Prediction of One Repetition Maximum Bench Press from Push-ups in College-Aged

Females

A thesis presented to

the faculty of

the College of Health and Human Services of Ohio University

In partial fulfillment

of the requirements for the degree

Master of Science

Elizabeth L. Guenther

June 2009

© 2009 Elizabeth L. Guenther. All Rights Reserved.

# This thesis titled

# Prediction of One Repetition Maximum Bench Press from Push-ups in College-Aged

Females

by

# ELIZABETH L. GUENTHER

has been approved for

the School of Recreation and Sport Sciences

and the College of Health and Human Services by

Sharon R. Rana

Associate Professor of Recreation and Sport Sciences

Gary S. Neiman

Dean, College of Health and Human Services

#### ABSTRACT

GUENTHER, ELIZABETH, L., M.S., June 2009, Exercise Physiology-Research <u>Prediction of One Repetition Maximum Bench Press from Push-ups in College-Aged</u> <u>Females</u> (54 pp.)

Director of Thesis: Sharon R. Rana

The purpose of this research was to develop an equation to predict 1RM bench press strength from push-ups to fatigue in trained and untrained college age females. Sixty-six females  $(21.02 \pm 2.32 \text{ yrs.})$  participated in this study. Body composition was found for each participant via 7-site skin fold technique and blood pressure was monitored prior to each testing session. Each participant performed both a push-ups to fatigue test and a 1 RM bench press test, within 48-72 hours. The push-ups to fatigue test required each participant to perform as many push-ups as possible set to a 60bpm cadence, while touching the chest to a 3.75 in (9.5 cm) tall plastic cup. The 1 RM bench press test followed standard 1 RM protocol. A hierarchical linear regression analysis was conducted to examine the extent to which push-ups to fatigue, body mass (kg), lean mass (kg) and training status accurately predicted 1RM bench press strength. Results indicated that together, push-ups and body mass accounted for a significant amount of variability in 1 RM bench press strength ( $R^2 = .273$ , p < .0001, SE = 5.30) and that both push-ups to fatigue and body mass served to accurately predict 1 RM in the presence of one another. Neither lean body mass nor training status was found to significantly predict 1 RM bench press strength, in the presence of push-ups or body weight. As a result, the final

prediction equation developed may be used to accurately predict 1 RM bench press strength in college-aged females.

Approved: \_\_\_\_\_

Sharon R. Rana

Associate Professor of Recreation and Sport Sciences

#### ACKNOWLEDGMENTS

There are several individuals that I would like to thank for their contributions to the completion of this thesis. First I would like to thank my thesis advisor, Dr. Sharon Rana, for her never ending support, guidance, advice and patience. I would also like to thank my other committee members, Dr. Sue Bullard and Dr. Roger Gilders, for their insightful suggestions and support. Thank you to my husband, Corey, who encouraged, challenged, and loved me through each step of this process. And finally, to my family, Mom, Dad, and Carrie for their unconditional love and guidance in everything I do.

# TABLE OF CONTENTS

Abstract	
Acknowledgments	5
List of Tables	
Chapter 1: Introduction	9
Significance and Hypothesis	
Definition of Terms	
Limitations	
Delimitations	
Chapter 2: Review of Literature	17
Accuracy of Prediction Equations	
Use of Push-ups	
Use of Structural Dimensions (Body Composition)	
Use of Cadence	
Chapter 3: Methods	
Body Composition	
Blood Pressure	
Push-ups and 1 RM bench press	
Chapter 4: Results	
Chapter 5: Discussion	
Use of Submaximal Tests	

Page

Use of Push-ups	. 35
Use of Body Composition and Body Weight	. 37
Use of Training Status	. 38
Assessing the Accuracy of the Developed Prediction Equation	. 40
Conclusion	. 41
Future Recommendations	. 41
References	. 43
Appendix A: Recruitment Flyer	. 47
Appendix B: Consent Form	. 48
Appendix C: Health History Questionnaire	. 52

7

# LIST OF TABLES

Table 1: Previously Developed 1RM Prediction Equations	20
Table 2: 1 RM Prediction Equations using Push-ups to Fatigue	23
Table 3: Structural Dimensions used to Predict 1 RM Bench Press Strength	24
Table 4: Physical Characteristics	31
Table 5: Physical Characteristics of Trained Participants	32
Table 6: Physical Characteristics of Untrained Participants	32
Table 7: Summary of Hierarchical Regression Analysis for Predicting	
1 RM Bench Press Strength	34

Page

#### **CHAPTER 1: INTRODUCTION**

Muscular strength and muscular endurance are two key components of any type of exercise program. By definition muscular fitness refers to the combination of muscular strength and muscular endurance. In any exercise or fitness setting, assessment and quantification of muscular fitness is necessary. Even though the purpose of every exercise program is different, the reason for assessing muscular fitness values is similar (Whaley, 2006). Reasons for assessing muscular fitness include: baseline determination, identification of areas of weakness, monitoring progress in a rehabilitation program, and measuring the effectiveness of a resistance training program (Humphries, Dugan, & Doyle, 2006).

There are a variety of definitions available to describe muscular strength. These definitions include: the force that a muscle or muscle group can exert against a resistance in 1 maximal effort through a full range of motion (Wathen, 1994) and the ability of a muscle to exert force at a given velocity of movement (Whaley, 2006). Muscular strength can be developed or enhanced simply by overloading the targeted muscle or muscle groups. Resistance training is the process of overloading a muscle in order to increase muscular strength. All types of strength training, including dynamic and isometric exercises have been shown to improve strength.

There are clear gender differences when examining muscular strength. Women, on average, possess less absolute muscular strength than men (McArdle, Katch, & Katch, 2001). Specifically, women have approximately 50% less upper body strength and 30% less lower body strength than men, when expressed in absolute terms (Heyward & Stolarczyk, 1996).

Muscular endurance is defined as the ability of the muscles to apply a submaximal force repeatedly or to sustain a submaximal muscular contraction for a certain period of time (Nieman, 1999). Muscular endurance can also be defined as the ability of a muscle to produce force continuously without producing movement (Humphries, et al., 2006). More simplified, it is the ability of a muscle to resist fatigue (Whaley, 2006). Muscular endurance is developed through placing an overload on targeted muscles or groups, similar to the development of muscular strength, except that the overload consists of less weight and more repetitions (Whaley, 2006).

There are many benefits that may be gained from participating in a resistance training program, which include: maintenance of muscle mass, injury prevention, improved performance of activities of daily living and athletic events, weight management or reduction in body fat, modest improvements in cardiorespiratory fitness, modest reduction in BP, improved blood lipid profile, and improved acid-base buffering capacity or decrease in lactic acid accumulation in the muscle. The most significant benefit is that once strength gains are made, the muscles or groups will be able to manage more weight. Trained muscles are better able to sustain a muscular activity, which is related to muscular endurance (Whaley, 2006).

When assessing muscular fitness, strength and endurance are normally assessed independently of one another. Muscular strength and endurance assessments are conducted for many reasons and in a variety of settings. There is much debate on how to measure strength. The most common method used for determining muscular strength is the 1 repetition maximum (1 RM) test (Whaley, 2006). This test can be used to measure strength in almost any muscle group (chest press, leg press, lat pull down). The 1 RM bench press test is considered the most accurate assessment of overall upper body strength (Whisenant & Panton, 2003). It is used as a reference standard for determining an individual's dynamic muscular strength (Invergo, Ball, & Looney, 1991). Even though it is accurate in determining strength there are some major disadvantages to using the test.

The two most common disadvantages of 1 RM are time and safety (Whisenant & Panton, 2003). One RM testing can be very time consuming. Even though the test is aimed at determining the 1 RM as efficiently and as quickly as possible (to avoid muscular fatigue) the design takes time: There are lengthy breaks that must be observed to ensure an accurate measurement (Invergo et al., 1991; Mayhew, Ball, Arnold, & Bowen, 1992). Safety is also a major concern when performing 1 RM testing. Some individuals are not comfortable or are not able to perform this type of maximal strength testing and may be at a higher risk of injury (Kim, Mayhew, & Peterson, 2002; Kravitz, Akalan, Nowicki, & Kinzey, 2003; LeSuer, McCormick, Mayhew, Wasserstein, & Arnold, 1997; Mayhew, Ball, Arnold, & Bowen, 1991; Mayhew et al., 1992; Mayhew, Prinster, Ware, Zimmer, Arabas, & Bemben, 1995; Reynolds, Gordon, & Robergs, 2006; Whisenant & Panton, 2003). In certain populations, such as elderly or diseased, this type of testing would not be advised due to limited strength and resulting safety concerns.

Overall muscular strength can also be assessed statically, i.e., without muscle or limb movement (Whaley, 2006). This type of muscular strength is referred to as isometric strength. Measurements of isometric strength tend to be very specific to the muscle and the joint being utilized during the testing. Because of this, there is little practicality in using isometric strength as an accurate predictor of muscular strength (Whaley, 2006). Even though there is little practical application of this type of strength testing, it is relatively easy to administer and can be assessed almost anywhere (Nieman, 1999). Traditionally, means of assessing isometric muscular strength include handgrip dynamometers, cable tensiometers, or static exercises, such as the flexed arm hang (Nieman, 1999; Whaley, 2006).

One final means of assessing muscular strength maximally is isokinetically. During isokinetic movements, the resistance is adjusted to match the force created by the muscle through the full range of joint motion (Nieman, 1999). With isokinetic strength assessment, the speed of the movement is controlled throughout the exercise to achieve this matching of force and resistance. This type of assessment requires specialized equipment, making it impractical as well (Nieman, 1999).

Submaximal strength testing is an alternative to maximal testing and in most instances is more time efficient and safer than maximal testing. There are many methods of submaximal strength testing, ranging from multiple repetitions at a certain percentage of the 1RM (Cummings & Finn, 1998; Horvat, Ramsey, Franklin, Gavin, Palumbo, & Glass, 2003; Kravitz et al., 2003; Mayhew et al., 1992; Reynolds et al., 2006;) to the YMCA Bench Press Test (Invergo et al., 1991; Kim et al., 2002; Nieman, 1999). Regression equations have been developed to predict maximal 1 RM strength from these submaximal strength tests. Most of these prediction equations have specific variables that must be considered to predict the most accurate 1 RM. For example, the Brzycki (1993) equation is designed for less than 10 repetitions to fatigue and the prediction equation utilizes the number of repetitions to fatigue (Cummings & Finn, 1998). The equation developed by Mayhew, et al. (1992) is designed for less than 15 repetitions to fatigue and the equation utilizes the weight lifted for the repetitions. Most of these equations, which are very specific to the population in which they were developed, will either over- or under-predict the 1 RM if the proper protocol and population are not utilized (Cummings & Finn, 1998; Wood, Maddalozzo, & Harter, 2002).

The most common method used to determine muscular endurance is the oneminute push-up test (Invergo et al., 1991; Mayhew et al., 1991). This test determines muscular endurance based on the number of push-ups completed in one minute. Push-ups have also been used to predict maximal strength, specifically 1 RM bench press. There has not been much research conducted on the reliability of the one-minute push-up test, with the exception of attempting to determine the relationship between push-ups and the 1 RM bench press test. Two studies that have looked at the relationship between push-ups and 1 RM bench press strength have determined that push-ups, specifically, are not significantly correlated with 1 RM bench press strength (Invergo et al., 1991; Mayhew et al., 1991). However, these studies did not standardize the protocol very well. The only criterion, was that each subject perform as many push-ups as possible in one minute (Invergo et al., 1991; Mayhew et al., 1991). The rate at which push-ups were performed was not standardized. This protocol has only been studied in an untrained population of both male and female subjects. Therefore, there is a need for additional research to further address the use of push-up tests for the assessment of muscular strength in both a trained and untrained female population.

Studies examining the relationship between muscular strength (1 RM bench press test) and muscular endurance (one-minute push-up test), have not been extremely successful. Nevertheless, research has shown the relationship between muscular strength and endurance to be relatively strong. Statistically, muscular strength and muscular endurance have been shown to have a high relationship (r = 0.75 or higher; Start & Graham, 1964). Specifically, one study conducted by Dean and colleagues (Dean, Foster, & Thompson, 1987) found the relationship between push-ups in one-minute and 1RM bench press to be as high as r = 0.86. Therefore, there is a great need for more research in this area to determine the relationship between 1 RM bench press strength and push-ups to fatigue.

In using a female population, it is assumed that participants will be performing fewer push-ups (or repetitions) to the point of fatigue than their male counterparts may be able to perform. Previous research has shown that fewer repetitions may better predict 1 RM bench press strength (Dohoney, Chromiak, Lemire, Abadie, & Kovacs, C., 2002; Reynolds et al., 2006). Therefore, a prediction equation developed from a female population and for a female population may be a more accurate predictor of 1 RM bench press strength from push-ups to fatigue.

#### Significance and Hypothesis

No research to this point has investigated the influence of training status in the female population in determining a prediction equation for 1 RM bench press from the number of push-ups to fatigue using a set cadence. The purpose of this research is to determine the relationship between a push-up test and a 1 RM bench press test and to create an equation that can be used to predict the 1 RM bench press from the number of push-ups performed to exhaustion with the pacing of a cadence, in a trained and untrained, female population, aged 18 to 34 years. The possibility of incorporating percentage of lean mass versus fat mass will also be explored. It is hypothesized that the number of push-ups to fatigue, performed in the two populations, will accurately predict the absolute 1 RM for each individual, based on the developed prediction equation.

#### Definition of Terms

*Muscular strength* is the ability of the muscle to exert force (ACSM). *Muscular endurance* is defined as the ability of the muscle to perform continuous successive exertions or repetitions (ACSM). *Muscular fitness* is a category used by ACSM that includes both muscular strength and muscular endurance (ACSM). *Submaximal* means not at maximal workload or work intensity. *1 RM Test* is the most commonly used method of determining muscular strength.

#### Limitations

 Subjects may not accurately report their weight training experience, three months upper body resistance training experience to be considered trained, and may be classified into the incorrect category, trained or untrained.

- 2. The type of previous resistance training experience, strength or endurance, may influence the results of the push-up and 1 RM bench press test.
- Past the three month upper body resistance training experience, there may be high variability in training status. Some subjects may only be at three months and others may be at multiple years of experience.
- 4. This study will be using the standard push-up in a female population, instead of the modified that is most commonly used for females. This may compromise the ability of the subjects to perform push-ups.

## Delimitations

- Subjects will be only females and fit into the non-obese category, based on standard tables.
- 2. The push-ups will all be performed at the same set cadence.
- 3. All testing will take place over a 48-72 hour time period; this will not permit for changes in training status or strength gains/losses.
- 4. The use of the non-modified push-ups will make the exercise more of a strength activity and less of an endurance activity.

#### **CHAPTER 2: REVIEW OF LITERATURE**

There have been multiple studies conducted to analyze the effectiveness of predicting a 1RM bench press from a submaximal test (Ball, Mayhew, & Bowen, 1995; Chandler, West, Larkin, Crady, & Mayhew, 1995; Cummings, & Finn, 1998; Dean et al., 1987; Dohoney et al., 2002; Horvat et al., 2003; Invergo et al., 1991; Kim et al., 2002; Kravitz et al., 2003; Mayhew et al., 1991; Mayhew et al., 1992; Reynolds et al., 2006; Whisenant et al., 2003). Examples of these submaximal, endurance tests include: the 225lb repeated bench press (used by the National Football League), the YMCA bench press protocol, a multiple repetition max test, and a push-ups tests (in one minute or to fatigue). Most of this testing has been conducted on men of various training status and age, using different methods of testing. However, there is not much literature to support the use of submaximal, endurance testing using female subjects. Multiple regression equations have been developed for the male population to predict maximal 1 RM from repetitions to fatigue but no such equation has been developed specifically for the female population.

1 RM prediction equations utilizing repetitions to fatigue

As previously stated, many of the tests that have been used to develop equations to predict 1 RM bench press strength have used an endurance model, in which the subject is required to perform repetitions to fatigue or failure. These endurance tests have utilized many different protocols and techniques, ranging from bench pressing or squatting a certain percentage of the pre-determined max to a multiple RM (20RM, 10RM, 5RM) to push-ups. Even though push-up repetitions to fatigue are the least utilized, it is considered by most the easiest, safest and most efficient method to use (Invergo et al., 1991; Mayhew et al., 1991).

Significant regression equations have been developed using multiple techniques: repetitions to fatigue with a set weight (Horvat et al., 2003), a certain multiple RM (20, 10, 5; Dohoney et al., 2002; Reynolds et al., 2006), a specific percentage of the 1 RM (Kravitz et al., 2003) or randomly selected percentage of 1 RM (Mayhew et al., 1995). It was found that 1 RM can accurately be predicted, in female collegiate athletes using either 70 or 55 lb loads (Horvat et al., 2003).

When examining the use of a 20, 10, or 5 RM load in 1 RM prediction of bench press or leg press, the lower repetitions (5 RM) and increased load were found to be significant in males and females (Reynolds et al., 2006). Similarly, when using a 4-6 or 7-10 RM, the lower the repetitions (4-6 RM) the better predictor of actual 1 RM (Dohoney et al., 2002). Regression equations have been developed for use with repetitions to failure at 70%, 80%, and 90% of 1 RM (Kravitz et al., 2003). Kravitz and colleagues (2003) found the best predictor, of the three 1 RM percentages, to be at 70% of 1RM. The number of repetitions performed in one minute of a randomly selected load, ranging from 55-95% 1RM has been found to be an accurate predictor of the 1 RM bench press in college aged men and women (Mayhew et al., 1992). Push-ups have also been determined to be an accurate prediction method for 1 RM bench press strength (Dean et al., 1987; Mayhew et al., 1991). When using push-ups as a predictor, the most accurate regression equations are adjusted for body mass (Dean et al., 1987; Mayhew et al., 1991).

The YMCA bench press protocol has also been determined to be an accurate predictor of 1RM bench press strength (Invergo et al., 1991).

There are a few studies that have explored the possibility of other types of resistance exercises in predicting 1 RM strength, although these studies were reported in abstract form. Lat pull-down repetitions to fatigue were not determined to be an accurate predictor of lat pull-down 1 RM strength (Chandler et al., 1995). Parallel dips were found to be highly correlated to 1 RM bench press strength but alone are ineffective in accurate prediction (Ball et al., 1995). However, with the addition of body mass to the equation, parallel dips, can be an accurate method for predicting 1 RM bench press strength.

#### Accuracy of Prediction Equations

The validity of several of the prediction equations used to estimate 1 RM based on a submaximal load and number of repetitions has been assessed (Table 1). Typically, the equations have a goal of performing 10 repetitions or less, so are not truly muscular endurance tests per say. When using different populations based on resistance training status, these prediction equations vary in their accuracy; some may accurately predict the 1 RM, while others may over- or under- estimate the 1 RM.

The Brzycki (1993) equation has been shown to significantly predict 1 RM bench press, in untrained men and women and men of various training stages, when performing less than 10 bench press repetitions to fatigue (LeSuer et al., 1997; Mayhew et al., 1995). However, it has also been found to significantly under-estimate the prediction of 1 RM in an untrained female population, when performing 4 to 8 bench press repetitions to fatigue

## Table 1

Previously Developed 1 RM Prediction Equations

Author	Equation	Purpose	Population
Brzycki	W/(1.0278-0.0278*R)	<10 repetitions, load is a % of 1 RM	males and females, trained and untrained
Lander	W/(1.013-0.0267123*R)	2-10 repetitions, 75-90% of 1 RM	trained college males
Epley	(0.33*R)*W+W	<10 repetitions, load is a % of 1 RM, equation includes load lifter	untrained females trained college males d
Mayhew	W/(52.2+41.9e <sup>-0.55*R</sup> )/100	# of repetitions in one minute, <1 RM load	trained and untrained college males
Wathen	W/(48.8+53.8e <sup>-0.075*R</sup> )/100		trained and untrained college males

*Note*. R = number repetitions; W = submaximal weight lifted per repetition.

test (Cummings & Finn, 1998) and significantly over-estimate 1 RM prediction in men of various training stages using greater than 10 repetitions to fatigue (Mayhew et al., 1995).

The Lander (1985) equation was found to be a significant predictor of 1 RM in trained college men, when performing 1 to 10 repetitions, using the NFL 225 lb repetition to fatigue test (Whisenant & Panton, 2003). However, it significantly over-estimated the 1 RM, in the same group when performing greater than 10 repetitions (Whisenant & Panton, 2003) and in a group of men of various training stages, when performing any number of repetitions (both less than and greater than 10 repetitions; Mayhew et al., 1995).

The Epley (1985) equation was found to be a significantly accurate predictor of 1 RM when used in an untrained female population performing 4 to 8 repetitions to fatigue test (Cummings & Finn, 1998) and in a group of trained college males, when performing any number of repetitions (greater or less than 10), using the NFL 225 lb repetitions to fatigue test (Whisenant & Panton, 2003). However, in a group of men of various training status, it significantly over-estimated the 1 RM bench press prediction in greater than and less than 10 repetitions to fatigue (Mayhew et al., 1995).

The Mayhew et al. (1991) equation was developed and found to be a significantly accurate 1 RM predictor in trained college males and females (Mayhew et al., 1992). In a group of college men using the NFL 225 lb repetitions to fatigue test, the Mayhew equation was found to significantly over-estimate actual 1RM values, when performing less than 10 repetitions and significantly under-estimate, when performing greater than 10 repetitions (Whisenant & Panton, 2003). These findings were verified in a group of men of various training stages, for less than 10 repetitions the equation significantly over-estimated the actual value and for more than 10 repetitions the equation significantly under-estimated the actual 1 RM value (Mayhew et al., 1995). However, in a group of untrained college students, this equation was a significant predictor of 1 RM bench press strength (LeSuer et al., 1997).

The Wathan (1994) equation was shown to produce values that were not significantly different from the actual 1 RM value, when performing less than 10

repetitions, in trained college men, using the NFL 225 lb repetitions to fatigue test (Whisenant & Panton, 2003). Also, when performing greater than 10 repetitions with the same subjects using the same protocol, this equation was the most accurate predictor of 1 RM. In a group of untrained college students, the Wathan (1994) equation predictive values for bench press and squat did not significantly differ from the actual 1 RM; however, it significantly under-estimated the 1 RM value for the dead lift (LeSuer et al., 1997).

The Lombardi (1989) equation has been found to be an accurate predictor in trained college men, performing less than 10 repetitions to fatigue, using the NFL 225 lb repetitions to fatigue test (Whisenant & Panton, 2003). However, it was found to significantly under-estimate the actual 1 RM, in the same group, when performing greater than 10 repetitions using the NFL 225 lb repetitions to fatigue test (Whisenant & Panton, 2003) and in men of various training stages, when performing any number (greater or less than 10) of repetitions to fatigue (Mayhew et al., 1995).

#### Use of Push-ups

Push-ups are a simple and efficient way of assessing strength, as seen in the summary in Table 2. A study conducted by Dean et al., (1987) used push-ups to fatigue as a means of predicting 1 RM strength in a group of college aged men and women; push-ups were adjusted for body mass (PU\*kg), body height (PU\*cm), and body height and body mass (PU\*cm\*kg\*100<sup>-1</sup>). This study concluded that the best predictor of 1 RM bench press strength was push-ups adjust for weight (PU\*kg; r = 0.86), with the equation:

1 RM = 0.22(PU\*kg) + 21.5 (Dean et al, 1987). The correlation between PU\*kg and 1 RM was r = 0.95 (Dean et al., 1987).

#### Table 2

#### 1 RM Prediction Equations using Push-ups to Fatigue

Author	Equation	Subjects	Correlation (r)
Dean et al. (1987)	0.22(PU*kg) + 21.5	men and women, various training levels	0.95
Mayhew et al. (1991)	0.014(PU*kg) + 29	trained men	0.71

*Note*. PU= number of pushups in one minute; kg = body mass in kilograms

In a related study, Mayhew et al., (1991) predicted 1 RM bench press strength from push-ups performed in one-minute. Push-ups were adjusted for height, body mass, lean body mass, and height and body mass. They concluded that the best predictor of 1 RM bench press strength was push-ups adjusted for body mass (PU\*kg) and push-ups adjusted for height and body mass (PU\*cm\*kg\*100<sup>-1</sup>; Mayhew et al., 1991). The equation that was developed, 1 RM = 0.014(PU\*kg) + 29, is based solely on body mass due to the fact that height did not add to the accuracy of the prediction (Mayhew et al., 1991).

#### Use of Structural Dimensions (Body Composition)

There have been a few studies in which structural dimensions of the body, such as height, body mass, body composition, arm length, and others have been used in prediction equations to increase the accuracy of predicting a 1 RM from a repetitions to fatigue test (Table 3).

#### Table 3

Structural Dimensions	Used to	Prediction	1 RM	Bench	Press S	Strength

Author	Structural Dimension	Correlation (r)
Dean et al. (1987)	Body mass (kg)	0.860
Mayhew et al. (1992)	Height, weight, LBM	
Cummings & Finn (1998)	Biacromial breadth	0.269
	Body mass	0.345
	CSA	0.507
	UAC	0.475
Reynolds et al. (2006)	Fat free mass	0.994 (leg press) 0.999 (chest press)

According to Dean et al. (1987), the accuracy of a 1 RM prediction equation based on push-ups to fatigue will increase when adjusted for body mass. Similarly, Mayhew et al. (1992) found when push-ups were corrected for height, body mass and lean body mass the correlation between 1 RM and timed push-ups increased. Cummings and Finn (1998) developed two equations, to predict 1 RM from a 4-8 RM test, in which structural dimensions, biacromial breadth, body mass, cross sectional area of the upper arm (CSA), and upper arm circumference (UAC) increased the correlation between the submaximal and maximal test. When developing a 1 RM leg and chest press prediction equation, fat free mass was found to have the highest correlation (Reynolds et al., 2006).

#### Use of Cadence

With so many options for protocols and methodology of testing, it is necessary to have some variable in place to standardize testing, especially with a protocol such as push-ups to fatigue. There is no time limiting the subject so each subject could possibly move at their own selected pace. Some may choose to perform push-ups fast in a shorter amount of time or others may choose to perform them slow in a longer amount of time. Cadence has been used in some studies as a means of standardizing the protocol (e.g., Kravitz et al., 2003).

The YMCA bench press protocol is a commonly used submaximal test to predict the 1 RM bench press. This test consists of lifting a set amount of weight (35 lbs. for women) to a cadence to fatigue. A study conducted by Kim et al. (2002) examined the influence of cadence on the YMCA bench press test to predict 1 RM bench press performance. This study used the standard cadence for the YMCA protocol, 60 b/min or 30 reps per minute and a cadence of 120 b/min or 60 reps per minute. In women the repetitions to fatigue were significantly greater when using the 60 b/min when compared with the 120 b/min cadence. Similarly, Kravitz et al. (2003) used a cadence (no more than a 2 second pause between each lift) to standardize the repetitions to failure at 70%, 80%, and 90% of the 1RM bench press. Reynolds et al. (2006) also used a 60 bpm cadence to standardize the repetitions for subjects performing 20 RM, 10 RM, and 5 RM.

#### **CHAPTER 3: METHODS**

Participants were recruited from the female student body at Ohio University and were included into this study based on specific inclusion criteria. Participants were required to be female, college aged, 18-34 years old, and non-obese, according to a seven site skin fold technique, as compared to standard tables (<25% body fat). Prior to testing, participants were required to complete an informed consent and health history questionnaire. The Health History Questionnaire was reviewed by the primary investigator to determine inclusion/exclusion to the study. The Health History Questionnaire assessed each potential participant's risk classification for participation in exercise and musculoskeletal injury status. Potential subjects were excluded if they were determined to be at high risk for participation in exercise (determined by one "high risk" box being checked or two "moderate risk" boxes being checked) or if previous musculoskeletal injury would prevent them from safely performing the requirements of the push-up and 1-RM tests.

Following the inclusion process, participants were asked about weight training experience in the 3 months prior to this study to determine training status. Trained participants had participated in a regular weight training program within the prior 3 months, and untrained participants had not participated in a regular weight training program within the prior 3 months. Participants then scheduled two visits over a 48 - 72 hour time period to complete the 1 RM bench press test and the push-ups to fatigue test. By completing testing in 48-72 hours, this controls for possible strength gains or losses and the female menstrual cycle.

#### **Body Composition**

When participants came in for the skin fold test they were instructed to wear a sports bra and a pair of shorts to provide access to areas that were measured. The same investigator made all skinfold measurements. Using a Lange Skin Fold caliper (Cambridge Scientific Industries, INC., Cambridge, Maryland) the investigator performed a series of skin fold measurements on the participant at seven different sites. The pinch was performed by gripping a small section of the skin between the thumb and first finger in order to separate the skin from subcutaneous fat. The seven sites that were measured were: subscapular, triceps, chest, midaxillary, abdominal, suprailiac, and thigh. Skin fold assessment and technique followed the standards and procedures outlined by the American College of Sports Medicine (Whaley, 2006). This series was performed in a rotating order until the measurements at one site were within 1 mm of each other (Whaley, 2006). The skin fold measurements were utilized in the following prediction equation to estimate body density (Pollock & Jackson, 1985):

 $1.097 - 0.00046971(sum of 7 sites) + 0.00000056(sum of 7 sites)^2 - 0.00012828(age)$ Body density was used in the following equations to predict body fat percentage: (5.01/Db) - 4.57 (Heyward & Stolarczyk, 1998). The standard error of estimate is 0.008 g/cm<sup>3</sup> for body density, or 3.8% for body fat percentage.

#### **Blood Pressure**

As a safety precaution, blood pressure was taken, according to ACSM techniques and procedures, prior to both the push-up and 1 RM test. The participant was instructed to sit quietly for 5 minutes prior to measurement. The appropriate size cuff was wrapped firmly around the upper part of the right arm, while the arm rested on a table at heart level. The stethoscope was placed just below the cuff, over the brachial artery. The cuff was inflated to approximately 20 mmHg above the first Korotkoff sound. The pressure in the cuff was slowly released as the investigator listened for the first Korotkoff sound and the disappearance of sound (fifth Korotkoff sound). The primary investigator determined the participant's blood pressure classification as normal, prehypertensive, stage I hypertensive, or stage II hypertensive (Whaley, 2006). If the participant presented with hypertensive blood pressure, they were required to reschedule their testing time. If the participant was hypertensive the second time, they were excluded from the study.

#### Push-ups and 1 RM bench press

Once the participant completed all the pre-test evaluations, meeting the acceptable criteria, they randomly performed the push-up test and the bench press test within a 48-72 hour time period. The push-up test required the participant to perform push-ups to fatigue. Each participant performed standard push-ups by positioning themselves with their hands directly under the shoulders, pointed forward, head up, back straight, using the toes as the pivot point. The participant began in the down position, with elbows bent and the chest touching a 3.75 in. (9.5 cm) plastic cup, which was centered directly below the sternum. They then raised the upper body and straightened the arms without locking the elbows; then lowered back down to touch the cup with the chest. The up and down movement of the push-up was coordinated by the beat of a metronome. The metronome was set to 60 beats per minute, as this was found to be a reliable cadence, according to Kim et al. (2002) and Kravitz et al. (2003). With each beat, there was a movement, either

an upward push of the body to straight arms or a lowering of the body to the point that the chest touched the plastic cup. This continued until fatigue, or the point at which the participant could no longer maintain the exercise cadence with metronome beat or proper form.

When performing a 1 RM bench press test the participant demonstrated the proper bench press technique: laying supine on a flat bench with a five point body contact position (back of the head, upper back/shoulders, and lower back/buttocks in contact with the bench, and right and left feet in contact with the floor), and grasping the bar with a closed, pronated, shoulder width grip. With the aid of a spotter, the participant moved the bar from the supports and positioned it above the chest with elbows fully extended, lowered the bar to touch the chest, kept the wrists rigid and directly above the elbows (while maintaining the five point contact), and pushed the bar upward until the elbows were once again fully extended. The goal of the investigator was to determine the participant's 1 RM bench press within 3 - 5 trials due to the fact that fatigue will begin to affect performance. The following procedures were used for the one repetition maximum bench press test, according to the National Strength and Conditioning Association (Baechle & Earle, 2000):

- 1. 5-10 warm-up repetitions with a light to moderate load
- 2. 1 minute rest
- 3. 3-5 heavier warm-up repetitions by adding 10-20 lbs (4-9kgs) or 5-10% of weight
- 4. 2 minute rest
- 5. 2-3 near maximum load repetitions by adding 10-20 lbs (4-9 kgs) or 5-10% of weight

- 6. 2-4 minutes rest
- 7. 1 maximum effort by adding 10-20 lbs (4-9 kgs) or 5-10% of weight
- 8. if successful, allow 2-4 minutes rest and repeat previous step
- 9. if unsuccessful, allow 2-4 minutes rest, 1 maximum effort by subtracting 5-10 lbs (2-4 kgs) or 2.5% weight
- 10. continue increasing or decreasing load until 1 maximal repetition is performed with proper technique

#### **CHAPTER 4: RESULTS**

A total of 73 female students were recruited to participate in this study. Of those recruited, 66 met the specific inclusion criteria and 7 did not. The 7 that did not meet the criteria were excluded from participating in this research based on high risk classification for participation in exercise or failure to complete all of the testing. Twenty- two of the total 66 participants were considered trained and 44 were considered untrained. The physical characteristics of the participants are summarized in Tables 4, 5, and 6.

#### Table 4

	Ν	Mean	SD	Range
Age (yrs.)	66	21.02	2.32	18 – 33
Body Mass (kg)	66	61.61	8.35	49.10 - 95.50
Height (in.)	66	65.45	2.56	61 – 71
Fat Mass (kg)	66	13.60	4.49	6.83 - 32.47
Lean Body Mass (kg)	66	48.01	4.95	39.90 - 48.01
1 RM (kg)	66	36.91	6.12	25.0 - 52.3
Push-ups	66	14.09	8.31	0-38

#### Physical Characteristics

*Note*. N = number of participants.

# Table 5

	Ν	Mean	SD	Range
Total Body Mass (kg)	22	59.85	8.40	49.1 – 77.3
Fat Mass (kg)	22	12.10	3.95	6.8 - 20.1
Lean Body Mass (kg)	22	47.74	5.38	40.3 - 61.6
1 RM (kg)	22	39.15	6.40	29.5 - 52.3
Push-ups	22	18.95	9.66	4.0 - 38.0

Physical Characteristics of Trained Participants

*Note*. N = number of participants.

# Table 6

# Physical Characteristics of Untrained Participants

N	Mean	SD	Range
44	62.48	8.28	50.0 - 95.5
44	14.34	4.60	7.1 – 32.5
44	48.14	4.78	39.9 - 63.0
44	35.79	5.72	25.0 - 50.0
44	11.66	6.38	0.0 - 24
	N 44 44 44 44 44 44	N         Mean           44         62.48           44         14.34           44         48.14           44         35.79           44         11.66	N         Mean         SD           44         62.48         8.28           44         14.34         4.60           44         48.14         4.78           44         35.79         5.72           44         11.66         6.38

*Note.* N = number of participants.

A hierarchical linear regression analysis was conducted to examine the extent to which push-ups to fatigue, body mass (kg), lean mass (kg) and training status accurately predict 1RM bench press strength. Results of this hierarchical analysis are summarized in Table 7.

The first block of variables entered into the model consisted of push-ups to fatigue and body mass. These variables were entered into the model simultaneously to control for body mass; therefore push-ups for each participant were relative to their body mass. Results indicated that together, these variables accounted for a significant amount of variability in 1 RM bench press strength,  $R^2 = .273$ , p < .0001, SE = 5.30. Furthermore, results also indicated that both push-ups to fatigue and body mass served to accurately predict 1 RM in the presence of one another. Specifically, it was found that, controlling for body mass, as the number of push-ups a participant could perform increased, so did the amount of weight they could lift for their 1 RM. Similarly, the amount of weight participants could lift for their 1 RM also increased as their body mass increased, controlling for push-ups to fatigue.

The second block of variables entered into the model consisted of lean mass. Results indicated that together, push-ups to fatigue, body mass, and lean mass accounted for a significant amount of variability in 1 RM,  $R^2 = .274$ , p < .0001, SE = 5.34. However, lean mass itself was not found to account for unique variability in 1 RM, above and beyond that already accounted for by push-ups to fatigue and body mass,  $R^2$  change = .001, p = .766. Importantly, push-ups to fatigue and body mass remained significant predictors of 1 RM in the presence of lean mass.

	Variable (s	ß standardized)	$\Delta F$	$\Delta R^2$
Step 1	Push-ups	0.452*	11.81*	0.273*
	Body Mass (kg)	0.412*		
Step 2	Lean Body Mass (kg)	-0.074	0.09	0.001
Step 3	Training Status	0.172	2.08	0.024
Note *n< 0001				

Summary of Hierarchical Regression Analysis for Predicting 1 RM Bench Press Strength

*Note*. \*p<.0001.

Finally, the third block of variables entered into the regression equation consisted of training status (0 = "untrained", 1 = "trained"). Together, push-ups to fatigue, body mass, lean mass, and training status accounted for a significant amount of variability in 1 RM bench press strength,  $R^2 = .298$ , p < .0001, SE = 5.29. However, as with lean mass, training status failed to significantly predict 1 RM in the presence of the other variables in the model,  $R^2$  change = .024, p = .155. Push-ups to fatigue and body mass, in contrast, continued to significantly predict 1 RM even after both lean mass and training status were entered in the regression equation. Therefore, because these variables were found to consistently predict 1 RM, and, because neither lean mass nor training status were found to significantly predict 1 RM, the final regression equation produced by the hierarchical analysis, using standardized beta coefficients is as follows:

$$1$$
RM (kg) = .452*push-ups* + .412*body mass* (*kg*) + 13.626

#### **CHAPTER 5: DISCUSSION**

#### Use of Submaximal Tests

This study indicates that push-up to fatigue, standardized by cadence, in collegeaged females, and body mass, regardless of training status, can be used to accurately predict 1RM bench press strength. These findings support a growing area of literature in which a submaximal strength test or an endurance test has been shown to accurately predict 1RM bench press strength. Kim et al. (2002) found that the YMCA bench press test, an endurance test, is an accurate predictor of 1RM bench press strength in both male and female populations ( $R^2 = .757$  and  $R^2 = .754$ , respectively). Kravitz et al. (2003) found that 70% of 1RM was the best predictor of 1RM strength in high school power lifters performing a squat and bench press, while Mayhew et al. (1992) found that an endurance load between 55-95% of 1RM is an accurate predictor of 1RM bench press strength in college men and women. Horvat et al. (2003) found that repetitions to fatigue, using a 70lb. barbell, accurately predicts 1RM bench press strength, in collegiate women athletes. Reynolds et al. (2006) similarly found that no more than 10RM can accurately predict 1RM leg press and chest press strength in males and females age 18-69.

#### Use of Push-ups

Previously mentioned literature examines the validity of submaximal or endurance tests, not including push-ups, which was the specific variable used in this research. The use of push-ups is supported largely through the work of Dean et al. (1987) who originally found that push-ups are indeed a valid indicator of 1RM bench press strength. Mayhew et al. (1991) also concluded that push-ups performed in one-minute, adjusted for body mass provide an accurate predictor of 1RM.

In contrast to the findings of this research, Mayhew et al. (1991) and Invergo et al. (1991) both indicated that push-ups are not an accurate indicator of 1RM bench press strength. Difference among the studies, using push-ups as the endurance component, may account for the discrepancies. For one, standardization of push-ups varied with each study. Mayhew et al. (1991) used a one-minute maximum push-ups test; with the number of correct repetitions performed within one minute as the number of push-ups performed. Similarly, Invergo et al. (1991) allowed each participant 60 seconds to complete as many repetitions as possible. Participants in this study were not given a time constraint; however they did have to keep pace with a metronome set to 60bpm. Once they could not keep pace with the cadence, the test was ended.

Depth of the push-ups is another area of standardization that may come into question. In the Mayhew et al. (1991) study, a fellow subject placed a fist under the chest of the subject and the subject had to touch the fist with their chest before extending the arms, in order to have a good push-up. The Invergo et al. (1991) study required subjects to touch their chin to a fellow subject's hand that was placed on the floor. Participants in the current investigation were required to touch their chest to a 3.75 in. (9.5 cm) plastic cup before extending to the up position in order to perform a good push-up. Subjects in both the Mayhew et al. (1991) and Invergo et al. (1991) studies were male, and it is assumed that standard push-ups were performed. Even though participants in the current investigation were all female, the standard push-up was also used, for an additional means of standardization.

#### Use of Body Composition and Body Weight

When lean body mass was added to the prediction equation, in the presence of push-ups and body mass , it was not found to account for any additional variance in the prediction of 1 RM. Currently there is little literature investigating the use of lean body mass, specifically in combination with push-ups, as a predictor of 1 RM. One study that has investigated the relationship between 1 RM and lean body mass (LBM) is Mayhew et al. (1991). In this study, the authors found a significant correlation (r = .64) between push-ups adjusted for lean body mass (PU\*kg\*LBM) and 1 RM. However, they also found the relationship between push-ups adjusted for body mass (PU\*kg) and 1 RM to be stronger (r = .71), and that push-ups adjusted for body mass served as a considerably better predictor of 1 RM than did push-ups adjusted for lean body mass. In fact, Mayhew et al.'s (1991) final prediction equation for 1 RM included push-ups adjusted for body mass, but not push-ups adjusted for lean body mass.

Similar results were found in the current investigation. Like Mayhew et al. (1991) a significant (albeit weaker) correlation (r = .286) was found between lean body mass and 1 RM. However, lean body mass failed to significantly predict 1 RM when in the presence of push-ups and body weight, and thus was left out of the final prediction equation. The lack of predictive power on the part of lean body mass may partly be due to the fact that there is a strong correlation between lean body mass and body mass (r =.895). This strong correlation between lean body mass and body mass that when entered into the prediction equation simultaneously, body mass diminishes the amount of variance in 1 RM that lean body mass accounts for. An additional explanation for the lack of predictive power of lean body mass is that during a push-up the entire body mass is being moved. Therefore, there is no differentiation between only moving lean body mass or moving the entire body mass. So it would make sense that lean body mass would not be as predictive as entire body mass.

#### Use of Training Status

It is surprising that when training status was taken into account, it did not change the accuracy of predicting 1RM from push-ups to fatigue. It may be assumed that with an increased level of training, the prediction would be more accurate and with a decreased level of training, the prediction would be less accurate. Engaging in a training program naturally comes with the expectation that the trained individual should be more consistent in their ability to perform both strength and endurance exercises, no matter their specific training background (either strength or endurance or a combination of both). Yet, in the current study training status failed to accurately predict 1 RM.

One reason training status may have lacked predictive ability in this study is that the definition of training status was vague. "Trained" was defined as participation in a regular resistance training program for three months directly prior to participation and "untrained" was defined as not having participated in a regular resistance training program in the three months prior to participation. Participants were allowed to selfreport their training status and were not required to provide any details of their training program. This could have led some participants who were trained to label themselves as untrained, and vice versa, thereby minimizing the differentiation that might naturally exist between these groups.

Additionally, defining trained participants as only those individuals who engage in a "regular" resistance training program may have also led participants who are in very good shape to be classified as untrained. For example, participants who perform resistance training every other week, only 1 day per week, or focus primarily on cardiovascular exercise may still be in very good shape but fail to be classified as "trained" in the current study. Therefore, it may simply be that the vague definition of trained prevented training status from accurately predicting 1RM bench press strength.

A more likely explanation for why training status may not have accurately predicted 1 RM in the present research is that there was simply too much variability in the push-ups and 1 RM performed by trained and untrained participants to warrant accurate predictive ability. Results of independent samples t-tests showed that, as would be expected, trained participants did perform a greater number of push-ups ( $\overline{X}_{trained} =$ 18.95,  $\overline{X}_{untrained} =$  11.66) and had a higher 1 RM bench press ( $\overline{X}_{trained} =$  39.15,  $\overline{X}_{untrained} =$ 35.79) than did untrained participants, t(64) = -3.67, p < .001, and t(64) = -2.16, p < .034, respectively. Similarly, trained participants also had less fat mass ( $\overline{X} =$  12.10) than did untrained participants ( $\overline{X} =$  14.34), t(64) = 1.95, p < .056. So, it is not that training status did not impact the strength or fitness of participants in the study's sample - trained participants did exhibit greater strength in both push-ups and 1 RM, and had less fat mass. However, the high degree of variability in push-ups performed by both trained (<u>SD</u> = 9.66) and untrained (<u>SD</u> = 6.38) participants, and, the high variability in the 1 RM of these participants ( $\underline{SD}_{trained} = 6.40$ ,  $\underline{SD}_{untrained} = 5.72$ ), likely undermined training status' ability to independently and accurately predict 1 RM. Using training status alone, it could be broadly predicted that any given trained individual should be able to do more push-ups and perform a higher 1 RM than any given untrained individual. However, because of the high degree of variability observed in the strength measures, the data simply may not be able to warrant a prediction any more precise than that. Therefore, the high degree of variability in push-ups and 1 RM for both groups may have prevented training status from increasing the accuracy of the prediction equation.

Assessing the Accuracy of the Developed Prediction Equation

To test the general accuracy of the prediction equation, each participant's actual push-ups and body weight were entered into the equation to yield a predicted 1 RM, which was then compared to participants' actual 1 RM. Specifically, the predicted 1 RM values were subtracted from actual 1 RM values to yield a single 1 RM difference score for each participant. Overall, these difference scores indicated a general tendency for the prediction equation to slightly overestimate participants' 1 RM ( $\overline{X} = -8.47$  kg).

Additionally, to explore whether this overestimation was consistent across populations, actual and predicted 1 RM values were separately compared for trained and untrained participants. Actual minus predicted difference scores again showed that for each of these groups, the prediction equation similarly overestimated 1 RM. For trained participants, the equation overestimated 1 RM by approximately 8 kg ( $\overline{X} = -7.70$ ), while for untrained participants the equation overestimated 1 RM by approximately 9 kg ( $\overline{X} =$  -8.85). Results of an independent samples t-test indicate that the degree of overestimation did not differ for trained and untrained participants, t(64) = -.822, p = .414. Thus, though the obtained prediction equation does serve to accurately predict 1 RM, it appears the equation produces a slight overestimation in 1 RM predictions.

#### Conclusion

The findings of this study are quite promising in the use of push-ups for determining maximal strength. However, there is a great need for future research and validation of this possibility, before push-ups can be considered a valid predictor of upper body strength.

#### **Future Recommendations**

Recommendations for continuing this study include a more specific or in-depth definition of training status. In order to achieve this, subjects may be expected to provide a record or example of a training program. Also, there may be a need to control for arm-length. An individual with longer arms would be at a disadvantage, when compared to an individual with shorter arms, in that the weight, for both push-ups and 1 RM bench press, would need to be moved a larger distance. As with arm-length, there may be a need to control for chest size, especially when using a female population. An individual with a smaller chest is at a disadvantage in that the distance the weight must travel for push-ups and 1 RM is larger than for those with a larger chest size. With push-ups, the distance from the ground was controlled for by using a standardized protocol for each subject; however, the distance that each subject had to move toward the ground was not controlled for. When looking at 1 RM, there was no standardization used in this

investigation to control for distance the weight traveled. Both variables, arm length and chest size, could easily be controlled for by using relative distances the weight must travel, instead of absolute distances. Relative distances could be found by measuring arm length and chest size for each subject and based on the measurements, determine the distance that the weight must be moved. Taking into account the variables of arm length and chest size may provide a more accurate prediction equation; however, it may in turn decrease the applicability and simplicity of the equation.

#### REFERENCES

- Baechle, T. R. & Earle, R. W. (2000). *Essentials of strength and conditioning*. (2<sup>nd</sup> ed.). Champaign, IL: Human Kinetics.
- Ball, T. E., Mayhew, J. L., & Bowen, J. C. (1995). Parallel dips as a predictor of 1-RM bench press strength. *Journal of Strength and Conditioning Research*, 9, 206.
- Brzycki, M. (1993). Strength testing: Predicting a one-rep max from reps to fatigue. Journal of Physical Education, Recreation & Dance, 64, 88-90.
- Chandler, T. G., West, S. C., Larkin, R. B., Crady, B. J., & Mayhew, J. L. (1995).
  Relationship of pullup and lat-pull performances to 1-RM lat-pull strength. *Journal of Strength and Conditioning Research*, 9, 205.
- Cummings, B., & Finn, K. J. (1998). Estimation of a one repetition maximum bench press for untrained women. *Journal of Strength and Conditioning Research*, 12, 262-265.
- Dean, J. A., Foster, C., & Thompson, N. (1987). A simplified method of assessing muscular strength. *Medicine and Science in Sport and Exercise*, 19, S63.
- Dohoney, P., Chromiak, J. A., Lemire, D., Abadie, B. R., & Kovacs, C. (2002).
  prediction of one repetition maximum strength from a 4-6 RM and a 7-10 RM submaximal strength test in healthy young adult males. *Journal of Exercise Physiology Online*, 5(3), 54-56. Retrieved April 12, 2007, from http://www.jeponline.org

Epley, B. (1985). Poundage chart. Lincoln, NE: Boyd Epley workout.

Heyward, V., & Stolarczyk, L. (1996). *Applied body composition assessment*. Champaign, IL: Human Kinetics.

- Horvat, M., Ramsey, V., Franklin, C., Gavin, C., Palumbo, T., & Glass, L. A. (2003). A method for predicting maximal strength in collegiate women athletes. *Journal of Strength and Conditioning Research*, 17, 324-328.
- Humphries, B., Dugan, E. L., & Doyle, T. L. A. (2006). Muscular fitness. In Kaminsky,
  L.A., ACSM's Resource Manual for Guidelines for Exercise Testing and
  Prescription (5<sup>th</sup> ed., pp. 206-224). Philadelphia, PA: Lipincott Williams &
  Wilkins.
- Invergo, J. J., Ball, T. E., & Looney, M. (1991). Relationship of push-ups and absolute endurance to bench press strength. *Journal of Applied Sport Science Research*, 5, 121-125.
- Kim, P. S., Mayhew, J. L., & Peterson, D. F. (2002). A modified YMCA bench press test as a predictor of 1 repetition maximum bench press strength. *Journal of Strength* and Conditioning Research, 16, 440-445.
- Kravitz, L., Akalan, C., Nowicki, K., & Kinzey, S. J. (2003). Prediction of 1 repetition maximum in high-school power lifters. *Journal of Strength and Conditioning Research*, 17, 161-172.
- Lander, J. (1985). Maximums based on reps. *National Strength and Conditioning* Association Journal, 6, 60-61.

LeSuer, D. A., McCormick, J. L., Mayhew, Wasserstein, R. L., & Arnold, M. D. (1997). The accuracy of prediction equations for estimating 1-RM performance in the bench press, squat, and deadlift. *Journal of Strength and Conditioning Research*, *11*, 211-213.

Lombardi, V. P. (1989). Beginning weight training. Dubuque, IA: W.C. Brown.

- Mayhew, J. L., Ball, T. E., Arnold, M. D., & Bowen, J. C. (1991). Push-ups as a measure of upper body strength. *Journal of Applied Sport Science Research*, *5*, 16-21.
- Mayhew, J. L., Ball, T. E., Arnold, M. D., & Bowen, J. C. (1992). Relative muscular endurance performance as a predictor of bench press strength in college men and women. *Journal of Applied Sport Science Research*, 6, 200-206.
- Mayhew, J. L., Prinster, J. L., Ware, J. S., Zimmer, D. L., Arabas, J. R., & Bemben, M. (1995). Muscular endurance repetitions to predict bench press strength in men of different training levels. *The Journal of Sports Medicine and Physical Fitness*, 35, 108-113.
- McArdle, W. D., Katch, F. I., & Katch, V. L. (2001). *Exercise physiology: Energy nutrition, and human performance* (5<sup>th</sup> ed.). Philadelphia, PA: Lippincott Williams & Wilkins.
- Nieman, D. C. (1999). *Exercise testing and prescription: A health-related approach* (5<sup>th</sup> ed.). Mountain View, CA: Mayfield.
- Pollock, M. L., Jackson, A. S. (1985). Practical assessment of body composition. *Physiology and Sports Medicine*, 13, 76-90.

- Reynolds, J. M., Gordon, T. J., & Robergs, R. A. (2006). Prediction of one repetition maximum strength from multiple repetition maximum testing and anthropometry. *Journal of Strength and Conditioning Research*, 20, 584-592.
- Start, K. B. & Graham, J. S. (1964). Relation between the relative and absolute isometric endurance of an isolated muscle group. *Research Quarterly in Exercise and Sport*, 35, 193-204.
- Wathen, D. (1994). *Essentials of strength training and conditioning* (1<sup>st</sup> ed.). Champaign, IL: Human Kinetics.
- Whaley, M. H. (2006). ACSM's guidelines for exercise testing and prescription (7<sup>th</sup> ed.).Philadelphia, PA: Lippincott Williams & Wilkins.
- Whisenant, M. J. & Panton, L. B. (2003). Validation of submaximal prediction equations for the 1 repetition maximum bench press test on a group of collegiate football players. *The Journal of Strength and Conditioning Research*, 17, 221-227.
- Wood, T. M., Maddalozzo, G. F., & Harter, R. A. (2002). Accuracy of seven equations for predicting 1-RM performance of apparently healthy, sedentary older adults. *Measurement in Physical Education and Exercise Science*, 6, 67-94.

# APPENDIX A: RECRUITMENT FLYER

Muscular Strength Research Exercise Physiology Research Libby Guenther guenthee@ohio.edu



Needed: Women ages 18-34 With or without previous weight training experience

> Will require: Body Fat Assessment 1-Rep Max Bench Press Test Push-ups to fatigue test

<u>Inclusion Criteria</u>: No physical, orthopedic, or health limitations Low or moderate disease risk Non-obese (<35% body fat)

# Will receive:

#1 muscular strength results#2 body fat determined by skin fold method#3 experience with exercise testing techniques

#### APPENDIX B: CONSENT FORM

## Ohio University Consent Form

Title of Research: <u>Prediction of one repetition maximum bench press from</u> <u>push-ups in trained and untrained college aged females</u>

Principal Investigator: <u>Elizabeth Wilson</u> Co- Investigator: \_\_\_\_\_ Department: <u>Recreation and Sport Science</u>

Federal and university regulations require signed consent for participation in research involving human subjects. After reading the statements below, please indicate your consent by signing this form.

## Explanation of Study

#### Purpose of the research

The purpose of this research is to develop an equation to predict one repetition maximal bench press results from the performance of push ups to fatigue. These tests are further described on the flowing page of this consent form.

#### Procedures to be followed

You will be included in this study if:

- you are a woman between the ages of 18-34 years old
- you are comfortable and willing to perform a 1 repetition max bench press test and a push- ups to fatigue test
- you have no physical, orthopedic, or health limitations that may cause harm or discomfort when performing push- ups or a 1 repetition max bench press test (which will be obtained from the health history questionnaire)
- you are classified as low risk, as described by the health history questionnaire
- you are classified as moderate risk however determined to be low risk after further review and questioning of primary investigator, as described by the health history questionnaire

- you are non- obese (< 35% body fat) based on skin fold analysis You will be excluded from this study if:

- you have a physical, orthopedic, or health limitation that may cause harm or discomfort when performing push- ups or a 1 repetition bench press test
- you are classified as moderate health risk (and after further questioning by the primary investigator are still determined to be moderate risk)
- you are classified as high risk as determined by the health history questionnaire
- you are obese (> 35% body fat) based on skin fold analysis

You will have your body composition analyzed using the skin fold technique. For this test, a technician will perform a series of 7 pinches on different sites on your body, these sites include: subscapular (back), triceps (back of arm), chest (near shoulder), midaxillary (under arm pit), abdominal (beside belly button), suprailiac (hip) and thigh. The pinches will be performed by holding a small section of the skin between the thumb and first finger and pinching, in order to separate the skin from subcutaneous fat. The pinch will be measured with a skin fold caliper which will lightly grip the pinch. The 7 sites will be measured 2- 3 times to ensure an accurate value. This test should take no more than 15 minutes.

If you meet the criteria listed above, you will be asked to perform both a one- repetition maximum bench press test and a push- ups to fatigue test. The push- ups to fatigue test will consist of the following steps: you will position yourself with your hands directly under the shoulders, pointed forward, head up, back straight, legs together with toes in contact with the floor and used as the pivot point. You will begin in the down position, with elbows bent and chin touching the floor then raise your body by straightening the elbows then return to the down position. The test will be set to a cadence of 60 beats per minute. You must perform the push- ups with the beat of the cadence – a movement up or down with each beat. This will continue until you can no longer maintain proper form or can no longer maintain the beat of the cadence.

The one repetition maximum bench press test will consist of the following steps:

- 11. 5-10 warm- up repetitions with a light to moderate load
- 12.1 minute rest
- 13. 3- 5 heavier warm- up repetitions by adding 10- 20 lbs (4- 9kgs) or 5- 10% of weight
- 14. 2 minute rest
- 15. 2-3 near maximum load repetitions by adding 10-20 lbs (4-9 kgs) or 5-10% of weight
- 16. 2-4 minutes rest
- 17. 1 maximum effort by adding 10- 20 lbs (4- 9 kgs) or 5- 10% of weight
- 18. if successful, allow 2-4 minutes rest and repeat previous step
- 19. if unsuccessful, allow 2- 4 minutes rest, 1 maximum effort by subtracting 5-10 lbs (2- 4 kgs) or 2.5% weight
- **20.** continue increasing or decreasing load until 1 maximal repetition is performed with proper technique

#### Duration of subject's participation

The screening procedure (informed consent, health history and physical activity questionnaires and skin fold assessment for body fat) will be completed within one week with each visit lasting 10 minutes to 1 hour. The two data collection visits (one being a push- up test and the other a one repetition maximum bench press test) will be completed within 48-72 hours with each visit lasting 20 minutes – 1 hour.

# Identification of specific procedures that are experimental $N/A \label{eq:N}$

# **Risks and Discomforts**

The risks associated with these tests include possible muscle/joint soreness and an increase in blood pressure. You will be screened for musculoskeletal and hypertensive problems prior to participation, and not allowed to participate in the study if any problems are found. There will be proper supervision and explanations/demonstrations of the tests to be performed, to avoid improper technique during the tests.

The age range and health status of the subject population inclusion has been selected to conform to the American College of Sports Medicine recommendations regarding these types of tests. Throughout all testing, you will be monitored by the primary investigator who is trained in First Aid and CPR. The primary investigator and all laboratory personnel are familiar with the emergency procedures in the laboratory in which all tests will be completed. If an emergency should arise, EMS will be called and immediate emergency care will be provided until the appropriate medical personnel arrive. Emergency numbers are posted by the phone in the research laboratory.

If at anytime after participation in this study, you develop any health issues or concerns that may be related to participation in this research please visit Student Health Services at Hudson Health Center or see your primary care physician and explain to them the type of physical activity you participated in for this research.

# **Benefits**

You will gain knowledge about your muscular strength and endurance (push- up test, one repetition maximum bench press test), your body composition (% body fat) and gain experience with techniques employed in this investigation.

# Alternative Treatments (if applicable)

N/A

# **Confidentiality and Records**

All data will be kept in the investigator's office in a locked file for five years. You will receive a subject number and only the investigator will be able to identify your records. A code key will be developed to match each subject's name with their subject number. This key will be destroyed after data collection is complete and you and other subjects have been provided with your individual results. The data will be compiled and analyzed with only group data being used for dissemination.

# **Compensation**

There is no compensation (monetary or otherwise) for participating in this study.

# Contact Information

If you have any questions regarding this study, please contact Elizabeth "Libby" Guenther at any time, by e- mail: <u>guenthee@ohio.edu</u> or phone: (740)593- 9918 or Dr. Sharon Rana, by e- mail: <u>rana@ohio.ed</u>u or phone: (740) 593- 9494

If you have any questions regarding your rights as a research participant, please contact Jo Ellen Sherow, Director of Research Compliance, Ohio University, (740)593-0664.

I certify that I have read and understand this consent form and agree to participate as a subject in the research described. I agree that known risks to me have been explained to my satisfaction and I understand that no compensation is available from Ohio University and its employees for any injury resulting from my participation in this research. I certify that I am 18 years of age or older. My participation in this research is given voluntarily. I understand that I may discontinue participation at any time without penalty or loss of any benefits to which I may otherwise be entitled. I certify that I have been given a copy of this consent form to take with me.

Signature	Date	
Printed Name	_	

#### APPENDIX C: HEALTH HISTORY QUESTIONNAIRE

## American Heart Association/American College of Sports Medicine Health/Fitness Facility Pre-participation Screening Questionnaire

#### Assess your health status by marking all true statements

#### History

You have had:

- \_\_\_ a heart attack
- \_\_\_\_ heart surgery
- \_\_\_\_ cardiac catherization
- \_\_\_\_ coronary angioplasty
- \_\_\_\_ pacemaker/implantable cardiac
- \_\_\_\_\_defibrillatory/rhythm disturbance
- \_\_\_\_heart valve disease
- \_\_\_\_heart failure
- \_\_\_ heart transplant
- \_\_\_\_ congenital heart disease

## **Symptoms**

- \_\_\_\_ chest discomfort with exertion
- \_\_\_\_unreasonable breathlessness
- \_\_\_ dizziness, fainting, blackouts
- \_\_\_\_you take heart medication

#### Other health issues

- \_\_\_\_ you have diabetes
- \_\_\_\_you have asthma or other lung disease
- \_\_\_\_you have burning or cramping in your lower
- legs when walking short distance
- \_\_\_\_you have musculoskeletal problems that limit Your physical activity
- \_\_\_\_you have concern about the safety of exercise
- \_\_\_\_you take prescription medications
- Please list:

\_ you are pregnant

#### **Cardiovascular risk factors**

- \_\_\_\_ you are a man older than 45 years
- \_\_\_\_you are a woman older than 55 years, have
- had a hysterectomy, or are postmenopausal
- \_\_\_\_ you smoke or quit smoking within the previous 6 months

If you marked any of these statements in this section, consult you physician or other health care provider before engaging in exercise. You may need to use a facility with a medically qualified staff.

If you marked two or more of the statements in this section you should consult your physician or other health care provider before engaging in exercise. You might benefit from using a facility with a professionally qualified exercise staff to guide your exercise program.

- \_\_\_ your blood pressure is >140/90mmHg
- \_\_\_\_you do not know your blood pressure
- \_\_\_\_\_you take blood pressure medication
- \_\_\_\_your cholesterol is > 200 mg/dL

\_\_\_\_\_you have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister) \_\_\_\_you are physically inactive (you get < 30 minutes of physical activity on at least 3 days

per week you are > 20 pounds overweight

None of the above

You should be able to exercise safely without consulting your physician or other health care provider in a self-guided program or almost any facility that meets
your exercise needs.

# Joint-Muscle Status (Check areas where you currently have problems)

Joint Areas	Muscle areas
( ) Wrists	( ) Arms
( ) Elbows	( ) Shoulders
( ) Shoulders	( ) Chest
() Upper Spine and Neck	() Upper Back and Neck
( ) Lower Spine	() Abdominal Regions
( ) Hips	( ) Lower Back
() Knees	( ) Buttocks
() Ankles	( ) Thighs
( ) Feet	( ) Lower Leg
( ) Other	( ) Feet
	( ) Other

Please expand on problem:

When did this injury/problem occur:

Have you been cleared by your primary care physician to participate in exercise: YES  $$\rm NO$$ 

All you currently able to excluse without pain/disconnion. I ES IN	Are y	you currently al	ble to exercise	without	pain/discon	nfort:	YES	NO
--	-------	------------------	-----------------	---------	-------------	--------	-----	----

# **Physical Activity Status** (Check any of the following if they are characteristic of your current habits)

Within the past 3 months have you:

- () participated in a fitness class, or uses aerobic training equipment
- ( ) gone for long walks
- () ridden a bicycle
- ( ) jogged/run for exercise
- () regularly participated in a weight training program

( ) engaged in a sports program more than once a week. If so, what does that program consist of?