

ABSTRACT

XI, J. Prediction of one maximum bench press from push-ups in active young males. MS in Adult Fitness/Cardiac Rehabilitation, 1993, 52pp. (L. Terry)

The purpose of this study was to determine the accuracy of predicting one maximal bench press (1RM) lifting strength from the maximum number of push-ups (PU) in 1 minute for active young males. 42 college males between 18 - 32 years of age volunteered for the study. 1 maximal bench press was done with standard Olympic freeweights. Subjects did as many PU as possible in 1 minute 2 to 3 days after doing 1RM. Push-ups, as a independent variable, was adjusted for weight (Wt) (PU x Wt); height (Ht) (PU x Ht); lean body mass (LBM) (PU x LBM); height and weight (PU x Ht x Wt); average circumference of arms (AC) and average weight of higher and lower position from palms when doing PU (WtA) (PU x AC x WtA); AC and LBM (PU x AC x LBM); AC and LBM and height from ground to shoulder joint when standing (HtGS) (PU x AC x LBM x HtGS), and AC and Wt (PU x AC x Wt). The data were processed with multiple regression analyses. Push-ups in 1 minute were not significantly related to 1RM ($p > .05$). The best prediction equation from independent variables was given by

$$1RM = 3.1043 \times AC + .0003 \times PU \times AC \times WtA - 28.1134.$$

It accounted for 69.8 % variance of prediction with the p-value of $p < .01$ for the goodness of fit of the model. However, the large standard error of estimate of ± 11.99 Kg could not make push-ups an accurate indicator for 1RM in active young males.

**PREDICTION OF ONE REPETITION MAXIMUM
BENCH PRESS FROM PUSH-UPS
IN ACTIVE YOUNG MALES**

**A THESIS PRESENTED
TO
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OF THE REQUIREMENT FOR THE
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**BY
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CHAPTER I

INTRODUCTION

Background

A simple calisthenic and economical submaximal test to predict maximal upper body strength has been the number of push-ups (PU) performed in 1 minute. Many researchers have examined the relationship between PU and upper body strength (Dean, Foster, & Thompson, 1987; Devlin, Soukup, Foster, & Timson, 1989; Hart, Ward, Mayhew, & Ball, 1990; Invergo, Ball, & Looney, 1991; Mayhew, Ball, Bowen, & Arnold, 1990; Mayhew, Ball, & Bowen, 1991; Nelson, Yoon, & Nebon, 1991). Most of this research has tried to find the relationship between PU and one maximum bench press (1RM), which is a commonly used method to estimate upper body strength (Dean et al., 1987) so that maximal upper body strength can be predicted through PU. The highest correlation they found was from a 1RM and an adjusted PU ($PU \times Wt$ and/or $PU \times Ht \times Wt$) among all of the related tests. This correlation ranged from $r = .43$ (Mayhew et al., 1990) to $r = .86$ (Dean et al., 1987). The variables used by the researchers were similar and included age, gender, weight (Wt), height (Ht), lean body mass (LBM), percent body fat (fat %), PU, 1RM, bench press/body weight, adjusted PU for weight ($PU \times Wt$), for height ($PU \times Ht$), for height and weight ($PU \times Ht \times Wt$), for

percent body fat ($PU \times Wt \text{ fat } \%$), and for LBM ($PU \times Wt \text{ LBM}$). The standard errors of estimate (SEE) for equations to predict 1RM ranged from as low as ± 6.3 Kg (Dean et al., 1987) to as high as ± 18.7 Kg (Hart et al., 1990). Due to the effect of either the SEE or the variances of prediction for 1RM, an accurate prediction was not possible. It has been suggested that the variability between 1RM and PU was so great that further study would be needed before PU could be used as an accurate predictor of bench press capacity (Devlin et al., 1989; Hart et al., 1990; Mayhew et al., 1990).

Need for the Study

The previous data show that the researchers (Dean et al., 1987; Devlin et al., 1989; Hart et al., 1990; Invergo et al., 1991; Mayhew et al., 1990; Mayhew et al., 1991) had used limited variables for the correlation and the prediction equation. Dean et al. (1987) were among the first to examine different variables and pointed out that PU might be an alternative to 1RM for assessing upper body strength ($r = .86$; $SEE = \pm 6.3$ Kg). Using similar variables but the more reliable methods to manipulate them, almost all of the latest research (Hart et al., 1990; Invergo et al., 1991; Mayhew et al., 1990; Mayhew et al., 1991) did not get a high correlation ($r < .75$). In addition, the high SEE made PU a poor indicator of 1RM. Thus, Devlin et al. (1989), Hart et al. (1990), and Mayhew et al. (1990)

mentioned that there are a number of variables that should be examined.

Recently, bench press repetitions (BPR) as a percent of 1RM to predict 1RM was tested to have an accurate correlation with 1RM. So, BPR was suggested as an accurate predictor for 1RM (Invergo et al., 1991; Mayhew, Ball, Arnold, & Bowen, 1992a; Mayhew, Ball, & Bowen, 1992b; Rose & Ball, 1992). While BPR seems to be similar to PU in performance, these results implied that a closer correlation between PU and 1RM might exist if the related variables used in BPR test would have been adopted.

This study examined some new different variables to find a possible closer correlation between 1RM and PU in one minute in active young males. This had not been done in previous studies.

Purpose

In the light of the information above, the first purpose of this study was to find the correlation between PU including adjusted PU and 1RM. Secondly, the purpose was to determine the accuracy of assessing 1RM lifting strength from PU in 1 minute in active young males.

Hypothesis

For the purpose of this study, the hypothesis for the study was that there would be a linear relationship between 1RM and the independent variables using a multiple regression model. The independent variables were age;

weight(Wt); weight in high position from palms when doing PU (WtH); weight in lower position from palms when doing PU (WtL); height (Ht); height from palms to shoulder joint when doing PU (HtPS); height from ground to shoulder joint when standing (HtGS); average circumference of arms (AC); lean body mass (LBM); fat percent (Fat %); PU, and adjusted variables. The adjusted PU variables include adjusted PU for Wt ($PU \times Wt$); for Ht ($PU \times Ht$); for Ht and Wt ($PU \times Ht \times Wt$); for LBM ($PU \times LBM$); for AC and Wt ($PU \times AC \times Wt$); for AC and average weight of WtH and WtL ($PU \times AC \times WtA$); for AC, LBM and HtGS ($PU \times AC \times HtGS$), and $PU \times AC \times LBM$.

Assumptions

In the conduct of this study, it was assumed that:

1. No action difference existed among the subjects.
2. Subjects exerted their maximal strength when they performed both 1RM and PU in 1 minute (i.e., no psychological effected existed).
3. There was no learning effect on the maximal weight a subject could lift and the number of PU between tests and among subjects.
4. No muscle soreness affected the number of PU 2 to 3 days after 1RM test.
5. The temperatures in the testing room where both 1RM and PU were tested were the same (i.e., that the temperature did not affect work output between the two tests).
6. All of the measures including 1RM in Kg, PU in numbers, skinfolds, weight, and length would be standardized.

Delimitations

The delimitations to this study were:

1. Subjects were college males.
2. All of the subjects were volunteers.
3. Tests were done only when subjects subjectively felt comfortable.
4. One repetition maximum bench press and the maximal number of PU each subject could perform were based on his own judgement (i.e., not objective evaluation).
5. Measurement of PU would be maximal number of repetitions in 1 minute.
6. The width between two index fingers should be .1 - .2 m wider than individual's shoulder. The same width between two index fingers was required when 1RM and PU were performed for each subject.
7. The intervals between doing PU and 1RM were from 2 to 3 days according to individual condition of recovery from soreness and availability.
8. Subjects who were hurt or sore with muscles around shoulders before and between tests, were not allowed to continue testing.

Limitations

The limitations to this study were:

1. Most of subjects had been doing weight lifting at least twice a week for at least 1 month before the study.

2. There were some psychological differences of the responses to the maximal tests (PU and 1RM) (i.e., encouragement influenced both 1RM and push-up number).
3. Different velocities for doing PU might influence maximal push-up number in 1 minute.

Definition of Terms

Active Lifting Exercisers - In this study, all subjects had been weight lifting at least twice a week for at least 1 month or had previous lifting experience before.

Adjusted PU - To find the best correlation, the maximal number of PU in 1 minute is corrected so that the adjusted PU would reflect relative PU (Dean et al., 1987). The adjusted PU in this study were $PU \times Wt$; $PU \times Ht$; $PU \times LBM$; $PU \times Ht \times Wt$; $PU \times AC \times Wt$; $PU \times AC \times WtA$; $PU \times AC \times LBM$, and $PU \times AC \times LBM \times HtGS$.

Bench Press Repetitions (BPR) - Subject lies on the back on the bench. A weight, which is either the relative weight of 1RM (percent of 1RM) or absolute weight is lowered and pressed vertically and repeatedly. One up and down cycle is counted as 1 BPR (Mayhew et al., 1992a). The two kinds of common BPR are 10 BPR without time limit and BPR in 1 minute.

Monitored Rack - The self-made rack was used to test PU performance. It attaches a pole which could be adjusted for height. A towel was hung on it. Before PU test, the height from the ground to towel edge was adjusted so that the towel

could touch the individual's back with the arms fully extended. When doing PU, the subject would touch it for every repetition.

One Repetition Maximum Bench Press (1RM) - Subject lies on the back on the bench with feet flat on the floor and grasp the bar with the distance between two indexes .01 - .02 m wider than his shoulder. The maximal weight following several calibrations is lowered to chest and pressed to full arm extension. The maximal weight in Kg one can lift is counted as 1RM (Mayhew et al., 1991).

Push-ups in One Minute (PU) - Subject keeps hands forward and the same distance between two index fingers as he does for the 1RM test. Body should be kept straight from feet to shoulders. The higher position for PU should be where arms are fully extended. The lower position should be where the subject's chest can touch the fist of the tester which is put on the floor. One down and up are counted as 1 PU. Subject does as many PU as possible in 1 minute (Mayhew et al., 1991).

Standard Error of Estimate (SEE) - In a multiple regression model with K-independent variables,

$$\hat{Y}_i = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \dots + \beta_k X_k + E.$$

Mean squared error (MSE) is equal to the sum of squares of the residuals divided by $n - k - 1$. The residual is equal to $Y_i - \hat{Y}_i$. SEE = the square root of MSE, $E = SEE$,

β = coefficient, n = sample size, k = number of independent variables, Y_i = desired value, and \hat{Y}_i = estimated value from a equation.

Weight from Palms - In this study, subject assumes PU performance with palms on a wood board which was put on the scale. Palms and toes were set up in the same height by placing a cushion under toes which was as high as the height of scale plate plus the thickness of the board. The net weight subtracting the weight of the wood board was the weight from palms for the person.

Significance of the Study

The most commonly used measure of upper body strength, one repetition maximum bench press, has some limitations when compared to PU. A 1RM can be very time consuming especially if a starting point has not been determined as is the case with untrained subjects. It can take 5-8 trials to adjust to the weight one can maximally lift. The high cost of free weights or machines can make this form of testing prohibitive. Potential injury situations must also be considered because maximal weight is loaded on the muscles. A spotter is also needed to prevent against injury. There is also a learning effect associated with the number of trials (Hakkinen & Komi, 1986; Moritani & DeVries, 1979).

Even BPR of percent of 1RM, which has been considered as an alternative to 1RM for predicting upper body strength (Invergo et al., 1991; Mayhew et al., 1992a, 1992b), still bears some of the disadvantages of 1RM mentioned above.

Push-ups, as a "low tech" test of upper body strength holds the advantages of little amount of time consumed, no-needed equipment, little technique needed, fewer potential injuries, and no spotter needed. If an accurate correlation between 1RM and PU could be found, the benefit would be evident for a number of different testing situations.

CHAPTER II

REVIEW OF RELATED LITERATURE

Introduction

Muscular strength is the maximal force (expressed in Newton or Kg) that can be generated by a specific muscle or muscle group (Pate et al., 1991). Muscular endurance refers to the ability of a muscle group to execute repeated contractions (i.e., perform work) over a period of sufficient time duration to cause muscular fatigue (Pate et al., 1991). In this study, one maximum bench press in Kg, as a measure of upper body strength, is more related to strength. The number of PU repetitions one can maximally do in 1 minute is predominantly an endurance measurement of upper body strength. With this in mind, the research dealing with strength and endurance as well as related literature were reviewed.

Related Physiology of 1RM and PU

Muscle strength and endurance performance are a result of the fibril structures. Muscle fibers are divided into two types, type I or slow twitch muscle fibers (ST), and type II or fast twitch muscular fibers (FT). Type I fibers are specific to long-term usage at relatively low velocity. Type II fibers, on the other hand, are specialized for burst work in which large power output and high velocity are

view of physiology, the differences between two fiber types are consistent with fundamental differences dealing with infrastructure, as well as metabolic and neurological properties (Pette & Heilman, 1979). The sarcoplasmic reticulum (ATPase activity, calcium uptake characteristics, phosphoprotein formation, and peptide pattern), the contractile proteins (isozyme of myosin and troponin) myosin ATPase activity, and the enzymes of energy metabolism (aerobic and anaerobic) all appear to undergo coordinated expression. In the case of the FT, calcium uptake by the sarcoplasmic reticulum, actomyosin cycling rate, ATP hydrolysis, and anaerobic regeneration of ATP (high energy phosphagen, anaerobic glycolysis) are all uniformly high. Burst work muscles possess the higher ability to form lactate at high rates. In contrast, slow twitch fibers depend on aerobic oxidation of both fats and carbohydrate to produce a high degree of efficiency in energy production. Actomyosin cycling rate, ATPase activity, and calcium uptake by sarcoplasmic reticulum act correspondingly lower than in the FT (Jones, McCartney, & McComas, 1986). Contraction time in ST and FT is, respectively, 90 - 110 msec and 40 - 84 msec for motor units (Garnett, O'Donovan, Stephens, & Taylor, 1978). When muscle contracts at different speeds and strengths, the metabolic pathway in proportion is different. Wilmore (1973) pointed out that 60% energy of ultra short-term maximal power, which is accomplished in 1

minute or less, is derived from aerobic processes, while short-term maximal power accomplished in 5 to 6 minutes accounts for 20% of anaerobic metabolic pathway and 80% of terminal oxidation. However, no difference exists between the two types of fibers in the peak ability to generate isometric force (Faulkner, Jones, Round, & Edwards, 1981; Gregor, Edgerton, Perrine, Campion, & Debus, 1979;). Because of the difference of shortening velocity, the peak power output of FT is fourfold that of ST fibers. Most human muscles are composed of a mixture of approximately 50% FT and 50% ST (Jones et al., 1986). The greatest work appears at the one third of maximal velocity of shortening both in FT and ST. Fast twitch fibers are most suitable for stronger strength and high velocity work (i.e., higher work like 1RM). In contrast, slow twitch fibers are more economical than fast twitch fibers in generating a sustained force at comparatively lower velocity, making them more suitable for the maintenance of posture. In this study, push-ups in 1 minute is predominantly related to type I fiber activity, while 1RM is related to type II activity.

Type I fiber is predominant in metabolism of aerobic and type II in anaerobic. The efficiency of work done anaerobically has been reported to be only about half that of work done aerobically (Christensen & Hogberg, 1950). But, Gladden and Welch (1978) later pointed out that anaerobic metabolism is not less efficient than aerobic metabolism.

The performance of PU and 1RM involves many groups of muscles. The relationships between PU and 1RM involve many parameters such as, velocities, time, strength, endurance, work, power, different fibers, neurological division, and metabolism. Their exact relationships in physiology are not clear at this time.

Related Literature Review

The correlation between 1RM and PU and their predictive equation have been studied (Dean et al., 1987; Hart et al., 1990; Invergo et al., 1991; Mayhew et al., 1990; Mayhew et al., 1991). Recent studies (Hart et al., 1990; Invergo et al., 1991; Mayhew et al., 1990; Mayhew et al. 1991) have exposed that a higher SEE did not make PU an accurate predictor for 1RM.

Dean et al. (1987) were among the first to do a prediction test. Seventy-three males and females were tested to formulate an equation. Maximal PU from toes was examined without time limit and at no cadence. Among the variables of 1RM (Universal Gym), PU, PU x Wt, PU x Ht, PU x LBM, and PU x Ht x Wt, the highest correlation with 1RM was acquired in PU x Wt and PU x Ht x Wt (both $r = .86$). Cross-validation from 9 subjects got a high correlation ($r = .95$) with SEE of ± 6.3 Kg. Thus, push-ups were strongly recommended as a good indicator of upper body strength for 1RM.

The later research (Hart et al., 1990; Invergo et al., 1991; Mayhew et al. 1990; Mayhew et al. 1991) showed us more reliable testing procedures in detail. Comparatively high correlations were obtained from the adjusted PU with 1RM (from $r = .71$ to $r = .75$). However, Hart et al. (1990), Invergo et al. (1991), and Mayhew et al. (1990; 1991) did not agree that PU including adjusted PU could be used as an accurate predictor of 1RM because of the large SEE.

Invergo et al. (1991) selected 144 college male subjects. Maximal PU in 1 minute was the measure. The best correlation obtained was $r = .75$ with $SEE = \pm 10.63$ Kg from adjusted PU, (PU x Wt). Because of the high SEE, push-ups could not be used as a good indicator of 1RM.

Hart et al. (1990) had similar results to Invergo et al. (1990) from 84 college males. Hart et al. (1990) at the same time pointed out that there is no significant difference in correlation using either free weight or Universal Gym to do 1RM. Eighty-four subjects were divided into two groups and trained respectively with free weight bench press and with Universal Gym bench press. Then, correlations both between PU and 1RM by free weight and between PU and 1RM by Universal Gym were tested and contrasted. No significant differences were found. The highest correlations were from PU x Wt ($r = .73$ by free weight and $r = .71$ by Universal Gym) and PU x Ht x Wt ($r = .75$ by free weight and $r = .71$ by Universal Gym). Standard

error of estimate was still as high as from ± 14 Kg to ± 18.7 Kg.

Other research (Mayhew et al., 1991) repeated the high correlation of $r = .71$ (both $PU \times Wt$ and $PU \times Ht \times Wt/100$) with the same variables. Standard error of estimate was also ± 14 Kg for the prediction. All of the 106 male subjects were trained for 14 weeks before being tested. The cross-validation result was $r = .70$ and $SEE = \pm 15.7$ Kg.

Mayhew et al. (1990) tried modified PU, PU from knees, to predict 1RM for young females ($n = 175$). The best correlation among the variables was still from $PU \times Wt$ and $PU \times Ht \times Wt/100$. However, both the r values (both $r = .43$) were lower than those obtained from PU from toes. Mayhew implied that gender and PU position might be the variables which influenced the correlation. A good attempt to use multiple regression decreased SEE to ± 5.2 Kg. But, only 31.4% variance of prediction was accounted for so that 1RM also could not be accurately predicted by this multiple regression model.

It is not known whether the correlation between 1RM and PU is not inherently high (i.e. that the variables between the two factors have not been treated completely, or that the correlation is so low that it can not be used as an accurate indicator of 1RM). Use of another variable to predict 1RM from PU has not been found in the literature review. DeVries (1986) reported that many researchers have

found the relationships between strength and absolute endurance to be high from $r = .75$ to $r = .97$. Hart et al. (1990); Invergo et al. (1991), and Mayhew et al. (1991) pointed out that there is too much variability in PU performance to make it an accurate indicator of bench press performance.

Bench press repetition is very similar to PU in performance except for the direction of force used and the muscle groups involved. The closer relationships between BPR and 1RM ($r > .90$) made BPR a more accurate predictor for 1RM (Invergo et al. 1991; Mayhew et al. 1992a, 1992b; Wallace, Wallace, Mayhew, & Jennings, 1993).

The relationship of absolute muscular endurance by BPR to 1RM was found to be as high as $r = .93$ ($SEE = \pm 6.03$ Kg) by Invergo et al. (1991). Each subject ($n = 144$ in males) did as many BPR using 80 pounds as possible in 1 minute at a metronome rate of 60 beats/min with an up or down in 1 beat and 1RM. It was concluded that body weight does not affect the prediction of 1RM from absolute endurance ($r = .93$) through BPR. While the absolute weight lifted for doing BPR is related to the prediction of the correlation.

A high relationship between relative muscular endurance and 1RM in college men and women was obtained ($r = .98$, $SEE = \pm 4.8$ Kg) by Mayhew et al. (1992a). Fifty-five to ninety-five percent of 1RM was utilized to test 184 subjects who performed as many BPR as possible in 1 minute. The results

showed that use of relative muscular endurance both in young males and young females can be used as an accurate indicator of 1RM.

In another study, Mayhew et al. (1992b) not only demonstrated a reliable predictor for 1RM from BPR but also supplied evidence that training status (trained and untrained subjects) makes no difference to predict 1RM from bench press repetitions.

The prediction for 1RM is based on the amount of weight lifted and the number of BPR. It coincides with a recent opinion (Wallace et al., 1993) about the relationships among PU, 1RM, and BPR. Gender, trained status, and endurance (absolute or relative) do not cause significant differences of 1RM prediction from bench press repetition. If we can assume PU and BPR are very close in performance, the tests above will be very helpful to find out possible variables for PU in order to predict 1RM.

Summary

One repetition maximum bench press and PU in 1 minute are, respectively, more pertinent to the measure of strength and endurance of the upper body. Type II or FT is more desirable for maximal strength at high velocity, or high power, like 1RM. Type I or ST is predominant in endurance exercises, like PU. When muscles are working at certain level (speed, force, and time), they will involve corresponding fibers (type I or II) and metabolism as well

as neurological divisions at different percentages. In physiology, there are a number of variables that can be examined to determine the relationships between 1RM and PU. How PU relates to 1RM is not clear at this time. The previous studies showed that the correlations between 1RM and PU (including adjusted PU) were from $r = .26$ to $r = .86$. Most research has found that PU could not be used as an accurate indicator of 1RM because of the higher SEE. Many more variables between PU and 1RM remain to be manipulated for a closer correlation. Bench press repetition in performance is assumed to be close to PU. That BPR in 1 minute can be an accurate predictor of 1RM implies that parameters used in BPR tests would be a good reference for determining the correct variables to predict 1RM from PU.

CHAPTER III

METHODS

Introduction

The purpose of this study was to test the effectiveness of PU as an indicator to predict 1RM by testing 1RM and PU in 1 minute separately, obtaining a correlation between them and developing a prediction equation. This chapter describes the methods used in (a) subjects, (b) instruments, (c) order of procedures, (d) testing procedures, and (e) statistical analyses.

Subjects

Subjects for this study were 46 college males, 18 to 32 years old. They were active lifting exercisers (see definition of terms) and volunteered to join the study. All subjects who participated in the study were free of injury and were relatively fresh regarding fatigue prior to testing. The consent form including the purpose, the procedures, and the effects of the test was signed before testing each subject. All subjects finished the two tests. No one was injured during or by the tests. Data for four subjects were not used because 1 minute did not allow enough time to do maximal PU. Data for 42 subjects were put into the computer to be analyzed.

Instruments

The following is a list of the instruments used to collect or analyze data in the study.

1. Free weight: The standard Olympic bar and plates were used to test 1RM maximally. After the test, bar and plates were weighed to make sure the specific weight a subject lifted was accurate (round to .01 Kg).
2. Skinfold caliper: Used for doing the anthropometry in assessing lean body mass (round to .01 mm).
3. Counter: Used for counting reps of PU in 1 minute to assure the number counted was correct.
4. Monitored rack: A self-made monitored rack was used for monitoring correct PU in performance.
5. Weight scale: Used for weighing body weight and weight from palms (round to .01 Kg). It was calibrated with two other scales before testing began.
6. Ruler: Used for measuring height from the ground to shoulder joint with arms fully extended and the distance between index fingers (round to .1 cm).
7. Stepwise with SAS system: Used to analyze the data.

Order of Procedures

A history of muscle injury or soreness was obtained before the test was administered. Each subject determined a time to perform the test (see appendix A) for 1RM. The consent form (see appendix B) was signed by both the subject and tester and all of the measuring of weight, height,

circumferences, and the skinfolds were completed before the 1RM test. After the 1RM test, the subject determined a time on the schedule (see appendix C) for PU testing within 2 to 3 days of 1RM testing (Mayhew et al., 1991). Before the PU test, the subject was asked whether there was any muscle soreness which could affect maximal PU test. If not, the maximum PU was performed.

Testing Procedures

Pretest

Every volunteer was required to sign the consent form and answered the required questions before the tests. Tests were started with measuring the weight (standing weight and weight from palms when doing PU), the height (body height, height from ground to shoulder joint, and height from palm to shoulder when doing PU), circumferences (average circumference at the middle point of upper arms), and skinfolds (triplicate at the chest, suprailiac at abdominal, and thigh site (Lohman, Roche, & Martorell, 1988)). The data were recorded on the test data sheet (see appendix D). The reliability for the skinfolds measurement is $r > .94$ (Mayhew & Clark, 1986). All the instruments used were calibrated before the tests. The equation from Jackson and Pollock (1978) was used to assess body density. Percent fat and LBM converted from density was calculated using Siri's (1961) equation.

Warm-up

Subjects did submaximal bench press or PU as a warm-up for 3 - 5 minutes before 1RM or PU.

One Repetition Maximum Bench Press

Most of the subjects knew their 1RM. For some who did not know their 1RM, a chart (see appendix E) designed by Fleck and Kraemer (1987) for estimating 1RM was used. One point one kg or 2.3 kg was added after each successful trial until the subject could not lift the weight any more. The interval between the trials was 2 to 3 minutes. The maximal weight the subject could lift was weighed and recorded as 1RM in pounds and converted to Kg. Each subject took 3 to 7 attempts to reach the maximal capacity. Invergo et al. (1991) noted that reliability for 5 to 8 trials was $r = .99$. This procedure also served as the warm-up.

Push-ups in One Minute

After warm-up, the height from the ground to towel edge was adjusted through the monitored rack so that the towel edge could touch the subject's back with arms fully extended. A stop watch was put on the ground so that both the subject and tester could time PU. The width between index fingers was the same as for 1RM. Following "start", the tester pressed the button of the stopwatch. At the same time, the tester monitored the PU in performance and counted the numbers of PU with the counter. A down and up was counted as 1 PU.

Statistical Analyses

One repetition maximum bench press and PU data from 42 subjects were analyzed by computer by means of stepwise multiple regression with SAS (Statistical Analysis System) to find the predictive relationships between the dependent variable, 1RM, and the independent variables. The independent variables are listed in Tables 2 and 3. Correlation coefficients between variables were first obtained. Then, stepwise procedure found significant variables in order of importance of the variable.

CHAPTER IV

RESULT AND DISCUSSION

Introduction

This study was conducted to determine the feasibility of predicting 1RM from PU in 1 minute in college males. Subjects did 1RM and PU with an interval of 2 to 3 days. One maximal bench press in Kg was measured with standard Olympic freeweights. Push-ups in 1 minute were measured with stop watch, counter, and monitored rack. Forty-six subjects joined this study. The data from 4 subjects were not included because 1 minute was not enough time for them to do PU maximally. Forty-two subjects' data were collected and analyzed to determine whether or not there was a significant correlation between 1RM and PU. Adjusted PU and 1RM was also examined to determine if an accurate prediction could be found through the multiple regression. The statistical results showed that PU itself did not have a significant correlation with 1RM with $r = .24$ ($p > .05$). One maximum bench press could be predicted by multiple regression variables with the standard error of estimate of ± 11.99 Kg ($p < .01$).

Subject Characteristics

The physical characteristics of the 42 subjects who completed the study are presented in Table 1. Their

in high position from palms when doing PU (WtH), Wt in lower position from palms when doing PU (WtL), Ht (Ht), Ht from palms to shoulder joint when doing PU (HtPS), Ht from ground to shoulder joint when standing (HtGS), average circumference of arms (AC), lean body mass (LBM), fat percent (Fat %), PU, and 1RM.

Table 1. Physical characteristics of the subjects (N = 42)

Variable	Mean	SD	Minimum	Maximum
Age (yrs)	22.0	2.7	18	32
Wt (Kg)	77.9	10.5	57.7	104.3
WtH (Kg)	52.5	7.6	39.8	69.8
WtL (Kg)	57.0	8.7	41.9	78.3
WtA (Kg)	54.8	8.1	40.9	74.1
Ht (cm)	178.3	6.9	163.1	191.6
HtGS (cm)	145.2	6.3	131.2	160.4
HtPS (cm)	58.6	2.6	53.5	66.0
AC (cm)	32.5	3.2	40.9	74.1
LBM (Kg)	70.6	8.9	52.5	94.9
Fat (%)	10.2	3.3	5.3	17.3
PU (reps/min)	55.3	12.7	31	77
1RM (Kg)	104.5	21.3	57.5	144.5

Results of the Study

It took 3 weeks to collect data including both 1RM and push-ups in 1 minute. There were 46 college males who finished the testing. The data of 4 subjects did not meet the requirement because 1 minute was not long enough to maximize their PU in 1 minute. Data were recorded for 42

Table 2. Correlation coefficients between the single variables

Variable	Correlation coefficients*											
	2	3	4	5	6	7	8	9	10	11	12	13
Age	-.02	-.07	-.03	.01	.06	.34	.13	.02	-.13	.09	-.13	.03
Wt		.95	.96	.97	.47	.32	.48	.75	.81	.57	-.29	.63
WtH			.97	.99	.45	.25	.47	.75	.75	.51	-.01	.66
WtL				.99	.44	.29	.45	.81	.76	.58	-.21	.68
WtA					.44	.27	.46	.79	.76	.55	-.21	.67
Ht						.57	.80	.11	.44	.14	-.39	.02
HtGS							.67	.11	.42	.11	-.41	-.01
HtPS								.07	.23	.11	-.39	-.10
AC									.66	.43	.01	.78
LBM										.24	-.09	.63
Fat %											-.35	.18
PU												.24
1RM												

* | r | > .42 is significant at p < .01

subjects. The correlation coefficients among the variables were computed with multiple regression of SAS. The variables were composed of single and adjusted variables. The single variables and their correlation coefficients with 1RM are presented in Table 2. The adjusted variables and their correlation coefficients with 1RM are presented in Table 3.

Table 3. Correlation coefficients between adjusted PU and 1RM

Variable	Correlation coefficients*							
	2	3	4	5	6	7	8	9
PU x Wt	.86	.98	.93	.95	.94	.92	.93	.63
PU x Ht		.83	.87	.68	.67	.71	.74	.26
PU x Ht x Wt			.91	.94	.93	.92	.92	.63
PU x LBM				.85	.83	.93	.95	.54
PU x AC x Wt					.99	.95	.95	.76
PU x AC x WtA						.93	.93	.77
PU x AC x LBM x HtGS							.99	.71
PU x AC x LBM								.71
1RM								

* $|r| > .42$ is significant at $p < .01$

It was found that the correlation coefficient between PU and 1RM was not significant ($p = .12$). This result revealed that 1RM could not be predicted by PU itself in active

males. Among all the variables, average circumference of arms had the best coefficient with 1RM ($r = .78$; $p < .01$). As a result, 1RM was most positively correlated to the average circumference of arms among all the variables (see Tables 2 and 3). The prediction equation obtained was

$$1RM \text{ (Kg)} = 5.2343 \times AC - 55.6108.$$

With the help of the stepwise program, the best correlation between 1RM and multiple regression model and the best prediction equation was obtained. The equation was

$$1RM = 3.1043 \times AC + .0003 \times PU \times AC \times WtA - 28.1134.$$

This multiple regression model explained 69.8% of the variance in 1RM ($p < .01$). Reliably, 1RM could be predicted by using the equation. However, the high SEE makes the predictive value range so wide that the significance of prediction of 1RM will be lost.

Discussion of Results

This study was undertaken to determine the correlation between 1RM and PU in college males and evaluate whether PU could be used as an accurate indicator for 1RM. The statistical analyses showed that within the active exercisers, PU was not significantly related to 1RM ($p = .12$). The best single predictor among the variables (see Tables 2 and 3) was average circumference of arms ($r = .78$; $SEE = \pm 13.59 \text{ Kg}$). The multiple regression model improved

the correlation coefficient of determination to $r^2 = 69.8$ with a SEE of ± 11.99 Kg.

Dean et al. (1987) earlier pointed out that PU could be used as a good indicator for 1RM in males and females. The correlations with 1RM they found were $r = .50$ for PU and $r = .86$ for adjusted PU (either $PU \times Wt$ or $PU \times Ht \times Wt$) with standard error of estimate of ± 6.3 Kg. There were some differences between Dean et al. research and this study. Dean et al. used both males and females as subjects in their study, which could increase the correlation compared to using either males or females (Devlin et al., 1989). Devlin et al. compared the relationships between PU and 1RM separately for male subjects, female subjects, and combined. The correlation coefficient of $PU \times Ht \times Wt$ for both males and females was increased by 13% for males and by 150% for females. The females in the Dean et al. study were those who could do a minimum of 10 PU. They could not represent young females who often can not do more than 10 PU. Using the Universal Gym machine, 1RM was not influenced by technical balance when compared to using Olympic weights when subjects were lifting. In addition, the Universal Gym machine, which was used in the Dean et al. (1987) investigation overestimates the actual weights by 12.7% (Hart et al., 1990). These affected the correlation between PU and 1RM.

Without considering the new variables created in this study, the correlation coefficient of $PU \times Ht \times Wt$ was still the highest ($r = .63$) among the variables previous researches have used. This point agreed with the previous studies and illustrated that 1RM is highly correlated with PU, weight, and height.

Many studies involving college males (Hart et al., 1990; Invergo et al., 1991; Mayhew et al., 1991), college females (Mayhew et al., 1990), high school males and females (Devlin et al., 1989) and high school males (Wallace et al., 1993) illustrate that PU including adjusted PU could not be used as an accurate predictor for 1RM because of the high SEE from ± 10.6 to 18.7 Kg. This study also found that 1RM could not be accurately predicted by adjusted PU because of the high SEE (± 11.99 Kg). The difference was that this study added new variables that previous studies had not included and lead to new findings. A comparison of previous studies with college students citing the highest correlation coefficients between 1RM and variables is presented in Table 4.

The previous study in males found the higher correlation coefficients ($r = .71$, $r = .75$) between adjusted PU, ($PU \times Wt$ and/or $PU \times Ht \times Wt$), and 1RM than variables in this study (both $r = .63$). The reason for this is that the subjects in this study were almost all active lifting exercisers who had stronger muscles. They had to speed up to finish maximal PU in 1 minute, which would cost more

Table 4. Comparison of studies in relationship between PU and 1RM

Research/variable	Subjects	Sex	1RM r	SEE#
Dean et al. (1987)	N = 82	M/F		
PU			.51	-##
PU x Wt			.86	6.30
PU x Ht x Wt			.86	-
Hart et al. (1990)	N1 = 84*	M		
PU			.44	-
PU x Ht x Wt			.75	14.30
	N2 = 65**			
PU			.45	-
PU x Wt			.71	14.10
PU x Wt x LBM			.71	14.00
Invergo et al. (1991)	N = 144	M		
PU			.56	13.33
PU x Wt			.72	10.63
Mayhew et al. (1991)	N = 106	M		
PU			.47	-
PU x Wt			.71	14.00
PU x Ht x Wt			.71	14.00
Mayhew et al. (1990)	N = 175	F		
PU			.27	-
PU x Wt			.43	5.60
PU x Ht x Wt			.43	-
Multiple regression			.56	5.20
This study (1993)	N = 42	M		
PU			.24 ^a	-
PU x Wt			.63	-
PU x Ht x Wt			.63	-
AC			.78	13.59
Multiple regression			.84	11.99

SEE in Kg
 ## Not supplied
 * Using Olympic freeweights
 ** Using Universal Gym machine
^a P > .05

power and, in turn, decrease PU reps. The mean of PU in 1 minute in this study was 55.3 with ± 12.7 standard deviation (SD). While the means were only 45.8 with SD of ± 13.1 in the Hart et al. study (1990); 37.6 with SD of ± 12.8 in the Mayhew et al. study (1991), and 34.7 with SD of ± 11.7 in the Invergo et al study (1991). Beelen and Sargeant (1991) in their study of the effect of velocities on maximal power output found that a greater effect on power output of muscles will exist at higher than at lower contraction velocities when a high-intensity voluntary dynamic exercise induces fatigue. This implies that using more power or at higher velocities, the active exercisers could have achieved the same PU reps as less active exercisers did by using less power, or that some of the power output was consumed by speeding up for PU to finish in 1 minute. This factor could affect the correlation.

The highest correlation coefficient from average circumference of arms was intended to say that 1RM was reliant on the size of arms to a great extent, mainly, biceps and triceps. It was positively related to strength or 1RM. In the best multiple regression equation, the adjusted PU (i.e., $PU \times AC \times WtA$, was picked up as one of the predictors. Average weight of higher and lower position from palms when doing PU was one of the variables. The possible explanation was that WtA is related to PU in reps. A person who has comparatively lower WtA should do more PU

than one who has higher WtA if all the other conditions are the same. If a person has the same WtA but different AC, one who has thicker AC should do more PU. Therefore, 1RM could be more accurately correlated with $PU \times AC \times WtA$ in the predictive relationship.

Hart et al. (1990) and Mayhew et al. (1990; 1991) noted that a predominantly different metabolism may influence the correlation between PU and 1RM. Push-ups take up 1 minute in the study and mainly depend on lactic acid metabolism. One maximum bench press takes up only 2 to 5 seconds and predominantly relies on adenosine triphosphate-phosphocreatine metabolism. However, this point conflicts with the notion that submaximal bench press in 1 minute could be accurately used to predict 1RM (Invergo et al., 1991; Mayhew et al., 1992a, 1992b; Rose & Ball, 1992; Wallace et al., 1993). They found that either BPR in 1 minute of relative weight of 1RM (55-95% of 1RM) or absolute weight was highly related to 1RM. As a result, one maximum bench press could be accurately predicted with a high correlation and low SEE from ± 2.9 Kg to ± 6.6 Kg. These results implied that two kinds of metabolism involved 1RM and maximum bench press repetition which has the same duration as PU does should not have significantly affected the correlation between PU and 1RM.

Patton, Kraemer, Knuttgen, and Harman (1990) pointed out maximal power is more dependent on these factors relevant to

body size than muscle fiber characteristics. The study revealed that Fiber type (type I or II) might not affect the relationship between PU and 1RM.

Actually, push-ups are very similar to RBP. The difference is that body position and muscle groups involved are not the same. The direction of force pushed for PU is a little different from that for RBP. Doing PU involve not only the muscles groups around shoulders but also trunk muscle groups. Does this influence their correlation between PU and 1RM or are there other factors that affect it (Devlin et al., 1989; Hart et al., 1990; Mayhew et al., 1990)? In this study, new variables AC and WtA were found to be highly related to 1RM ($r = .78$; $r = .67$), which would provide a new clue to make the relationship clear.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The primary purpose of the study was to find the relationship between PU and 1RM compared to previous study, and determine the feasibility of prediction of 1RM from PU. One maximum bench press and PU in 1 minute were done in order within an interval of 2 to 3 days. Each subject was instructed to do 1RM and PU in the same way before the tests and were measured with anthropometry. Standard Olympic freeweights were used for 1RM test. A stop watch, a monitored rack, and a counter were used to check for PU performance. Push-ups were adjusted for weight ($PU \times Wt$); height ($PU \times Ht$); weight and height ($PU \times Ht \times Wt$); lean body mass ($PU \times LBM$); Average circumference of arms and weight ($PU \times AC \times Wt$); AC and average weight of higher and lower position from palms when doing PU ($PU \times AC \times WtA$); AC, LBM, and height from ground to shoulder joint when standing ($PU \times AC \times LBM \times HtGS$), and AC and LBM ($PU \times AC \times LBM$). It took 3 weeks to collect the data. Forty six college males volunteered to join the study. Data of 42 subjects met the requirement and were recorded for the statistical analyses. Push-ups did not have a significant relationship with 1RM ($p > .05$). All of the adjusted PU had significant correlations

with 1RM ($p < .01$) except for PU x Ht. Among all of the variables (see Tables 2 and 3), average circumference of arms was most positively correlated to 1RM ($r = .78$). A multiple regression equation was achieved through stepwise procedure. The equation was

$$1RM \text{ (Kg)} = 3.1043 \times AC \text{ (cm)} + .0003 \times PU \text{ (reps/min)} \times AC \text{ (cm)} \times WtA \text{ (Kg)} - 28.1134 \text{ (} p < .01 \text{)}.$$

Conclusions

Based on the statistical analyses of the data the following conclusion were reached:

1. Push-ups in 1 minute can not be used as an indicator to predict 1RM in active young males ($p < .05$).
2. All of the adjusted PU except PU x Ht ($p = .12$) are significantly related to 1RM ($p < .01$) in active young males. The adjusted PU are PU x Wt; PU x Ht x Wt; PU x LBM; PU x AC x Wt; PU x WtA; PU x AC x LBM x HtGS, and PU x AC x LBM.
3. One maximum bench press can be predicted by using multiple regression model in active young males. The best multiple regression equation ($p < .01$, SEE = 11.99 Kg) is

$$1RM \text{ (Kg)} = 3.1043 \times AC \text{ (cm)} + .0003 \times PU \text{ (reps/min)} \times AC \text{ (cm)} \times WtA \text{ (Kg)} - 28.1134.$$

This equation can not be used as an accurate prediction.

Recommendations

Based upon the results of this investigation, the following recommendations for future study were made:

1. A similar investigation should be performed using the same subjects but PU time is extended to failure or exhaustion.

Notice: Standard PU performance should be checked with the help of monitored rack.

2. A similar study should be conducted with subjects who are less active.
3. A similar study should be done with some new variables which could be related to 1RM, based on this study.

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APPENDIX A
TIME SCHEDULE FOR 1RM

Time schedule for 1 RM

Date	Name	Phone
6:00 -- 6:30		
6:30 -- 7:00		
7:00 -- 7:30		
7:30 -- 8:00		
8:00 -- 8:30		
8:30 -- 9:00		
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8:30 -- 9:00		

APPENDIX B
INFORMED CONSENT FORM

Informed Consent Form

Title: Prediction of One Repetition Maximum Bench Press from Push-ups in Active Young Males.

Principal investigator: Jianwei Xi

I, _____, volunteer to participate in the test of Push-ups (PU) and 1 Repetition Maximum (1 RM) bench press for the study of predicting upper body strength from PU.

I understand that the study is to find a best correlation equation in order to predict one repetition maximal bench press from push-ups in one minute by testing 1 RM and PU on me. I am going to have 4 through 8 trails of bench press in order to achieve the 1 RM, the maximal weight I can lift at a time. Then, I will do as many PU as possible in 1 minute two to three days after 1 RM test according to muscular soreness recovery. Before the test, a simple anthropometry such as weight, height, and skinfolds thickness in three spots (triplicate, suprailiac, and thigh), will be measured. I know that I can stop the test at any time because of personal feelings of fatigue or discomfort.

I understand that doing 1 RM might cause muscle, ligament, and/or tendon injuries, if I do not do appropriate warm-up, even though a spotter will support me and I have done with warm-up. I know that I will feel muscle soreness after the test. And that will not hurt muscles.

To my knowledge, I have no medical or physical conditions or limitation which would affect my participation and the test results in this study.

I have read the foregoing and have been fully advised of the nature and risks involved in the procedures and test including in this study. Any questions which may have occurred have been answered to my satisfaction. I hereby acknowledge that no assurances of any kind pertaining to the University of Wisconsin-La Crosse, the officers, administrators, employees or by anyone acting on behalf of any of them.

I understand any questions about the procedures in the test, I may ask for further explanations.

I will be free to deny consent or stop the test at any point, if I desire.

I have read this form and understand the test procedures that I will perform.

I consent to participate in this test.

Participant Signature: _____, Date: _____

Tester Signature: _____, Date: _____

APPENDIX C
TIME SCHEDULE FOR PU

Appointment for PU

Date	Name	Phone
6:00 -- 6:20		
6:20 -- 6:40		
6:40 -- 7:00		
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8:40 -- 9:00		

APPENDIX D
TEST DATA SHEET

Test Data Sheet

Name: _____ Age: _____ Phone: _____

Time: 1 RM: _____ PU: _____

Weight: Wt: _____ (lbs) _____ (Kg)
 Wt: WtH: _____ (lbs) _____ (Kg)
 WtL: _____ (lbs) _____ (Kg) Average: _____ (Kg)

Height: Ht: _____ (cm) _____ (in)
 HtGS: _____ (cm) _____ (in)
 HtPS: _____ (cm) _____ (in)
 Shoulder width: _____ (cm) _____ (in)
 Distance between indexes: _____ (cm) _____ (in)

Skinfold: Chest: _____ (mm)
 Abdomen: _____ (mm)
 Thigh: _____ (mm)

Circumference of arms:

Left: _____ (cm) _____ (in)
 Right: _____ (cm) _____ (in) Average: _____ (cm)

LBM: _____ (lbs) Fat%: _____ (lbs)
 _____ (Kg) _____ (Kg)

Fat%: _____ (%)

1RM: _____ (lbs) _____ (Kg) _____ (trials)

PU: _____ (reps/min)

Comment:

APPENDIX E
MAXIMUM BASED ON REPS

Maximum Based on Reps

This chart tells you that the approximate weight that you can do based on a certain number of repetitions. It also intensifies % of 1RM for 95 % to 75 %. For example: If you can do 10 REPS @ 450 pounds on the LEG PRESS, then your projected maximum effort is 600 pounds.

% OF RM / REPS

100/1	95/2	90/4	85/6	80/8	75/10
350.00	332.50	315.00	297.50	280.00	262.50
345.00	327.75	310.50	293.25	276.00	258.75
340.00	323.00	306.00	289.00	272.00	255.00
335.00	318.25	301.50	284.75	268.00	251.25
330.00	313.50	297.00	280.50	264.00	247.50
325.00	308.75	292.50	276.25	260.00	243.75
320.00	304.00	288.00	272.00	256.00	240.00
315.00	299.25	283.50	267.75	252.00	236.25
310.00	294.50	279.00	263.50	248.00	232.75
305.00	289.75	274.50	259.25	244.00	228.75
300.00	285.00	270.00	255.00	240.00	225.00
295.00	280.25	265.50	250.75	236.00	221.25
290.00	275.50	261.00	246.50	232.00	217.50
285.00	270.75	256.50	242.25	228.00	213.75
280.00	266.00	252.00	238.00	224.00	210.00
275.00	261.25	247.50	233.75	220.00	206.25
270.00	256.50	243.00	229.50	216.00	202.50
265.00	251.75	238.50	225.25	212.00	196.75

% OF RM / REPS

100/1	95/2	90/4	85/6	80/8	75/10
260.00	247.00	234.00	221.00	205.00	195.00
255.00	242.25	229.50	216.75	204.00	191.25
250.00	237.50	225.00	212.50	200.00	187.50
245.00	232.75	220.50	208.25	196.00	183.75
240.00	228.00	216.00	204.00	192.00	180.00
235.00	223.25	211.50	199.75	188.00	176.25
230.00	218.50	207.00	195.50	184.00	172.50
225.00	213.75	202.50	191.25	180.00	168.75
220.00	209.00	198.00	187.00	176.00	165.00
215.00	204.25	193.50	182.75	172.00	161.25
210.00	199.50	189.00	178.50	168.00	157.50
205.00	194.75	184.50	174.25	164.00	153.75
200.00	190.00	180.00	170.00	160.00	150.00
195.00	185.25	175.50	165.75	156.00	146.25
190.00	180.50	171.00	161.50	152.00	142.50
185.00	175.75	166.50	157.25	148.00	138.75
180.00	171.00	162.00	153.00	144.00	135.00
175.00	166.25	157.50	148.75	140.00	131.25
170.00	151.50	153.00	144.50	136.00	127.50
165.00	156.75	148.50	140.25	132.00	123.75
160.00	152.00	144.00	136.00	128.00	120.00
155.00	147.25	139.50	131.75	124.00	116.25
150.00	142.50	135.00	127.50	120.00	112.50
145.00	137.75	130.50	123.25	116.00	108.75

‡ OF RM / REPS

100/1	95/2	90/4	85/6	80/8	75/10
140.00	133.00	125.00	119.00	112.00	105.00
135.00	128.25	121.50	114.75	108.00	101.25
130.00	123.50	117.00	110.50	104.00	97.50
125.00	118.75	112.50	106.25	100.00	93.75
120.00	114.00	108.00	102.00	96.00	90.00
115.00	109.25	103.50	97.75	92.00	86.25
110.00	104.50	99.00	93.50	88.00	82.50
105.00	99.75	94.50	89.25	84.00	78.75