.3	47.5	49.1	49.1	48.6
26	44.2	44.6		44.4	17.5	49.2	49.4		49.3
27	40.2	40.3		40.3	15.8	42.7	45.1	46.1	44.6
28	44.1	44.8		44.5	17.5	41.3	49.0	48.7	46.3
29	44.5	43.8		44.2	17.4	44.4	43.8		44.1
30	45.1	45.1		45.1	17.8	43.7	43.4		43.6
31	50.2	50.5		50.4	19.8	41.9	42.0		42.0
32	48.3	48.3		48.3	19.0	50.9	51.7		51.3
33	40.3	40.0		40.2	15.8	48.3	48.1		48.2
34	37.5	37.8		37.7	14.8	40.1	43.2	42.7	42.0
35	41.8	41.8		41.8	16.5	48.0	49.5	50.8	49.4
36	44.1	43.8		44.0	17.3	48.8	48.3		48.6
37	40.5	40.9		40.7	16.0	42.8	41.6		42.2
38	36.2	36.2	37.5	36.6	14.4	43.1	45.1	45.1	44.4
39	37.9	37.9		37.9	14.9	46.3	45.1	46.9	46.1
40	35.9	35.9		35.9	14.1	47.1	47.9	47.2	47.4
41	47.5	47.5		47.5	18.7	43.2	43.3		43.3
42	45.6	45.7		45.7	18.0	43.5	45.8	51.5	46.9
43	39.7	40.0		39.9	15.7	46.1	44.9	47.6	46.2
44	47.9	47.8		47.9	18.8	43.7	45.4	47.4	45.5
45	49.5	49.8		49.7	19.5	44.6	46.4	46.4	45.8
46	42.0	42.0		42.0	16.5	42.9	46.0	45.6	44.8
47	41.8	41.6		41.7	16.4	41.7	40.0	40.5	40.7
48	44.0	44.2		44.1	17.4	45.8	45.0	45.0	45.3
49	40.1	40.0		40.1	15.8	39.1	43.2	43.1	41.8
50	40.0	39.9		40.0	15.7	40.7	41.4		41.1
51	42.6	42.5		42.6	16.8	46.2	46.3		46.3
52	39.9	39.8		39.9	15.7	44.6	47.2	49.3	47.0
53	39.8	39.6		39.7	15.6	51.2	51.6		51.4
54	49.5	49.5		49.5	19.5	48.4	47.3	45.7	47.1
55	40.3	39.8	39.9	40.0	15.7	51.4	52.1		51.8
56	39.5	39.9		39.7	15.6	44.6	47.5	46.2	46.1
57	44.8	44.1		44.5	17.5	44.5	43.4	43.0	43.6
58	43.2	42.9		43.1	16.9	45.8	46.0		45.9
59	39.7	40.0	39.7	39.8	15.7	46.5	45.8	46.1	46.1
60	48.5	49.0		48.8	19.2	45.6	45.6		45.6
61	39.1	39.1		39.1	15.4	42.5	44.4	43.8	43.6
62	37.8	37.5		37.7	14.8	47.8	48.7		48.3
63	41.5	41.5		41.5	16.3	45.0	45.3		45.2
64	40.3	40.2		40.3	15.8	36.8	32.3	31.3	33.5
65	42.0	42.0		42.0	16.5	41.6	43.9	44.1	43.2
66	39.7	39.4		39.6	15.6	39.1	39.1		39.1

Subject Data for Calf Circumference, and Drop Distance

67	42.0	42.0		42.0	16.5	46.8	47.3		47.1
68	35.8	35.4		35.6	14.0	46.1	44.1	45.2	45.1
69	39.4	39.7		39.6	15.6	47.3	45.7	47.5	46.8
70	39.0	38.8		38.9	15.3	42.8	43.3		43.1
71	46.5	47.0		46.8	18.4	42.3	43.4	43.8	43.2
72	47.7	48.0		47.9	18.8	53.7	52.7		53.2
73	39.6	39.1		39.4	15.5	41.3	44.0	44.0	43.1
74	38.5	38.3		38.4	15.1	48.1	49.3		48.7
75	41.6	41.6		41.6	16.4	45.0	45.6		45.3
76	38.8	38.9		38.9	15.3	44.1	42.9		43.5
77	42.5	42.5		42.5	16.7	47.0	45.2	48.0	46.7
78	45.1	45.1		45.1	17.8	45.2	43.3	43.1	43.9
79	37.5	37.8		37.7	14.8	44.1	44.1		44.1
80	41.5	41.6		41.6	16.4	39.8	41.4	43.1	41.4
81	36.5	36.5		36.5	14.4	41.2	44.6	42.4	42.7
82	41.4	41.0		41.2	16.2	42.0	43.2	42.6	42.6
83	39.8	40.0		39.9	15.7	45.0	47.9	48.2	47.0
84	39.4	39.7		39.6	15.6	49.4	50.1		49.8
85	43.5	42.9		43.2	17.0	42.6	43.3	44.8	43.6
Mean	41.8	41.9	39.5	41.8	16.5	44.9	45.5	45.8	45.4
Median	41.2	41.2	39.8	41.2	16.2	45.0	45.4	46.1	45.6
Mode	39.9	40.0	#N/A	41.2	16.2	45.0	43.3	43.1	43.6
Standard Deviation	3.5	3.5	1.5	3.5	1.4	3.3	3.3	3.2	3.2
Minimum	35.8	35.4	37.5	35.6	14.0	36.5	32.3	31.3	33.5
Maximum	50.2	50.5	41.0	50.4	19.8	53.7	52.7	51.5	53.2
Count	85	85	85	85	85	85	85	85	85

Subject Data for Tricep, Chest, Suprailiac, and Abdomen Skin Folds

Subject #	Tricep 1	Tricep 2	Tricep 3	Tricep Average	Chest 1	Chest 2	Chest 3	Chest Average	Suprailiac 1	Suprailiac 2	Suprailiac 3	Suprailiac Average	Abdominal Average	Abdominal 2	Abdominal 3	Abdominal 4
1	18.6	16.6	16.4	17.2	15.0	13.4	15.6	14.7	40.2	40.4		40.3	46.3	46.4		46.4
2	6.2	5.6		5.9	4.7	4.6		4.7	9.8	10.0		9.9	12.8	11.4	13.3	12.5
3	11.6	11.8		11.7	6.8	7.6		7.2	22.4	17.2	24.2	21.3	26.0	26.2		26.1
4	12.0	11.8		11.9	8.2	9.8	8.9	9.0	12.3	12.6		12.5	22.2	20.8	22.1	21.7
5	8.2	8.6		8.4	9.8	9.6		9.7	15.2	18.7	15.5	16.5	31.5	31.1		31.3
6	16.6	18.8	20.7	18.7	12.2	15.6	16.2	14.7	39.2	37.6	43.1	40.0	47.4	44.6	48.4	46.8
7	6.2	6.6		6.4	5.2	5.2		5.2	12.6	9.6	9.0	10.4	16.6	16.3		16.5
8	7.8	7.2		7.5	7.8	7.6		7.7	29.0	25.4	30.4	28.3	41.6	37.4	39.2	39.4
9	8.0	8.6		8.3	4.6	4.7		4.7	6.5	6.8		6.7	8.6	8.8		8.7
10	7.2	6.4		6.8	6.4	5.1	5.1	5.5	10.2	9.8		10.0	12.0	13.0		12.5
11	11.5	11.4		11.5	9.0	8.0	6.4	7.8	31.6	32.1		31.9	39.2	39.6		39.4
12	7.9	7.6		7.8	4.5	4.5		4.5	6.5	6.4		6.5	6.0	5.9		6.0
13	7.8	7.4		7.6	3.6	3.6		3.6	6.6	5.3	7.0	6.3	7.0	9.4	10.2	8.9
14	7.7	6.8		7.3	9.2	9.7		9.5	14.6	19.2	21.8	18.5	23.4	22.4	22.2	22.7
15	5.8	5.9		5.9	6.4	5.6		6.0	7.7	9.9	9.8	9.1	10.8	10.2		10.5
16	10.6	9.8		10.2	7.2	6.3		6.8	29.8	32.4	29.0	30.4	32.5	31.8		32.2
17	15.8	14.0	15.4	15.1	10.9	9.2	8.8	9.6	30.6	29.4	28.2	29.4	30.2	32.0	30.4	30.9
18	3.9	3.9		3.9	5.6	4.7		5.2	7.2	5.2	5.9	6.1	8.5	8.5		8.5
19	9.4	11.4	11.8	10.9	10.8	11.0		10.9	15.5	12.6	17.4	15.2	29.0	27.2	28.2	28.1
20	8.6	8.0		8.3	6.4	6.1		6.3	10.0	10.8		10.4	14.5	14.7		14.6
21	8.2	8.1		8.2	4.9	5.1		5.0	11.5	11.2		11.4	19.6	19.5		19.6
22	13.2	13.2		13.2	7.5	8.1		7.8	11.6	13.2	12.1	12.3	19.0	23.0	21.0	21.0
23	7.6	7.8		7.7	5.2	5.0		5.1	16.4	22.6	16.0	18.3	30.6	30.2		30.4
24	6.5	7.2		6.9	13.4	15.0	13.6	14.0	35.4	32.3	33.8	33.8	46.2	46.8		46.5
25	18.5	18.2		18.4	14.2	14.0		14.1	42.6	41.2		41.9	40.3	38.8	36.8	38.6
26	12.8	12.6		12.7	13.2	13.2		13.2	42.6	39.2	37.6	39.8	44.2	47.6	44.8	45.5
27	8.2	9.0		8.6	4.8	5.0		4.9	9.1	8.6		8.9	13.7	13.2		13.5
28	6.2	6.8		6.5	9.2	8.8		9.0	26.4	20.9	25.8	24.4	34.8	12.5	31.4	26.2
29	22.0	24.8	22.2	23.0	13.4	13.0		13.2	42.4	42.2		42.3	46.4	45.8		46.1
30	10.8	11.8	11.6	11.4	12.7	10.8	13.4	12.3	31.4	31.2		31.3	36.0	38.0	42.0	38.7
31	14.8	17.4	15.8	16.0	14.6	12.2	12.6	13.1	30.0	28.4	32.2	30.2	43.0	37.0	43.0	41.0
32	14.2	18.2	14.0	15.5	21.4	15.4	15.8	17.5	42.2	42.4		42.3	44.4	46.8	43.2	44.8
33	10.4	11.8	11.4	11.2	7.5	7.3		7.4	12.6	8.8	9.6	10.3	20.3	19.0	18.2	19.2
34	6.6	5.8		6.2	3.8	3.7		3.8	5.8	6.1		6.0	9.0	9.5		9.3
35	9.4	8.6		9.0	7.0	7.4		7.2	24.6	20.2	18.2	21.0	26.8	26.6		26.7
36	17.2	16.4		16.8	6.2	6.2		6.2	10.4	11.0		10.7	16.3	15.3	15.7	15.8
37	10.4	11.2		10.8	6.7	5.2	5.8	5.9	12.0	11.4		11.7	16.3	17.0		16.7
38	5.8	5.6		5.7	3.7	4.0		3.9	5.1	5.2		5.2	6.6	7.0		6.8
39	5.8	6.8	5.9	6.2	4.2	4.0		4.1	5.5	6.2		5.9	6.3	6.3		6.3
40	6.8	7.0		6.9	4.2	4.2		4.2	6.2	7.3	7.3	6.9	11.0	10.1		10.6
41	17.2	16.2	14.8	16.1	16.8	16.4		16.6	31.4	30.6		31.0	46.4	41.2	40.6	42.7
42	16.6	14.4	14.4	15.1	11.4	11.2		11.3	28.4	30.4	33.6	30.8	29.8	27.4	29.6	28.9
43	6.9	6.8		6.9	5.8	5.4		5.6	9.9	8.6	8.0	8.8	13.2	12.8		13.0
44	25.8	24.4	26.8	25.7	23.6	19.4	13.4	18.8	41.6	46.0	46.2	44.6	43.6	40.4	36.2	40.1
45	15.2	15.2		15.2	10.4	13.6	11.2	11.7	37.2	35.4	37.4	36.7	32.8	34.6	32.0	33.1
46	15.1	15.1		15.1	10.2	10.6		10.4	31.4	32.2		31.8	35.2	34.7		35.0
47	11.5	9.5	9.8	10.3	9.6	9.0		9.3	20.5	20.2		20.4	19.8	20.0		19.9
48	8.2	7.6		7.9	13.2	14.2	13.8	13.7	27.6	28.8	28.2	28.2	36.2	34.6	35.4	35.4
49	9.0	8.3		8.7	5.8	4.5	5.9	5.4	13.3	13.2		13.3	15.3	15.4		15.4
50	5.6	5.3		5.5	4.2	4.5		4.4	5.8	5.2		5.5	7.3	7.6		7.5
51	10.1	9.4		9.8	6.1	6.2		6.2	10.6	8.4	8.8	9.3	14.2	14.2		14.2
52	6.4	6.5		6.5	6.0	6.3		6.2	10.0	13.1	10.8	11.3	18.4	18.3		18.4
53	6.7	6.0		6.4	5.6	5.7		5.7	15.0	12.0	10.2	12.4	14.8	13.6	14.0	14.1

Subject Data for Tricep, Chest, Suprailiac, and Abdomen Skin Folds

54	13.8	14.2		14.0	15.4	15.2		15.3	35.2	35.9		35.6	35.4	36.6	36.4	36.1
55	12.8	13.4		13.1	9.4	9.1		9.3	24.2	22.8	19.0	22.0	24.3	22.1	23.5	23.3
56	10.1	9.8		10.0	4.5	4.8		4.7	6.5	6.8		6.7	10.5	10.1		10.3
57	7.1	7.6		7.4	5.6	6.1		5.9	10.5	12.5	10.8	11.3	15.5	16.3		15.9
58	7.0	7.0		7.0	6.8	6.3		6.6	7.7	7.9		7.8	9.0	9.0		9.0
59	14.8	15.9	15.6	15.4	16.1	14.2	12.8	14.4	27.2	30.4	28.0	28.5	36.8	34.8	35.8	35.8
60	22.6	26.8	25.7	25.0	8.8	10.6	10.6	10.0	39.2	34.8	39.6	37.9	53.0	48.6	50.0	50.5
61	6.8	7.5		7.2	5.0	6.2	5.8	5.7	8.1	7.5		7.8	13.1	12.2		12.7
62	14.0	12.2	13.2	13.1	9.1	9.8		9.5	11.8	12.7		12.3	22.0	20.4	21.4	21.3
63	11.6	12.6	12.4	12.2	10.9	8.8	11.8	10.5	28.2	27.4		27.8	33.2	34.2	33.8	33.7
64	5.4	5.3		5.4	5.9	5.8		5.9	9.2	9.0		9.1	12.2	13.2	13.2	12.9
65	6.5	6.5		6.5	4.6	5.1		4.9	7.2	8.4	9.0	8.2	8.4	9.1		8.8
66	9.4	9.4		9.4	8.6	8.4		8.5	12.5	14.3	10.6	12.5	18.9	18.8		18.9
67	13.2	13.9		13.6	12.2	12.8		12.5	14.0	16.2	13.0	14.4	25.8	26.2		26.0
68	8.1	7.8		8.0	5.8	5.4		5.6	10.2	11.0		10.6	13.8	13.4		13.6
69	11.8	11.4		11.6	6.4	6.4		6.4	8.8	9.8	9.3	9.3	11.0	11.5		11.3
70	12.6	13.6		13.1	8.2	9.6	9.6	9.1	13.8	12.1	11.9	12.6	19.8	19.2		19.5
71	15.0	14.8		14.9	12.5	11.4	14.3	12.7	33.7	33.8		33.8	34.2	32.2	35.2	33.9
72	15.6	15.2		15.4	19.0	15.6	16.8	17.1	40.8	42.0	36.4	39.7	41.4	41.4		41.4
73	4.4	4.6		4.5	6.1	4.3	5.5	5.3	15.2	15.2		15.2	19.2	20.3	21.2	20.2
74	13.9	14.2		14.1	7.1	8.1		7.6	14.2	18.2	11.8	14.7	19.4	18.6		19.0
75	13.4	12.8		13.1	11.4	11.9		11.7	26.6	25.4	28.8	26.9	36.8	37.9	37.6	37.4
76	8.4	9.0		8.7	11.6	8.4	10.2	10.1		32.6	34.2	33.4	35.4	31.4	34.6	33.8
77	13.8	11.8	12.6	12.7	12.6	13.4		13.0	29.6	30.2		29.9	35.6	37.0	35.8	36.1
78	12.9	12.8		12.9	9.9	8.8	10.2	9.6	19.8	15.8	21.0	18.9	31.2	28.5	29.4	29.7
79	12.8	13.0		12.9	10.7	11.2		11.0	26.8	25.8	28.4	27.0	28.2	25.2	27.1	26.8
80	11.0	12.2	11.2	11.5	11.0	11.0		11.0	22.4	21.6		22.0	26.8	24.6	25.6	25.7
81	6.0	5.8		5.9	5.2	5.3		5.3	7.6	6.2	5.6	6.5	9.3	8.9		9.1
82	11.4	10.6		11.0	5.5	5.2		5.4	10.6	11.6		11.1	15.5	15.1		15.3
83	8.8	9.0		8.9	6.3	4.6	5.7	5.5	11.2	12.4		11.8	14.7	14.6		14.7
84	9.6	8.3	8.6	8.8	6.3	5.8		6.1	11.4	9.6	11.8	10.9	12.5	11.0	10.0	11.2
85	6.6	5.8		6.2	7.8	7.2		7.5	17.8	16.6	18.2	17.5	19.2	18.9		19.1
Mean	10.7	10.8	14.8	10.8	8.8	8.5	10.8	8.6	19.4	19.3	20.5	19.4	24.3	23.6	30.0	24.0
Median	10.1	9.5	14.0	10.0	7.5	7.6	10.9	7.6	14.4	15.2	18.2	14.7	20.3	20.3	31.4	21.0
Mode	8.2	11.8	#N/A	5.9	6.4	5.2	13.4	4.7	6.5	5.2	9.0	10.4	46.4	26.2	35.8	12.5
Standard Deviation	4.4	4.6	5.3	4.5	4.1	3.7	3.8	3.8	11.7	11.6	11.5	11.7	12.7	12.3	10.7	12.3
Minimum	3.9	3.9	5.9	3.9	3.6	3.6	5.1	3.6	5.1	5.2	5.6	5.2	6.0	5.9	10.0	6.0
Maximum	25.8	26.8	26.8	25.7	23.6	19.4	16.8	18.8	42.6	46.0	46.2	44.6	53.0	48.6	50.0	50.5
Count	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85

Subject Data for Axial, Subscapular, Thigh, and Calf skin folds

Subject #	Axial 1	Axial 2	Axial 3	Axial Average	Subscapular 1	Subscapular 2	Subscapular 3	Subscapular Average	Supraspinale 1	Supraspinale 2	Supraspinale 3	Supraspinale Average	Thigh 1	Thigh 2	Thigh 3	Thigh Average	Calf 1	Calf 2	Calf 3	Calf Average
1	28.2	25.4	26.2	26.6	23.2	27.4	26.2	25.6	26.2	27.2	24.6	26.0	32.6	28.4	25.2	28.7	14.0	13.2		13.6
2	7.5	7.4		7.5	10.3	11.3	12.4	11.3	5.6	6.8	8.2	6.9	8.3	8.2		8.3	7.0	7.1		7.1
3	15.0	17.8	16.2	16.3	21.0	22.0	21.4	21.5	10.0	9.4		9.7	13.6	12.4	13.2	13.1	11.8	10.2	11.0	11.0
4	11.6	12.1		11.9	15.2	15.3		15.3	10.9	8.8	10.6	10.1	13.1	12.0	12.5	12.5	10.4	9.6		10.0
5	12.7	12.2		12.5	13.1	13.6		13.4	14.4	12.5	14.2	13.7	12.2	10.2	11.4	11.3	9.0	7.8	7.4	8.1
6	28.4	27.2	28.2	27.9	40.2	45.2	35.0	40.1	25.2	26.1		25.7	30.4	28.4	29.2	29.3	12.4	7.4	12.2	10.7
7	7.6	6.7		7.2	10.6	11.5		11.1	6.9	7.9	8.2	7.7	13.4	13.3		13.4	9.9	10.2		10.1
8	15.4	16.6	16.7	16.2	18.6	17.8		18.2	16.4	15.2	15.2	15.6	16.5	16.6		16.6	11.4	11.2		11.3
9	6.5	5.8		6.2	7.7	7.3		7.5	5.2	5.2		5.2	7.4	7.0		7.2	6.3	5.5		5.9
10	7.1	6.5		6.8	9.4	9.4		9.4	6.9	7.7		7.3	9.6	8.6		9.1	5.6	7.0	6.4	6.3
11	19.8	18.8	18.9	19.2	28.6	31.2	30.0	29.9	20.7	20.2		20.5	15.4	14.8		15.1	11.2	10.2	9.4	10.3
12	4.9	6.0	5.2	5.4	7.8	7.8		7.8	4.3	4.7		4.5	6.9	7.9	7.5	7.4	5.2	5.0		5.1
13	5.6	5.3		5.5	6.9	8.0	7.4	7.4	4.6	5.2		4.9	8.0	7.4		7.7	7.8	7.1		7.5
14	16.9	18.6	20.0	18.5	22.3	21.2	23.2	22.2	11.4	11.0		11.2	10.0	10.5		10.3	11.0	10.8		10.9
15	7.2	7.8		7.5	9.2	9.4		9.3	5.0	5.1		5.1	6.6	7.0		6.8	5.0	5.2		5.1
16	22.0	22.6		22.3	25.2	29.5	22.6	25.8	13.2	12.8		13.0	11.2	10.6		10.9	9.1	7.2	8.8	8.4
17	22.2	19.9	17.5	19.9	28.0	25.3	29.1	27.5	13.5	14.1		13.8	15.2	15.4		15.3	8.5	8.9		8.7
18	6.0	5.7		5.9	7.7	8.3		8.0	3.4	3.6		3.5	6.7	6.3		6.5	5.0	5.2		5.1
19	12.0	10.8	11.7	11.5	13.8	13.4		13.6	12.2	11.4		11.8	14.8	15.5		15.2	10.8	9.8	11.1	10.6
20	6.7	6.7		6.7	8.1	7.6		7.9	5.9	6.6		6.3	9.1	9.8		9.5	6.2	6.7		6.5
21	13.2	13.1		13.2	12.1	11.6		11.9	10.2	11.1		10.7	12.3	12.2		12.3	9.2	7.8	8.2	8.4
22	13.2	13.8		13.5	15.7	16.2		16.0	8.0	6.6	7.2	7.3	14.0	14.4		14.2	9.4	9.5		9.5
23	20.4	19.4	18.6	19.5	13.4	15.2	13.6	14.1	13.6	12.0	14.2	13.3	13.6	15.7	14.4	14.6	9.0	9.8		9.4
24	21.8	24.6	21.6	22.7	24.4	23.4	21.6	23.1	20.2	18.6	21.4	20.1	10.4	10.2		10.3	5.8	5.6		5.7
25	22.6	26.4	25.6	24.9	36.2	33.6	30.6	33.5	21.3	20.7		21.0	19.4	19.6		19.5	8.2	10.2	10.4	9.6
26	27.6	28.2		27.9	42.6	39.8	45.2	42.5	29.0	26.2	28.6	27.9	17.2	14.6	13.2	15.0	8.8	8.6		8.7
27	5.4	5.1		5.3	9.1	10.2	9.8	9.7	6.7	6.6		6.7	9.8	11.0	10.2	10.3	4.9	5.0		5.0
28	18.7	19.6	15.2	17.8	14.6	15.2		14.9	11.3	10.4		10.9	14.6	13.7		14.2	7.8	10.1	9.6	9.2
29	26.2	26.3		26.3	28.2	27.4		27.8	23.4	24.2		23.8	13.6	16.4	20.6	16.9	15.2	11.2	13.0	13.1
30	17.4	17.2		17.3	23.0	22.4		22.7	12.8	12.8		12.8	15.4	17.4	14.2	15.7	9.8	10.4		10.1
31	23.2	20.4	18.6	20.7	30.2	29.6		29.9	16.6	16.6		16.6	27.6	23.8	27.8	26.4	16.0	13.6	16.8	15.5
32	28.2	27.4		27.8	38.1	40.6	45.8	41.5	33.6	30.2	28.6	30.8	17.4	15.4	13.6	15.5	10.8	12.2	9.6	10.9
33	11.2	10.0	9.8	10.3	11.1	11.2		11.2	6.1	6.0		6.1	8.6	8.6		8.6	7.6	6.6	7.2	7.1
34	5.5	5.4		5.5	6.9	7.3		7.1	4.6	4.4		4.5	7.7	8.5		8.1	9.0	8.8		8.9
35	16.0	15.2		15.6	21.5	18.8	22.2	20.8	13.6	13.0		13.3	13.0	13.5		13.3	8.2	8.2		8.2
36	8.2	7.8		8.0	11.2	10.6		10.9	5.8	7.6	6.2	6.5	23.6	20.0	23.4	22.3	10.2	7.3	11.6	9.7
37	10.5	9.4	9.1	9.7	12.8	13.0		12.9	8.9	8.5		8.7	12.0	12.1		12.1	9.8	9.6		9.7
38	5.3	5.4		5.4	7.2	7.3		7.3	4.0	3.8		3.9	5.9	5.8		5.9	5.2	4.7		5.0
39	6.5	5.9		6.2	7.2	7.4		7.3	3.9	4.4		4.2	5.0	5.2		5.1	4.4	4.2		4.3
40	7.1	7.0		7.1	8.2	7.8		8.0	5.0	5.6		5.3	7.1	7.1		7.1	6.1	5.6		5.9
41	19.8	20.1		20.0	33.4	37.0	35.6	35.3	19.6	19.3		19.5	18.6	15.6	17.5	17.2	14.8	14.8		14.8
42	17.6	18.2		17.9	16.2	17.2	17.1	16.8	16.6	16.0		16.3	22.4	20.6	19.4	20.8	14.8	16.0	15.1	15.3
43	8.8	9.7		9.3	10.7	10.8		10.8	6.5	6.6		6.6	7.1	7.4		7.3	5.9	6.0		6.0
44	28.4	26.2	25.6	26.7	43.6	40.8	41.4	41.9	30.2	24.6	24.4	26.4	30.2	31.2	32.4	31.3	13.4	11.2	14.6	13.1
45	24.6	30.4	24.2	26.4	39.4	40.6	41.8	40.6	30.2	26.0	24.0	26.7	12.6	14.0	12.4	13.0	6.0	6.6		6.3
46	19.0	18.9		19.0	25.6	23.5	22.1	23.7	18.8	17.5	17.8	18.0	18.0	19.9	19.6	19.2	13.4	12.6		13.0
47	13.8	12.6	13.8	13.4	12.8	11.8	12.8	12.5	13.4	13.8		13.6	11.2	11.2		11.2	4.6	4.6		4.6
48	22.2	21.2	24.4	22.6	36.2	33.2	32.6	34.0	18.6	18.6		18.6	16.4	15.2	16.5	16.0	10.8	10.0		10.4
49	10.3	10.5		10.4	11.8	12.4		12.1	10.5	10.4		10.5	10.6	9.0	9.8	9.8	8.2	8.3		8.3
50	5.8	5.2		5.5	7.4	7.2		7.3	5.6	5.4		5.5	5.2	5.2		5.2	5.3	5.9		5.6
51	7.6	7.4		7.5	10.8	10.3		10.6	7.5	7.4		7.5	11.2	13.3	12.2	12.2	10.1	10.3		10.2
52	8.4	8.1		8.3	10.1	8.7	8.8	9.2	8.3	7.8		8.1	6.8	7.4		7.1	6.0	6.1		6.1
53	9.5	10.2		9.9	11.9	12.6		12.3	6.7	6.1		6.4	7.6	8.4		8.0	6.6	6.2		6.4
54	24.2	23.2	24.8	24.1	25.8	26.6		26.2	22.0	22.2		22.1	14.8	14.4		14.6	15.8	15.8		15.8
55	12.6	13.8	13.1	13.2	11.1	10.2		10.7	10.3	10.1		10.2	21.6	20.4	17.0	19.7	11.8	11.2		11.5
56	5.8	5.9		5.9	8.4	8.6		8.5	4.9	5.2		5.1	8.4	9.2		8.8	6.6	6.5		6.6
57	7.2	7.0		7.1	9.5	9.8		9.7	8.4	8.4		8.4	12.7	11.9		12.3	7.1	6.4		6.8
58	7.4	6.9		7.2	12.3	12.0		12.2	5.4	6.7	6.5	6.2	8.8	8.2		8.5	6.7	7.0		6.9
59	16.6	17.2		16.9	19.0	20.2	18.8	19.3	13.0	12.8		12.9	16.5	16.8		16.7	12.6	12.9		12.8
60	27.4	23.6	22.6	24.5	42.6	39.2	44.8	42.2	27.4	29.6	30.0	29.0	22.2	20.4	20.2	20.9	8.6	8.2		8.4
61	6.2	6.0		6.1	9.1	9.0		9.1	8.0	6.6	6.0	6.9	9.4	8.1	8.0	8.5	7.7	6.4	6.4	6.8
62	10.8	9.2	9.5	9.8	12.0	12.0		12.0	8.8	8.0		8.4	13.2	13.4		13.3	13.1	11.6	13.5	12.7
63	15.7	15.7		15.7	17.6	17.8		17.7	13.9	24.9	13.7	17.5	14.4	13.2	14.6	14.1	11.6	8.4	9.6	9.9
64	8.8	7.3	6.8	7.6	10.2	10.3		10.3	8.0	7.6		7.8	8.3	8.2		8.3	5.8	5.3		5.6
65	5.8	5.8		5.8	6.9	6.8		6.9	4.6	4.9		4.8	10.1	10.0		10.1	7.3	6.8		7.1
66	10.6	10.6		10.6	14.2	14.0		14.1	9.2	9.4		9.3	10.0	10.0		10.0	6.4	7.6		7.0
67	10.8	11.6		11.2	14.9	14.6		14.8	12.0	11.9		12.0	16.6	16.3		16.5	9.6	10.5		10.1
68	7.6	6.8		7.2	7.9	8.7		8.3	5.8	5.6		5.7	9.2	8.4		8.8	8.8	8.0		8.4

Subject Data for Axial, Subscapular, Thigh, and Calf skin folds

69	7.7	7.7		7.7	11.8	11.9		11.9	5.8	6.0		5.9	16.2	17.0		16.6	11.7	11.5		11.6
70	10.2	9.2		9.7	11.4	11.6		11.5	9.1	9.1		9.1	14.6	14.3		14.5	12.3	11.2	11.3	11.6
71	22.6	26.8	25.2	24.9	29.6	28.2	32.8	30.2	26.2	27.4	25.2	26.3	15.9	16.2		16.1	21.4	14.2	17.5	17.7
72	27.4	32.8	27.2	29.1	35.0	35.4		35.2	28.2	25.2	19.5	24.3	24.6	24.6		24.6	15.2	13.2	11.6	13.3
73	11.3	10.8		11.1	9.4	9.6		9.5	10.1	9.3		9.7	12.5	12.8		12.7	6.1	5.9		6.0
74	9.4	8.6		9.0	11.4	11.8		11.6	9.2	9.5		9.4	13.4	13.3		13.4	10.4	10.5		10.5
75	21.5	19.6	20.4	20.5	19.0	17.2	19.2	18.5	14.2	15.2	14.9	14.8	17.4	18.2		17.8	12.4	12.7		12.6
76	18.1	17.3		17.7	28.2	28.0		28.1	20.6	19.2		19.9	14.5	14.5		14.5	6.8	6.6		6.7
77	25.2	26.0		25.6	26.5	28.2	26.2	27.0	18.2	19.2	20.4	19.3	23.0	25.2	25.2	24.5	14.8	15.8	15.7	15.4
78	14.4	15.1		14.8	13.9	14.2		14.1	10.4	13.8	14.8	13.0	17.8	16.6	16.8	17.1	8.5	5.6	6.6	6.9
79	15.8	15.6		15.7	14.8	14.0		14.4	13.2	12.5		12.9	15.4	15.2		15.3	13.3	14.0		13.7
80	16.4	16.1		16.3	16.0	16.3		16.2	11.8	11.8		11.8	14.6	14.3		14.5	14.0	13.0	13.4	13.5
81	6.3	6.3		6.3	8.8	9.2		9.0	5.5	5.6		5.6	6.8	7.1		7.0	5.4	5.6		5.5
82	8.3	7.8		8.1	10.8	10.5		10.7	7.3	7.4		7.4	14.1	14.5		14.3	10.8	12.4	12.2	11.8
83	8.1	8.8		8.5	9.3	9.8		9.6	6.4	5.6		6.0	15.6	12.9	15.1	14.5	10.4	9.8		10.1
84	9.8	9.5		9.7	13.6	12.4	12.0	12.7	4.6	5.2		4.9	8.4	8.2		8.3	8.8	8.2		8.5
85	10.6	10.3		10.5	15.2	12.6	11.8	13.2	10.0	9.5		9.8	9.2	9.5		9.4	7.2	7.2		7.2
Mean	14.0	13.9	18.5	13.9	17.4	17.4	25.0	17.4	12.3	12.2	16.9	12.2	13.6	13.4	17.0	13.5	9.4	9.0	11.1	9.2
Median	11.6	11.6	18.8	11.5	13.4	13.0	22.6	13.2	10.2	9.5	15.1	10.1	13.2	13.3	15.1	13.3	9.0	8.4	11.1	8.9
Mode	7.6	7.8	18.6	7.2	6.9	7.3	26.2	8.0	4.6	6.6	8.2	9.7	13.6	8.2	25.2	8.3	10.8	11.2	9.6	5.1
Standard Deviation	7.2	7.5	6.6	7.2	10.1	10.1	11.5	10.1	7.5	7.1	7.8	7.1	5.8	5.5	6.4	5.6	3.3	3.0	3.1	3.1
Minimum	4.9	5.1	5.2	5.3	6.9	6.8	7.4	6.9	3.4	3.6	6.0	3.5	5.0	5.2	7.5	5.1	4.4	4.2	6.4	4.3
Maximum	28.4	32.8	28.2	29.1	43.6	45.2	45.8	42.5	33.6	30.2	30.0	30.8	32.6	31.2	32.4	31.3	21.4	16.0	17.5	17.7
Count	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85	85

Subject Data for Sum of Seven Skin Folds, Body Density, % Fat, Endomorphy, Mesomorphy, Ectomorphy, and Cross Sectional Area

Subject #	sumss	bdensity	% Fat	LBMKG	LBMLB	Endo	Meso	Ecto	CSA
1	199.5	1.0	25.3	102.5	225.5	4.1	11.4	0.1	176.4
2	60.0	1.1	7.2	67.5	148.5	1.6	5.7	1.5	100.5
3	117.1	1.1	15.6	94.7	208.4	3.1	9.4	0.1	170.4
4	94.7	1.1	12.6	80.2	176.5	2.5	6.6	1.5	114.6
5	102.9	1.1	13.8	85.8	188.8	2	6.3	0.6	110.4
6	217.5	1.0	27.2	96.7	212.6	5	8.8	0.2	154.6
7	70.0	1.1	9.0	86.5	190.2	1.5	8.1	0.8	145.5
8	133.9	1.1	17.9	87.3	192.1	2.5	9.5	0.1	147.7
9	49.2	1.1	5.5	66.6	146.5	1.4	6.4	1.2	85.6
10	60.1	1.1	7.6	81.1	178.4	1.4	7.8	0.6	130.8
11	154.7	1.1	20.4	77.5	170.4	4.1	7.7	0.4	130.6
12	45.3	1.1	5.0	77.7	171.0	1.4	8.3	0.1	108.9
13	47.0	1.1	5.3	72.4	159.2	1.2	5.5	2.8	96.2
14	108.9	1.1	14.9	94.8	208.6	2.8	8.1	0.1	162.7
15	55.1	1.1	6.9	82.9	182.5	1.2	4.5	2.9	91.7
16	138.5	1.1	18.4	90.9	200.0	3.4	7.1	0.4	135.5
17	147.6	1.1	19.8	85.7	188.6	4	7.4	0.7	119.5
18	44.0	1.1	4.9	69.2	152.2	0.9	7.7	1	109.2
19	105.3	1.1	14.3	102.1	224.7	2.3	7.9	0.3	162.6
20	63.6	1.1	8.0	78.6	173.0	1.4	6.4	0.8	103.7
21	81.3	1.1	10.6	87.4	192.3	1.9	8.2	0.1	134.6
22	98.0	1.1	12.8	88.0	193.5	2.8	7.2	0.4	104.2
23	109.6	1.1	14.5	93.7	206.1	1.9	6.6	0.9	118.0
24	157.3	1.1	20.9	115.4	253.8	2.6	7	0.1	142.6
25	190.8	1.0	24.3	100.8	221.7	4.7	8	0.1	110.7
26	196.7	1.0	24.9	106.5	234.2	4.7	7.3	0.1	148.6
27	61.1	1.1	7.5	77.4	170.2	1.7	6.2	1.1	99.2
28	113.0	1.1	15.8	92.2	202.9	2	9.2	0.1	154.3
29	195.5	1.0	24.7	91.7	201.8	4.7	8.7	0.1	131.8
30	149.3	1.1	19.8	87.8	193.2	3.2	8.2	0.1	111.4
31	177.4	1.0	22.8	92.3	203.0	4.5	10.7	0.1	129.9
32	204.9	1.0	26.0	103.9	228.7	5.1	9.8	0.1	165.0
33	78.2	1.1	10.3	78.3	172.2	2	5.1	2	98.6
34	45.8	1.1	5.3	80.1	176.1	1	5.7	1.8	110.6
35	113.6	1.1	15.4	88.5	194.6	2.9	8.1	0.2	116.7
36	90.7	1.1	11.8	81.0	178.2	2.7	7.8	0.5	96.0
37	79.7	1.1	10.2	82.5	181.4	2.2	7.2	0.9	117.7
38	40.0	1.1	4.2	67.5	148.4	1.1	5.6	1.6	86.5
39	41.0	1.1	4.3	75.7	166.5	1.1	6.3	1.1	106.0
40	50.7	1.1	5.9	71.9	158.2	1.2	4.6	2.7	92.9
41	178.9	1.0	23.4	106.3	233.8	4.5	8.7	0.1	154.0
42	141.7	1.1	18.9	108.4	238.4	2.8	8.7	0.1	164.3
43	61.5	1.1	7.4	82.9	182.4	1.6	6.8	0.4	106.5
44	229.1	1.0	28.1	109.6	241.0	5.9	10.4	0.1	148.7
45	176.7	1.0	23.1	112.9	248.3	4.9	10.7	0.1	176.7
46	154.1	1.1	20.2	86.7	190.8	3.5	7.1	0.9	121.0

Subject Data for Sum of Seven Skin Folds, Body Density, % Fat, Endomorphy, Mesomorphy, Ectomorphy, and Cross Sectional Area

47	96.9	1.1	12.9	87.9	193.3	2.1	7.9	0.6	122.9
48	157.9	1.1	20.7	98.0	215.6	3.9	8.7	0.1	159.5
49	75.0	1.1	10.0	87.6	192.7	1.9	6.7	0.6	110.1
50	40.8	1.1	4.2	79.2	174.3	1	6.7	1.1	110.2
51	69.7	1.1	8.8	86.2	189.7	1.9	9	0.5	124.9
52	66.8	1.1	8.2	81.7	179.8	1.3	7.7	0.8	134.4
53	68.6	1.1	8.8	84.6	186.1	1.6	6	1.6	123.3
54	165.9	1.0	21.9	106.5	234.3	3.7	10.8	0.1	170.3
55	111.1	1.1	15.2	80.2	176.4	2.2	6.6	1.1	112.0
56	54.7	1.1	6.7	79.7	175.4	1.6	5.4	2.2	98.0
57	69.4	1.1	9.0	90.6	199.3	1.5	8.9	0.3	134.1
58	58.2	1.1	7.3	91.5	201.2	1.7	8.6	0.3	141.1
59	147.0	1.1	19.4	80.6	177.2	3.4	7.2	0.3	122.2
60	211.1	1.0	26.3	112.2	246.8	5.7	10.7	0.1	154.3
61	56.9	1.1	7.0	74.4	163.8	1.4	7.1	1.1	107.4
62	91.2	1.1	12.0	69.6	153.1	2.4	5.3	2.4	106.0
63	131.7	1.1	17.6	82.4	181.2	2.9	8.2	0.4	127.6
64	59.3	1.1	7.2	77.2	169.8	1.4	7.6	0.5	127.1
65	51.0	1.1	6.0	79.5	174.8	1.1	7.5	0.8	114.2
66	83.9	1.1	11.1	70.7	155.6	2.3	7.1	1.1	111.5
67	108.9	1.1	14.5	93.3	205.2	2.5	5.9	1.6	103.0
68	62.1	1.1	7.9	69.1	152.0	1.4	5.1	2	96.2
69	74.7	1.1	9.4	81.5	179.3	2	4	3.1	88.7
70	90.0	1.1	11.9	85.6	188.4	2.3	6.5	0.7	118.9
71	166.4	1.0	22.0	105.7	232.5	4.3	2.5	0.1	187.8
72	202.6	1.0	25.5	111.0	244.3	4.4	9.2	0.1	161.8
73	78.4	1.1	10.1	73.1	160.9	1.2	7	0.9	113.7
74	89.3	1.1	11.7	77.4	170.4	2.3	3.8	2.6	96.7
75	145.9	1.1	19.7	84.7	186.3	3	8	0.2	136.1
76	146.3	1.1	19.3	84.0	184.7	3.4	4.9	0.8	99.4
77	168.8	1.0	22.2	91.5	201.4	3.7	9.1	0.1	165.6
78	116.9	1.1	15.5	90.7	199.5	2.6	9.1	0.1	137.0
79	123.1	1.1	16.4	65.4	143.8	2.7	5.7	1.6	89.2
80	117.0	1.1	15.7	78.5	172.8	2.8	8.3	0.1	116.5
81	49.0	1.1	5.8	78.3	172.4	1.3	6.6	1.2	125.3
82	75.8	1.1	9.8	77.0	169.5	2	6.4	1.8	97.4
83	73.4	1.1	9.6	88.7	195.2	1.5	6.6	2	132.2
84	67.6	1.1	8.6	81.0	178.2	2	8	0.7	137.2
85	83.3	1.1	11.2	90.4	198.9	1.7	8.7	0.6	146.0
Mean	107.5	1.1	13.9	86.6	190.4	2.6	7.4	0.8	125.5
Median	94.7	1.1	12.6	85.6	188.4	2.3	7.4	0.6	121.0
Mode	#N/A	#N/A	#N/A	#N/A	#N/A	1.4	6.6	0.1	#N/A
Standard Deviation	51.3	0.0	6.8	11.9	26.2	1.2	1.7	0.8	24.8
Minimum	40.0	1.0	4.2	65.4	143.8	0.9	2.5	0.1	85.6
Maximum	229.1	1.1	28.1	115.4	253.8	5.9	11.4	3.1	187.8
Count	85	85	85	85	85	85	85	85	85

Subject Data for 5-RM, 1-RM, 225 Reps To Failure

47	310	335	20
48	335	385	22
49	245	285	14
50	215	315	13
51	275	315	16
52	335	405	23
53	225	275	7
54	385	455	29
55	205	245	6
56	235	265	10
57	275	315	22
58	300	365	18
59	265	315	17
60	315	335	22
61	225	275	9
62	245	275	12
63	265	315	18
64	310	365	21
65	245	315	16
66	235	250	6
67	175	225	1
68	225	245	7
69	160	185	0
70	265	300	15
71	365	455	28
72	300	315	21
73	235	295	12
74	225	265	6
75	335	375	20
76	245	275	8
77	310	365	20
78	275	315	14
79	185	195	0
80	225	275	5
81	300	360	18
82	205	245	7
83	275	315	16
84	300	365	18
85	300	365	18
Mean	261.8	308.9	14.1
Median	255	300	14
Mode	225	315	12
Standard Deviation	51.2	59.2	8.1
Minimum	160	185	0
Maximum	390	495	38
Count	85	85	85

Subject Data for 5-RM, 1-RM, 225 Reps To Failure

Subject #	5-RM lb	1-RM lb	225 lb
1	315	365	24
2	225	275	10
3	385	405	28
4	225	265	13
5	255	300	12
6	335	385	25
7	295	345	19
8	315	365	22
9	185	255	4
10	255	315	13
11	265	315	17
12	205	345	18
13	185	265	0
14	390	495	38
15	185	245	3
16	255	295	12
17	240	280	9
18	220	275	4
19	335	405	28
20	255	285	11
21	275	315	19
22	185	205	0
23	245	285	12
24	275	320	16
25	245	285	13
26	245	275	10
27	225	245	6
28	295	335	19
29	275	315	16
30	265	275	11
31	225	290	10
32	275	325	17
33	225	275	12
34	235	265	7
35	275	335	15
36	180	220	0
37	245	275	13
38	225	245	3
39	245	300	10
40	170	195	0
41	315	345	15
42	315	365	26
43	245	300	15
44	315	365	30
45	315	405	29
46	245	275	12

Appendix C: Regression Equation Development

The REG Procedure
Model: MODEL1
Dependent Variable: __RM_ 1-RM

Stepwise Selection: Step 0

First Var Entered: R-Square = 0.6939 and C(p) = 287.8338

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	204137	204137	188.19	<.0001
Error	83	90032	1084.72252		
Corrected Total	84	294169			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	59.71880	18.51079	11290	10.41	0.0018
* CSA	1.98610	0.14478	204137	188.19	<.0001

* Forced into the model by the INCLUDE= option

Bounds on condition number: 1, 1

Stepwise Selection: Step 1

Variable F90 Entered: R-Square = 0.8826 and C(p) = 62.4923

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	2	259631	129815	308.21	<.0001
Error	82	34538	421.19674		
Corrected Total	84	294169			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	179.79310	15.57181	56150	133.31	<.0001
* CSA	0.36719	0.16743	2025.92942	4.81	0.0311
F90	5.87596	0.51192	55494	131.75	<.0001

* Forced into the model by the INCLUDE= option

The REG Procedure
Model: MODEL1
Dependent Variable: __RM_ 1-RM

Stepwise Selection: Step 1

Bounds on condition number: 3.4441, 13.776

Stepwise Selection: Step 2

Variable __RM Entered: R-Square = 0.9088 and C(p) = 32.8763

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	267348	89116	269.14	<.0001
Error	81	26821	331.11963		
Corrected Total	84	294169			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	112.31315	19.64678	10821	32.68	<.0001
* CSA	0.04964	0.16237	30.95259	0.09	0.7606
__RM	0.53309	0.11042	7717.44212	23.31	<.0001
F90	3.59295	0.65547	9949.02502	30.05	<.0001

* Forced into the model by the INCLUDE= option

Bounds on condition number: 8.0935, 58.189

Stepwise Selection: Step 3

Variable FAA Entered: R-Square = 0.9255 and C(p) = 14.7993

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	4	272249	68062	248.40	<.0001
Error	80	21920	273.99891		
Corrected Total	84	294169			

The REG Procedure
Model: MODEL1
Dependent Variable: __RM_ 1-RM

Stepwise Selection: Step 3

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	353.26745	59.71133	9590.52889	35.00	<.0001
* CSA	2.02608	0.49012	4682.35210	17.09	<.0001
FAA	-11.52940	2.72614	4900.77783	17.89	<.0001
__RM	0.47202	0.10148	5927.94379	21.63	<.0001
F90	3.73744	0.59724	10730	39.16	<.0001

* Forced into the model by the INCLUDE= option

Bounds on condition number: 45.37, 401.19

Stepwise Selection: Step 4

Variable ArmA Entered: R-Square = 0.9317 and C(p) = 9.2696

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	274087	54817	215.65	<.0001
Error	79	20082	254.20169		
Corrected Total	84	294169			

Variable	Parameter Estimate	Standard Error	Type II SS	F Value	Pr > F
Intercept	390.69668	59.17421	11081	43.59	<.0001
* CSA	1.66746	0.49055	2937.08297	11.55	0.0011

FAA	-8.61112	2.84126	2334.95069	9.19	0.0033
ArmA	-2.70424	1.00569	1837.97879	7.23	0.0087
__RM	0.43676	0.09862	4985.79852	19.61	<.0001
F90	3.67194	0.57577	10339	40.67	<.0001

* Forced into the model by the INCLUDE= option

Bounds on condition number: 48.991, 560.68

All variables left in the model are required or significant at the 0.0500 level.

No other variable met the 0.0500 significance level for entry into the model.

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