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An Accurate VO2max Non-exercise Regression Model for 18 to 65 Year Old Adults

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AN ACCURATE VO$_{2max}$ NON-EXERCISE REGRESSION MODEL

FOR 18 TO 65 YEAR-OLD ADULTS

By

Danielle I. Bradshaw

A thesis submitted to the faculty of

Brigham Young University

in partial fulfillment of the requirements for the degree of

Master of Science

Department of Physical Education

Brigham Young University

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BRIGHAM YOUNG UNIVERSITY

GRADUATE COMMITTEE APPROVAL

of a thesis submitted by

Danielle I. Bradshaw

This thesis has been read by each member of the following graduate committee and by
majority vote has been found to be satisfactory.

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BRIGHAM YOUNG UNIVERSITY

As chair of the candidate's graduate committee, I have read the thesis of Danielle I. Bradshaw in its final form and have found that (1) its format, citations, and bibliographical style are consistent and acceptable and fulfill university and department style requirements; (2) its illustrative materials including figures, tables and charts are in place; and (3) the final manuscript is satisfactory to the graduate committee and is ready for submission to the university library.

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ABSTRACT

AN ACCURATE VO$_{2max}$ NON-EXERCISE REGRESSION MODEL

FOR 18 TO 65 YEAR-OLD ADULTS

Danielle I. Bradshaw

Department of Physical Education

Master of Science

The purpose of this study was to develop a regression equation to predict VO$_{2max}$ based on non-exercise (N-EX) data. All participants (N = 100), aged 18-65 years old, successfully completed a maximal graded exercise test (GXT) to assess VO$_{2max}$ (mean ± SD; 39.96 mL·kg^{-1}·min^{-1} ± 9.54 mL·kg^{-1}·min^{-1}). The N-EX data collected just before the maximal GXT included the participant's age, gender, body mass index (BMI), perceived functional ability (PFA) to walk, jog, or run given distances, and current physical activity (PA-R) level. Multiple linear regression generated the following N-EX prediction equation (R = .93, SEE = 3.45 mL·kg^{-1}·min^{-1}, %SEE = 8.62): VO$_{2max}$ (mL·kg^{-1}·min^{-1}) = 48.0730 + (6.1779 x gender) – (0.2463 x age) – (0.6186 x BMI) + (0.7115 x PFA) + (0.6709 x PA-R). Cross validation using PRESS (predicted residual sum of squares) statistics revealed minimal shrinkage (R$_p$ = .91 and SEE$_p$ = 3.63 mL·kg^{-1}·min^{-1}); thus, this model should yield acceptable accuracy when applied to an independent sample of adults

(aged 18-65) with a similar cardiorespiratory fitness level. Based on standardized β-weights the PFA variable (0.41) was the most effective at predicting VO_{2max} followed by age (-0.34), gender (0.33), BMI (-0.27), and PA-R (0.16). This study provides a N-EX regression model that yields relatively accurate results and is a convenient way to predict VO_{2max} in adult men and women.

Key Words: Exercise Testing, Cardiorespiratory Fitness

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AN ACCURATE VO$_{2max}$ NON-EXERCISE REGRESSION MODEL

FOR 18 TO 65 YEAR-OLD ADULTS

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Abstract

The purpose of this study was to develop a regression equation to predict VO_{2max} based on non-exercise (N-EX) data. All participants (N = 100), aged 18-65 years old, successfully completed a maximal graded exercise test (GXT) to assess VO_{2max} (mean ± SD; 39.96 mL·kg^{-1}·min^{-1} ± 9.54 mL·kg^{-1}·min^{-1}). The N-EX data collected just before the maximal GXT included the participant's age, gender, body mass index (BMI), perceived functional ability (PFA) to walk, jog, or run given distances, and current physical activity (PA-R) level. Multiple linear regression generated the following N-EX prediction equation (R = .93, SEE = 3.45 mL·kg^{-1}·min^{-1}, % SEE = 8.62): VO_{2max} (mL·kg^{-1}·min^{-1}) = 48.0730 + (6.1779 x gender) – (0.2463 x age) – (0.6186 x BMI) + (0.7115 x PFA) + (0.6709 x PA-R). Cross validation using PRESS (predicted residual sum of squares) statistics revealed minimal shrinkage (R_p = .91 and SEE_p = 3.63 mL·kg^{-1}·min^{-1}); thus, this model should yield acceptable accuracy when applied to an independent sample of adults (aged 18-65) with a similar cardiorespiratory fitness level. Based on standardized β-weights the PFA variable (0.41) was the most effective at predicting VO_{2max} followed by age (-0.34), gender (0.33), BMI (-0.27), and PA-R (0.16). This study provides a N-EX regression model that yields relatively accurate results and is a convenient way to predict VO_{2max} in adult men and women.

Key Words: Exercise Testing, Cardiorespiratory Fitness

Introduction

Cardiorespiratory fitness (CRF) is the ability to perform dynamic, moderate-to-high intensity exercise with the large muscle groups for long periods of time (American College of Sports Medicine (ACSM), 2000). Cardiorespiratory fitness depends on the respiratory, cardiovascular, and skeletal muscle systems and, therefore, is an important component of health and physical fitness (ACSM). The assessment of CRF is valuable when educating individuals about their overall fitness status, developing exercise programs, and stratifying cardiovascular risk (ACSM).

The standard test for determining CRF is the measurement of maximal oxygen uptake (VO_{2max}) during the performance of a maximal graded exercise test (GXT) (ACSM, 2000). VO_{2max} is the most accurate way to assess CRF, however, the test requires costly equipment, the necessary space to house the equipment, and trained personnel to administer the test. In addition, maximal GXTs are unappealing to some individuals because the test requires strenuous exercise to the point of volitional exhaustion. Because of this, some older or higher-risk individuals should not perform the test without medical supervision (ACSM).

Due to the possible drawbacks of maximal GXTs and the direct measurement of VO_{2max}, submaximal exercise tests are available and provide an acceptable prediction of CRF and VO_{2max}. Submaximal exercise tests use prediction variables such as age, gender, body mass, exercise pace, and exercise heart rate to predict VO_{2max} (ACSM, 2000). Although not as accurate as maximal GXTs, submaximal exercise tests are easier to perform, require less time and effort to complete, and can be administered at lower costs and

reduced risk (ACSM). These tests use a variety of exercise modes including cycle ergometry, stepping and walking, jogging or running on a treadmill or track (ACSM, 2000; Bruce, Kusumi, & Hosmer, 1973; Cooper, 1968; Kline, Porcari, Hintermeister, Freedson, & Ward, 1987; Astrand & Ryhming, 1960).

Other methods that do not require exercise are also available to predict VO_{2max} (ACSM, 2000). Non-exercise (N-EX) regression equations provide a convenient estimate of CRF without the need to perform a maximal or submaximal exercise test. This approach is inexpensive, time-efficient, and realistic for large groups. To date, N-EX predictor variables include age, gender, body mass index (BMI), percent body fat, physical activity rating (PA-R) (Jackson, Blair, Mahar, Wier, & Rossand, 1990; Heil, Freedson, Ahlquist, Price, & Rippe, 1995) and perceived functional ability (PFA) (George, Stone, & Burkett, 1997). The PFA includes simple questions which ask individuals to rate their ability to exercise at a comfortable pace for one and three miles. Studies show N-EX equations are relatively accurate and provide a quick and easy way to predict VO_{2max} (Jackson et al., 1990, Heil et al., 1995, George et al., 1997). To date, PA-R has been validated in a large sample of 18-70 year-old men and women, but PFA has only been validated in a sample of college-aged men and women. Thus, there is a need to further evaluate PFA as a predictor variable in estimating CRF with a broader age range.

Methods

Participants

One hundred participants (50 females and 50 males), aged 18-65 years, participated in this study. Participants were recruited from the Y-Be-Fit Wellness Program at Brigham Young University and employees from the LDS Hospital in Salt Lake City, Utah. Participants were classified as either low or moderate risk according to ACSM guidelines for exercise testing. Moderate risk individuals (males $\geq$ 45 years of age, females $\geq$ 55 years of age) were tested at the LDS Hospital under physician supervision to comply with ACSM recommendations (ACSM, 2000). All participants completed a Physical Activity Readiness Questionnaire (PAR-Q) and signed an informed consent document that was approved by the BYU Institutional Review Board for Human Subjects.

Procedures

Participants' height and body mass were measured and recorded while wearing lightweight clothing and no shoes, using a stadiometer and balance beam scale, respectively. All participants completed a maximal treadmill GXT. Instructions about the maximal GXT (involving the protocol, electronic heart rate monitor, head-gear, mouth piece, nose-clip, and rating of perceived exertion (RPE) scale (Borg, 1982) were given to all participants prior to testing.

Maximal Treadmill Graded Exercise Test

Participants performed a maximal GXT using a modified version of the Arizona State University (ASU) maximal protocol (George, 1996), with only a slight change in

the warm-up. The warm-up consisted of having participants complete up to three 4-minute stages and reach 75% of maximum heart rate (HR_{max}). During the first stage, participants walked at a self-selected brisk pace, 3-4 mph. If participants progressed to the second stage the speed was increased to a self-selected jogging pace between 4 and 6 mph. If 75% of HR_{max} was not achieved by the end of the second stage, participants continued to the third stage where the speed was increased to 6 mph or greater. Following the warm-up, participants rested for approximately 5 minutes, while the test administrator explained the test procedures for the maximal GXT and fit participants with a mouthpiece and nose clip. The ending speed of the warm-up served as the necessary pace for the maximal GXT. Thereafter, the grade was increased 1.5% each minute, while pace remained the same, and continued until participants reached volitional fatigue and were no longer able to continue.

During the maximal GXT, metabolic gases were collected using the TrueMax 2400 metabolic measurement system (Consentius Technologies, Sandy, UT). The VO_2 and respiratory exchange ratio (RER) were computed, averaged, and printed by an on-line computer system every 15 seconds. The participants' exercise heart rate (HR) and RPE score was recorded at the end of each stage. VO_{2max} was considered valid when at least two of the following three criteria were met (ACSM, 2000; Howley, Bassett, & Welch, 1995):

1. Maximal heart rate within 15 beats of age predicted maximal heart rate.

2. Respiratory exchange ratio equal to or greater than 1.10.

3. Plateau in VO_2 despite an increase in work load.

Participants who failed to meet at least two of these criteria were dropped from the study.

Non-exercise Questionnaire

Prior to exercise testing participants completed the PFA (George et al., 1997) and a modified PA-R non-exercise questionnaire (Jackson et al., 1990; George et al., 1997). The PFA includes two questions that ascertain how fast participants feel they can cover a 1 and 3 mile distance at a comfortable pace. The participant's sum total of both 13-point questions is counted as the PFA score (range 2-26).   The original PA-R questionnaire has individuals rate their level of activity on a 7-point scale over the past month. However, Kolkhorst and Dolgener (1994) noted that an extended time reference might represent participants' overall average physical activity level more accurately. Thus, the PA-R questionnaire was modified with a longer 6-month time reference and expanded 10-point scale.

Statistics

Multiple linear regression was used to create a VO_{2max} regression model using age, gender, BMI, PFA, and PA-R as predictor variables. The validity of the VO_{2max} equation was evaluated based on the correlation coefficient and the standard error of estimate (SEE). Predicted residual sum of squares (PRESS) statistics (Holiday, Ballard, & McKeown, 1995) were also computed to estimate the degree of shrinkage one could expect when the VO_{2max} prediction equation is used across similar, but independent samples. Our data was also inputted into the Jackson et al. (1990) N-EX equation to cross validate its accuracy in predicting $VO_{2max.}$ The statistical significance level was set at $p < .05$.

Results

One hundred and nine participants (aged 18 to 65 years) volunteered for this study, however, nine participants were dropped from the analysis because they did not satisfy the VO_{2max} criteria. Descriptive statistics for the total sample and specific age groups are presented in Table 1. All participants achieved a valid VO_{2max} during the maximum GXT with the average ($\pm$ SD) VO_{2max} equal to 39.96 ± 9.54 mL·kg⁻¹·min⁻¹. Corresponding RER_{max} values (1.19 ± 0.05), HR_{max} (184.40 ± 12.30 beats·min⁻¹), and maximum RPE scores (19.19 ± 0.75) were all indicative of maximum effort. Participants body mass, height, and BMI ranged from 48.08 to 115.94 kg, 1.47 to 1.92 m, and 18.79 to 38.93 kg·m⁻², respectively. Participants PFA and PA-R scores ranged from 2 to 26 and 1 to 10, respectively. Descriptive statistics for the male and female samples are also presented in Table 2.

Multiple linear regression generated the following N-EX prediction equation (R = .93; SEE = 3.45 mL·kg⁻¹·min⁻¹): VO_{2max} (mL·kg⁻¹·min⁻¹) = 48.073 + (6.178 x gender) – (0.246 x age) – (0.619 x BMI) + (0.712 x PFA) + (0.671 x PA-R). Each independent variable was statistically significant ($p < .05$) in predicting VO_{2max}. Standardized β-weights showed the PFA variable (0.41) to be the most effective at predicting VO_{2max}, followed by age (-0.34), gender (0.33), BMI (-0.27), and PA-R (0.16). Figure 1 provides a scatter plot of predicted versus observed VO_{2max} values for the N-EX regression model. The cross-validation PRESS statistics ($R_p = .91$ and $SEE_p = 3.63$ mL·kg⁻¹·min⁻¹) show minimal shrinkage in predictive accuracy.

Discussion

The N-EX regression model developed in this study predicts VO_{2max} accurately

(R = .93; SEE = 3.45 mL·kg⁻¹·min⁻¹) in this sample of men and women, aged 18 to 65

years. Other age-generalized N-EX models created by Jackson et al. (1990) (R = .78,

SEE = 5.70 mL·kg⁻¹·min⁻¹) and Heil et al. (1995) (R = .88, SEE = 4.90 mL·kg⁻¹·min⁻¹) are

also relatively accurate, but less precise. The results of this study are very similar to

those reported by George et al. (1997; R = .85 and SEE = 3.44 mL·kg⁻¹·min⁻¹) who was

the first to include the PFA variable. Surprisingly, the best maximal EX models such as

the 1.5 mile run developed by Cooper (1968) (R = .90), the Bruce treadmill test (1973) (R

=.93, SEE = 3.13 mL·kg⁻¹·min⁻¹), and the ASU treadmill test (George, 1996) (R = .95,

SEE = 2.13 mL·kg⁻¹·min⁻¹) are only slightly more accurate than the present N-EX model.

Several submaximal EX models are less accurate, such as the Rockport Fitness Walking

Test (R = .88 and SEE = 5.00 mL·kg⁻¹·min⁻¹), the 20-Meter Shuttle Test (R = .72 and SEE

= 5.26 mL·kg⁻¹·min⁻¹), and the Ebbeling treadmill walking test (R = .91, SEE = 4.84

mL·kg⁻¹·min⁻¹).

The β-weight analyses show that the PFA variable explains most of the variance

in predicting VO_{2max}. Table 3 shows the β-weights for each independent variable with

PFA (0.412) higher than age (-0.341), gender (0.326), BMI (-0.270) and PA-R (0.162).

Dropping PFA out of the model lowers the multiple correlation coefficient (R) from .93

to .89 and increases the SEE from 3.45 mL·kg⁻¹·min⁻¹ to 4.20 mL·kg⁻¹·min⁻¹. A possible

reason why the PFA variable is effective is that it mimics the role of an EX variable and

helps to classify participants as walkers, joggers, or runners based on their response to

how fast they feel they can cover a one and three mile distance at a comfortable pace. According to PFA scores, 25 participants were in the walking category (PFA = 7.12 ± 2.24, measured VO_{2max} = 29.51 ± 5.21 mL·kg⁻¹·min⁻¹), 53 participants were in the jogging category (PFA = 14.96 ± 2.33, measured VO_{2max} = 40.42 ± 6.25 mL·kg⁻¹·min⁻¹), and 22 participants were in the running category (PFA = 21.73 ± 2.07, measured VO_{2max} = 50.71 ± 5.77 mL·kg⁻¹·min⁻¹) with each group significantly different (p< .05) (see Figure 2). In a similar way, EX models such as the 1.5-mile run, separate participants into categories, based on how fast the 1.5-mile distance is completed (Cooper, 1968).

As a cross-validation comparison, we entered our data (age, gender, BMI, and PA-R scores) into the Jackson et al. (1990) N-EX regression equation. The estimated VO_{2max} results were relatively accurate (r = .89, SEE = 4.42 mL·kg⁻¹·min⁻¹) and very similar to the current N-EX model with the PFA variable not included (R = .89, SEE = 4.20 mL·kg⁻¹·min⁻¹). The Jackson model slightly underestimated measured VO_{2max} (predicted VO_{2max} = 38.06 mL·kg⁻¹·min⁻¹, measured VO_{2max} = 39.95 mL·kg⁻¹·min⁻¹; p < .0001). These small differences may be a result of sample differences or differences in response to the original versus modified PA-R question.

Dustman-Allen et al. (2003) reported contrasting results in a cross validation of the N-EX regression equation developed by George et al. (1997). Dustman-Allen et al. (2003) assessed 66 participants who were similar in age (18-29 yr) to the validation sample. The study reported r and SEE values of .53 and 5.3 mL·kg⁻¹·min⁻¹ for females and .59 and 4.4 mL·kg⁻¹·min⁻¹ for males. The measured and predicted VO_{2max} values were similar for females, (measured VO_{2max} = 40.8 ± 6.2 mL·kg⁻¹·min⁻¹ and predicted

$VO_{2max} = 39.9 \pm 4.8$ mL·kg^{-1}·min^{-1}), but dissimilar for males (measured $VO_{2max} = 50.4 \pm$

5.4 mL·kg^{-1}·min^{-1} and predicted $VO_{2max} = 47.2 \pm 5.0$ mL·kg^{-1}·min^{-1}). It is difficult to

explain why the results of the Dustman-Allen et al., (2003) study were so different than

the present study and the original George et al. (1997) study. In addition, it is logical to

assume that if Dustman-Allen et al., (2003) had not included the PFA data in the

prediction of VO_{2max} their results would have been worse. Future studies need to clarify

the accuracy of the PFA variable across various samples.

It is interesting to note that the 30-39 year old group reported a higher mean PFA

(15.8 vs. 17.1) and PA-R levels (4.6 vs. 5.6) than the 18-29 year old group (see Table 1).

The older group also had a slightly higher mean absolute VO_{2max} (3.25 L·min^{-1} vs. 3.28

L·min^{-1}), yet a lower mean relative VO_{2max} (45.1 mL·kg^{-1}·min^{-1} vs. 43.9 mL·kg^{-1}·min^{-1})

because of a higher mean body mass (72.4 kg vs. 74.8 kg). This finding is difficult to

explain. It may be that the 30-39 year old group has a slightly higher mean relative

VO_{2max} than that the actual population norm for this group, along with correspondingly

higher PFA and PA-R values. It may also be partially explained by the subjective nature

of the questionnaire. However, this small difference between age groups does not appear

to affect the overall accuracy of the model.

Although the N-EX model developed in this study presents excellent results, there

are obvious limitations when using non-exercise data. For instance, individuals who are

unfamiliar with prolonged aerobic exercise or unfamiliar with the pace it would take to

cover 1 and 3 miles may report inaccurate PFA scores. Individuals who dislike to jog or

run may underestimate their PFA score because they prefer to walk. Former athletes may

overestimate their PFA score because they believe they still have the ability to run at a fast pace. The PA-R score is subjective as well and depends on participants being able to distinguish between light, moderate, and vigorous activity. To be accurate, participants must correctly recall their level of physical activity over the past 6 months. Finally, it is possible to measure body mass and height (and calculate BMI scores) and not have it self-reported, which may help to decrease some possible error. However, whether body mass and height are measured or self-reported probably has little bearing on the VO_{2max} prediction as reported by Jackson et al. (1990) and George et al. (1997).

There are various advantages and disadvantages to EX and N-EX VO_{2max} regression models. An important feature of EX models is the actual exercise test. As the test progresses from a low-to-high exercise intensity the participant's HR and RPE response can be used in developing a safe and effective aerobic exercise prescription. In addition, EX models yield relatively accurate VO_{2max} predictions. However, EX tests take time to complete, often require expensive equipment, and may not allow for testing large groups of people at the same time. Despite these possible drawbacks, EX models are still preferred over N-EX models when the participant can safely perform an exercise test. However, N-EX models serve as a valuable alternative to EX tests. Such models predict CRF through questionnaire based data and are administered without expensive administrative costs and time restraints. Non-exercise models are the most practical method for assessing VO_{2max} in large populations and may be useful in large epidemiological studies. Non-exercise models may also be used in university wellness and physical education classes to teach students the relationship between VO_{2max} and

PFA. Finally, because of the subjective nature of N-EX models, they are not suitable for

settings where CRF or the functional capacity of the person must be measured (e.g., when

qualifying for the military, civil service, or police academy).

In conclusion, the new N-EX prediction model developed in this study provides

an accurate and convenient way to predict VO_{2max} in adult men and women. The

accuracy of this N-EX model is similar to many of the popular N-EX models. The results

show that the PFA variable significantly improves the ability of the regression model to

accurately predict VO_{2max}. Future studies are needed to evaluate the accuracy and

generalizability of the PFA variable and N-EX regression model in a variety of samples.

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Table 1

Descriptive Statistics for Exercise and N-EX Data

Variable	Total (n = 100)	18-29 yr (n = 30)	30-39 yr (n = 23)	40-49 yr (n = 26)	50-65 yr (n = 21)
Age (yr)	37.50 ± 13.21	22.10 ± 1.92	32.22 ± 2.89	45.23 ± 3.19	55.71 ± 4.86
Female	50	15	13	13	9
Male	50	15	10	13	12
Height (m)	1.71 ± 0.09	1.74 ± 0.10	1.72 ± 0.10	1.70 ± 0.09	1.70 ± 0.06
Body mass (kg)	74.71 ± 15.18	72.43 ± 14.49	74.85 ± 13.88	75.20 ± 15.76	77.21 ± 17.34
Maximal Treadmill Test					
VO_{2max} (L·min^{-1})	2.96 ± 0.82	3.25 ± 0.73	3.28 ± 0.85	2.78 ± 0.83	2.41 ± 0.59
VO_{2max} (mL·kg^{-1}·min^{-1})	39.96 ± 9.54	45.17 ± 7.59	43.91 ± 8.91	37.31 ± 8.98	31.47 ± 5.93
HR_{max} (beats·min^{-1})	184.40 ± 12.30	194.73 ± 5.41	189.30 ± 8.19	178.65 ± 9.23	171.38 ± 10.84
RPE_{max} (15-point scale)	19.19 ± 0.75	19.50 ± 0.68	19.26 ± 0.62	18.96 ± 0.72	19.95 ± 0.86
RER_{max} ($VCO_2 \div VO_2$)	1.19 ± 0.05	1.19 ± 0.05	1.16 ± 0.04	1.20 ± 0.05	1.18 ± 0.04
N-EX Questions					
PFA	14.49 ± 5.52	15.87 ± 4.92	17.13 ± 5.06	14.15 ± 5.10	10.05 ± 4.83
PA-R	4.95 ± 2.30	4.60 ± 1.73	5.61 ± 2.59	5.54 ± 2.44	4.00 ± 2.21

All data = mean ± SD.

PFA = perceived functional ability (2-26 point scale).

PA-R = physical activity rating (10 point scale).

Table 2

Descriptive Statistics For The Total, Female, and Male Participants

Variable	Total (n = 100)	Females (n = 100)	Males (N = 100)
Age (yr)	37.50 ± 13.22	37.24 ± 13.79	37.76 ± 12.76
Height (m)	1.72 ± 0.09	1.65 ± 0.07	1.78 ± 0.06
Body mass (kg)	74.71 ± 15.19	66.40 ± 12.39	83.02 ± 13.10
BMI (kg·m^{-2})	25.22 ± 4.17	24.27 ± 3.85	26.16 ± 4.29
Perceived Functional Ability (PFA)	14.49 ± 5.52	12.88 ± 5.34	16.10 ± 5.26
Physical Activity Rating (PA-R)	4.95 ± 2.30	4.88 ± 2.32	5.02 ± 2.30
Maximal Treadmill Values			
VO$_{2max}$ (L·min^{-1})	2.96 ± 0.82	2.35 ± 0.49	3.56 ± 0.63
VO$_{2max}$ (mL·kg^{-1}·min^{-1})	39.96 ± 9.54	36.32 ± 8.91	43.59 ± 8.80
HR$_{max}$ (beats·min^{-1})	184.40 ± 12.30	181.98 ± 13.66	186.82 ± 10.35
RPE (15-point scale)	19.19 ± 0.75	19.26 ± 0.66	19.12 ± 0.82
RER (VCO$_2$ ÷ VO$_2$)	1.19 ± 0.05	1.18 ± 0.05	1.19 ± 0.05

Table 3

N-EX VO$_{2max}$ Regression Equation (n = 100)

Variable	β	β-weight
Intercept	48.073	
Gender (0 = female, 1 = male)	6.178	0.326
Age	-0.246	-0.341
BMI (kg·m^{-2})	-0.619	-0.27
Perceived Functional Ability (PFA)	0.711	0.412
Physical Activity Rating (PA-R)	0.671	0.162
R	0.93	
SEE (ml· kg^{-1}·min^{-1})	3.44	
SEE PRESS (mL·kg^{-1}·min^{-1})	3.63	
% SEE (% of VO$_{2max}$)	8.62	

[a]β-weights = standard multiple regression coefficients

$R_{PRESS} = (1-(PRESS/SS_{total}))^{-1/2}$
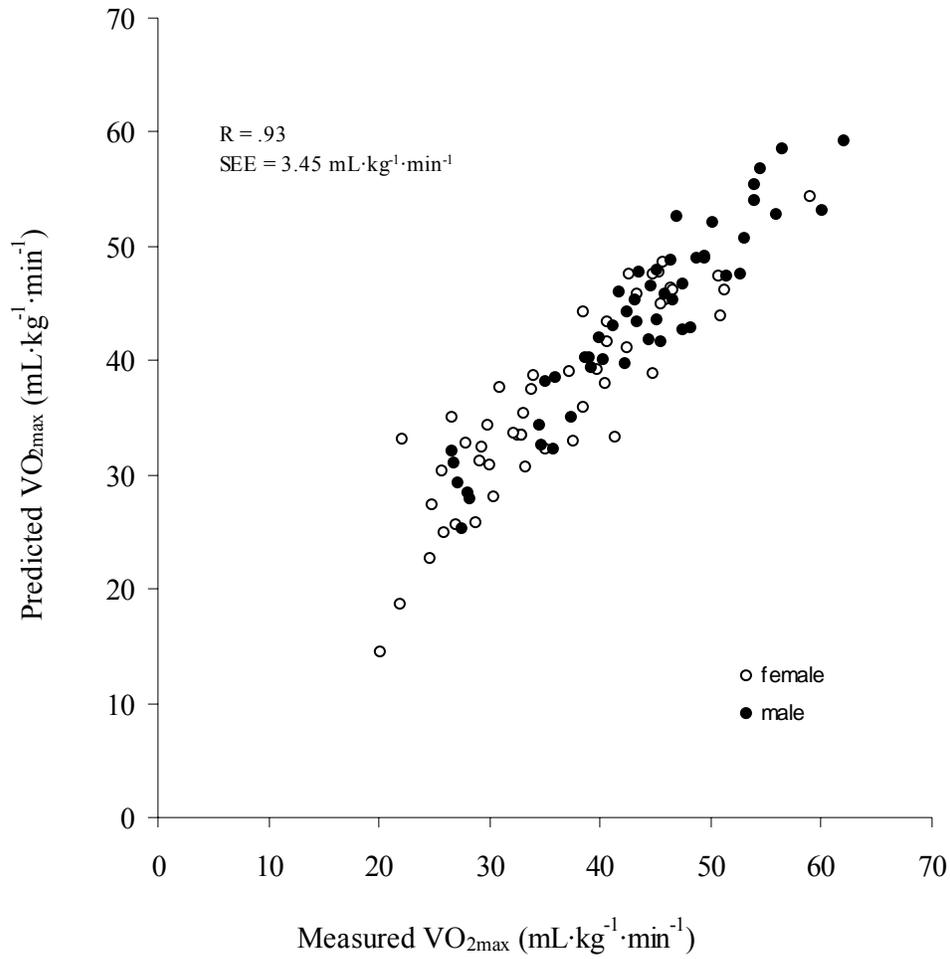
$SEE_{PRESS} = (PRESS/n)^{-1/2}$

Figure 1. Predicted VO_{2max} vs. Measured VO_{2max} Scatter Plot
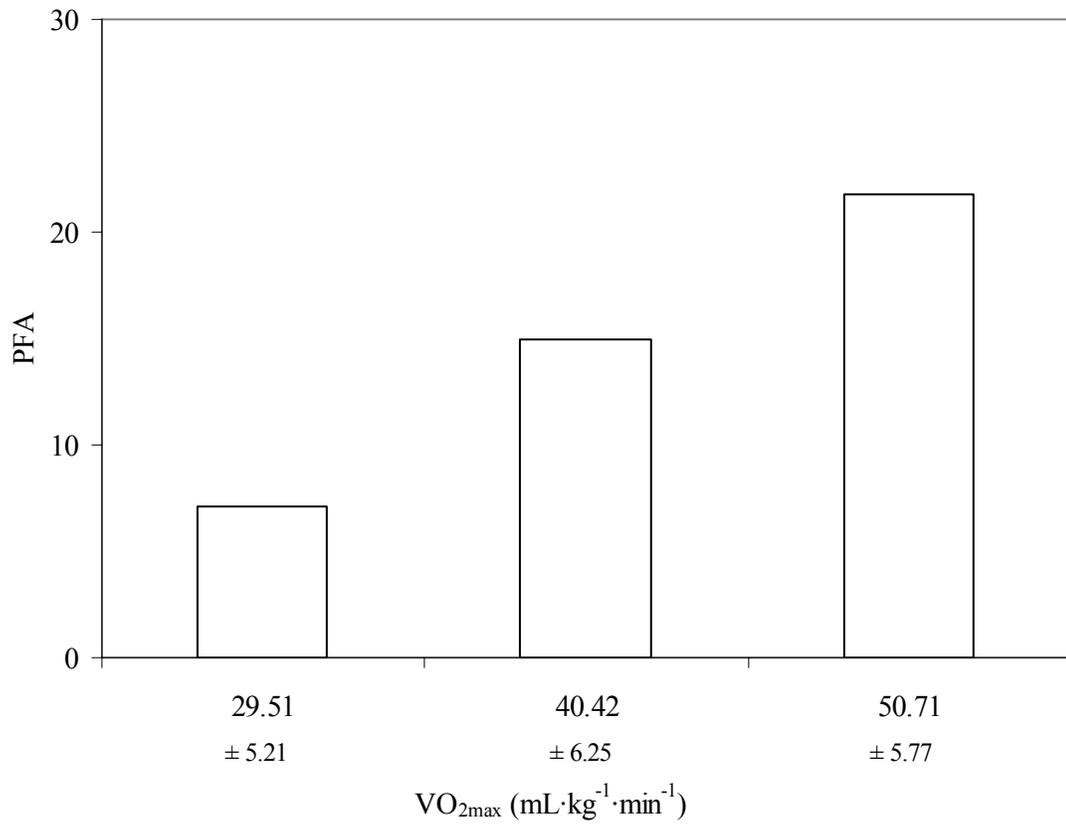
Figure 2. PFA and Measured VO_{2max} (mean $\pm$ S.D.)
Significantly different ($p < .05$) between groups

Appendix A

Prospectus

Chapter 1

Introduction

Cardiorespiratory fitness (CRF) is the ability to perform dynamic, moderate-to-high intensity exercise with the large muscle groups for long periods of time (American College of Sports Medicine, 2000). CRF depends on the respiratory, cardiovascular, and skeletal muscle systems and therefore is an important component of health and physical fitness (ACSM). The assessment of CRF is valuable when educating individuals about their overall fitness status, developing exercise programs, and stratifying cardiovascular risk (ACSM).

The standard test for determining CRF is the measurement of maximal oxygen uptake (VO_{2max}) during the performance of a maximal graded exercise test (GXT) (ACSM, 2000). VO_{2max} is the most accurate way to assess CRF however, the process involves inconvenient methods that require costly equipment, space, and trained personnel. In addition, maximal GXTs are unappealing to some individuals because the test requires strenuous exercise to the point of volitional exhaustion. Because the potential risk for injury is high, this type of maximal exertion is not recommended for some populations (elderly, obese, sedentary, injured, or diseased individuals) without medical supervision (ACSM).

Due to the possible drawbacks of maximal GXT's and the direct measurement of VO_{2max} many submaximal exercise tests are available to predict VO_{2max}. Submaximal exercise tests use variables such as exercise pace, exercise heart rate, body mass, gender, and age to predict VO_{2max} (ACSM, 2000). Although not as accurate as maximal GXT's,

submaximal exercise tests are easier to perform, require less time and effort to complete, and can be administered at lower costs and reduced risk (ACSM). These tests use a variety of exercise modes including cycle ergometry, stepping and walking, jogging or running on a treadmill or track.

Other methods that do not require exercise are also available to predict VO_{2max} (ACSM, 2000). Non-exercise (N-EX) regression equations provide a convenient estimate of CRF without the need to perform a maximal or submaximal exercise test. This approach is inexpensive, time-efficient, and realistic for large groups. Common N-EX predictor variables include age, gender, body mass index (BMI), percent body fat, physical activity rating (PA-R) (Jackson et al., 1990; Heil et al., 1995) and perceived functional ability (PFA) (George et al., 1997). The PFA includes simple questions which ask individuals to rate their ability to exercise at a comfortable pace for 1 and 3 miles. Studies show N-EX equations are relatively accurate and provide a quick and easy way to predict VO_{2max} (Jackson et al., 1990, Heil et al., 1995, George et al., 1997). Although the PA-R has been used in a non-exercise model to predict CRF in a large sample of 18-70 year old men and women, the PFA questionnaire has only been validated in a sample of college aged men and women. Thus, there is a need to further evaluate PFA as a predictor variable in estimating CRF with a more diverse age range.

This study will 1) examine the relationship between measured VO_{2max} and predicted VO_{2max} from N-EX variables in men and women between the ages of 18 and 65 years of age 2) evaluate how well the N-EX predictor variables (PFA, PA-R, BMI,

gender, and age) estimate VO_{2max} and 3) create a N-EX VO_{2max} prediction equation using multiple linear regression.

Purpose

The purpose of this study is to generate a N-EX regression equation based on N-EX independent variables to predict VO_{2max} in an older population, aged 18-65.

Hypothesis

Non-exercise questionnaires and anthropometric variables accurately predict VO_{2max} in men and women between the ages of 18-65.

Null Hypothesis

Non-exercise questionnaires and anthropometric variables do not accurately predict VO_{2max} in men and women between the ages of 18-65.

Operational Definitions

Age Predicted Maximum Heart Rate: 220 – age

Cardiorespiratory Fitness (CRF): The ability to perform dynamic, moderate-to-high intensity exercise with the large muscle groups for prolonged periods of time

Graded Exercise Test (GXT): A test to assess an individuals' cardiorespiratory endurance where exercise intensity is gradually increased until one reaches fatigue.

Maximum oxygen consumption (VO_{2max}): The body's maximal ability to deliver and consume oxygen.

Physical activity rating (PAR): A numerical value (1-10) describing ones' self-reported physical activity over the previous 6 months.

Perceived functional ability (PFA): A numerical value (1-13) describing ones' perceived ability to walk, jog, or run for 1-mile and 3-miles.

Assumptions

Participants will reach a true VO_{2max} during the maximal GXT on the treadmill. Participants will accurately self-report their physical activity level and perceived functional ability when completing the non-exercise questionnaires. The metabolic equipment used to measure VO_2 during the maximal GXT will be calibrated correctly.

Delimitations

Participants will be 18-65 years old. Only participants who can complete a valid maximal GXT will be included in the data set.

Limitations

Participants will be recruited from the LDS Hospital in Salt Lake City, UT and the Y-Be-Fit Program at Brigham Young University. Thus the sample may not be representative of the general population.

Significance of Study

Non-exercise prediction models provide useful measures of CRF because they allow for quick, easy predictions of VO_{2max}. N-EX models provide an alternative to submaximal or maximal exercise tests since they are time-efficient, convenient, and can be applied to many different people. The evaluation of the PFA variable in the prediction of CRF in a broad age group is an important contribution of this study.

Chapter 2

Review of Literature

Cardiorespiratory fitness (CRF) is the ability to perform moderate-to-high intensity dynamic exercise with the large muscle groups for prolonged periods of time and is an important component in assessing individual health (American College of Sports Medicine, 2000). Cardiorespiratory fitness relies on the functional state of the respiratory, cardiovascular, and skeletal muscle systems to perform physical activity and work (ACSM, 2000). Maximal oxygen uptake (VO_{2max}) is the maximal amount of oxygen an individual can utilize during exercise and is the best measure of CRF (ACSM, 2000; Mitchel & Blomqvist, 1971).

Knowledge of an individual's VO_{2max} is important in the evaluation of cardiovascular function. Highly fit individuals have a greater capacity to transport oxygen to the body's active tissues and therefore have high VO_{2max} values (Noakes, 1988). Individuals who are sedentary or less active have lower VO_{2max} values, and are at greater risk for cardiovascular disease and all-cause mortality (Blair, Kannel, Kohl, Goodyear & Wilson, 1988). Thus, VO_{2max} is a useful criterion in assessing one's fitness level and risk for cardiovascular disease. Knowledge of VO_{2max} can also be used to make appropriate recommendations to improve individual health, functional capacity and athletic performance (ACSM, 2000).

The gold standard for determining CRF is the direct measurement of VO_{2max} during a maximal GXT. Maximal GXTs provide the most accurate method for assessing an individuals' aerobic capacity. Several maximal exercise tests (Maud & Foster, 1995;

George, 1996; ACSM, 2000) exist and although each test has its advantages, performing a maximal GXT is not practical in many situations. The process involves inconvenient methods that require costly equipment, space, trained personnel and exercise to the point of volitional fatigue. To alleviate some of the disadvantages associated with maximal GXTs, alternative methods have been devised to estimate VO_{2max}. These include a variety of maximal and submaximal exercise tests and non-exercise protocols.

Exercise Tests

There are several maximal exercise test protocols available for use on treadmills (Maud & Foster, 1995; George, 1996; ACSM, 2000). All protocols advance the participant from a walking pace to a vigorous intensity of exercise as speed and/or grade of the treadmill is incrementally increased until the point of volitional fatigue or the appearance of significant adverse signs or symptoms. Each exercise stage typically lasts one to three minutes. Protocols differ by the length of the stages, initial workload, and the magnitude of the work increments between stages. Each protocol is suitable for specific purposes and few protocols are appropriate for all individuals. The Bruce or Ellestad protocols are most appropriate for younger and/or physically active individuals, while the Naughton or Balke-Ware protocols are most appropriate for older or deconditioned participants and patients with disease (ACSM, 2000).

A well-known and accepted maximal treadmill protocol is the Bruce multistage exercise test (Bruce, Kusumi, & Hosmer 1973). This test consists of six, three minute stages in which participants exercise to the point of volitional fatigue. The Bruce protocol starts with participants walking 1.7 mph at a 10% grade and imposes large

increments in the metabolic cost of exercise throughout test with each 3-min stage. The

Bruce protocol demonstrates relatively high predictive accuracy (r = .93, SEE = 3.13

mL·kg^{-1}·min^{-1}). However, the test is unappealing to many individuals because of the high

demand of work it abruptly enforces at the beginning of each stage. Because of large

increases in workload, the Bruce protocol is best suited for younger, healthy, physically

active individuals (ASCM, 2000).

Traditional maximal exercise test protocols require strict adherence to a protocol

which the participant has no control over. To overcome this problem, George (1996)

developed an individualized treadmill protocol that realistically accommodates

participants' fitness capabilities. The test, known as the Arizona State University (ASU)

protocol, allows participants, aged 18-29 years, to self-select their own exercise pace.

During the first three-minute stage of the GXT, participants walk at a brisk pace on a 5%

grade. In the second stage participants choose to either continue walking (5% grade) or

self-select a comfortable jogging pace on level ground. The first two stages last six

minutes and serve as a warm up. Afterwards, grade is increased 1.5% each minute until

the participant reaches volitional fatigue and is no longer able to continue. The ASU

protocol is valid (r = .98, SEE = 2.08-2.13 mL·kg^{-1}·min^{-1}), and compares favorably with

the Bruce protocol (SEE = 3.13 mL·kg^{-1}·min^{-1}) (Spackman, M.B., George, J.D.

Pennington, T.R., & Fellingham, G.W., 2001). The VO$_{2max}$ predictor variables include

gender, body mass, maximal treadmill speed, and maximal treadmill grade.

Many laboratory or clinical submaximal tests have been developed to predict

VO$_{2max}$. These tests often use physiological responses (heart rate) to a bout of exercise to

predict CRF. To be valid several assumptions must be met: a steady-state heart rate is obtained for each exercise work rate, a linear relationship exists between heart rate and work rate, the maximal heart rate for a given age is uniform, and mechanical efficiency is the same for everyone (ACSM, 2000). Submaximal clinical tests are similar to maximal tests in that they both involve methods that require costly equipment, space, and trained personnel. In addition, the number of submaximal tests to be performed at one time is limited by the test protocol. Although submaximal tests are not as precise as maximal tests they are recognized as valid predictors of VO_{2max} and CRF (ACSM, 2000). Moreover, submaximal tests offer many advantages to maximal tests in that they are performed at a lower cost, reduced risk, and require less time and effort from the participant (ACSM, 2000). Submaximal laboratory tests use a variety of exercise modes including cycle ergometry, and walking, jogging or running on a treadmill.

Field-based exercise tests are often used to assess the CRF of an individual or group and can be performed outside of the traditional laboratory without the need of expensive equipment. Field-based tests often use performance as a predictor of CRF and consist of walking or running for either a certain distance or a given amount of time (ACSM, 2000). These tests are based on the premise that participants who complete the prescribed distance in the least amount of time or a longer distance in the prescribed amount of time have the highest levels of CRF. The 12-minute run test (Balke, 1963; Cooper, 1968) requires sustained vigorous exercise since the objective is to complete the furthest distance as possible in 12 minutes. The 1.5 mile (Cooper, 1963) run also requires sustained vigorous exercise while the participant completes the 1.5 mile distance in as

little time as possible. Because high exercise intensity is required, the 12-minute and 1.5

mile run tests are not considered submaximal tests. Submaximal tests, such as the one-

mile walk (Kline et al., 1987), require participants to walk one mile as fast as possible

and use heart rate recorded at the end of the mile in a regression equation to predict CRF.

The 1-mile track jog test (George et al., 1993) requires participants to jog at a self-

selected submaximal pace for 1 mile then uses the steady state heart rate in a regression

equation to predict CRF. Tests which use heart rate response to a submaximal workload

to predict CRF are based on the fact that regular exercise results in a lower heart rate

response to a given submaximal workload. Therefore, participants who have lower heart

rates during the submaximal exercise tests have higher levels of CRF. Field based tests

should be selected based on the appropriateness for the individual being tested.

Non-exercise Tests

N-EX protocols provide an estimate of CRF without the need to perform a

maximal or submaximal exercise test. These protocols are inexpensive, time-efficient,

realistic for large groups, and accommodate all levels of fitness. N-EX protocols use

information about the physical characteristics of an individual and his/her current

physical activity levels to predict CRF (Jackson et al., 1990, Heil et al., 1995, George et

al., 1997). Using simple questionnaires, self-reported N-EX predictor variables can be

assessed and used in regression equations to predict VO_{2max}. N-EX predictor variables

include age, gender, BMI, percent body fat, self-reported physical activity ratings (PA-R;

Jackson et al., 1990) and perceived functional ability (PFA; George et al., 1997). Studies

have validated the accuracy of N-EX equations, and suggest that they provide a quick and

useful prediction of VO_{2max} (Jackson et al., 1990, Heil et al., 1995, George et al., 1997). There are however, limitations involved in the self reporting of physical activity and body measurements. Generally individuals tend to underestimate their weight and overestimate their height and physical activity level.

In 1985, Siconolfi, Lasater, Snow, & Carleton studied the validity between two indices developed by Paffenbarger. Siconolfi et al. (1985) assessed Paffenbarger's Physical Activity Index Questionnaire and the reported number of times per week that vigorous activity caused sweating to occur (Paffenbarger, R.S Jr., Wolf, P.A., Notkin J. et al., 1966). Participants responded to the questionnaires and performed a VO_{2max} test on a cycle ergometer. The study population included 36 men and 32 women between the ages of 20 and 70 years old. Regression coefficients and equations were derived relating the maximal oxygen uptake, the physical activity level, and the frequency of sweating. Results showed correlations between maximal oxygen uptake and both activity measures (physical activity index with $VO_{2max} = 0.29$, $p < 0.05$; sweating frequency with $VO_{2max} = 0.46$, $p < .01$). The study concluded that the frequency of activity, sufficient to generate sweat, related closer to VO_{2max} than the Physical Activity Index.

In 1987 Kohl, Blair, Paffenbarger, Macera & Kronenfeld investigated the association between self-reported responses to physical activity and an objective measure of physical fitness. The study included 375 men of an average age of 47 years. All participants responded to a numeric physical activity questionnaire and completed a maximal treadmill protocol. Participants' reported exercise values were converted to estimates of energy expenditure and combined into overall indices of physical activity

participation. The variables that proved to be significant predictors of physical fitness

were age (β = -0.34), an index of running, walking, and jogging participation (β = 0.31)

and the frequency of sweating response (β = 0.35). The study reported a multiple

correlation coefficient of 0.65 between these variables and total treadmill time.

Jackson and colleagues (1990) developed a N-EX prediction model based on

2,009 individuals between 18 and 70 years old. The predictor variables included self-

reported PAR, age, body composition and gender. Participants VO_2 peak was measured

during the first three walking stages of the Bruce treadmill protocol. Self-reported PAR

was the most highly correlated variable with measured VO_2 peak. The multiple

regression equation developed by Jackson et al., (1990; VO_2 peak = 56.363 + 1.921(PA-

R) – 0.381(Age) – 0.754(BMI) + 10.987(F = 0, M = 1)) can be generalized to men and

women. The study confirmed that the N-EX model including self-reported PA-R, age,

BMI, and gender provided a valid estimate (R = 0.783, SEE = 5.70 ml· kg^{-1}·min^{-1}) of VO_2

peak. Results also illustrated that the N-EX model was more accurate than estimated

VO_2 peak from Astrand bicycle tests and established submaximal treadmill prediction

models. Although the N-EX prediction model proved to be an accurate method for

predicting VO_2 peak, Jackson et al., (1990) mentioned that predictions of CRF were less

accurate in individuals who had high aerobic capacities ($VO_2 \geq 55$ ml· kg^{-1}·min^{-1}).

Heil, Freedson, Ahlquist, Price, & Rippe (1995) conducted a study to determine if

a more precise N-EX model could be developed for predicting VO_2 peak than the model

presented by Jackson et al. (1990). The study included 439 participants between the ages

of 20 and 79 years. Each participant performed a maximal walking treadmill test to

determine VO_2 peak. Independent variables included both age and age-squared, percent

body fat, gender, and the same self-reported activity rating used by Jackson et al. (1990).

Self-reported activity demonstrated to be a valuable variable in predicting VO_{2max}. The

standard error of estimate and multiple correlation coefficient (4.90 mL·kg⁻¹·min⁻¹ and

.88, respectively) reported by Heil et al (1995) were similar to those reported by Jackson

et al. (1990). Heil et al. (1995) concluded that their N-EX model was at least as accurate,

stable, and generalizable as the N-EX model reported by Jackson et al. (1990) and the

one-mile walk test (Kline, Porcari, Hintermeister, Freedson, Ward, McCarron, Ross, &

Rippe, 1987).

George and colleagues (1997) developed an N-EX regression model using self-

reported perceived functional ability (PFA) to walk, jog, or run given distances, a

modified PA-R, BMI, and gender. One hundred college students (50 males and 50

females) aged 18-29 years, participated in the study. Compared to other studies using N-

EX regression models, the N-EX regression model reported by George et al. (1997) had a

higher correlation coefficient (R = 0.85) and a lower SEE (3.44 mL·kg⁻¹·min⁻¹). The

George N-EX regression model provides valid VO_{2max} estimates for college aged

students. The linear regression equation developed by George et al. (1997) was: VO_{2max}

(mL·kg⁻¹·min⁻¹) = 44.895 + (7.042 x gender) – (0.823 x BMI) + (0.738 x PFA) + (0.688 x

PA-R). A disadvantage inherent in this study is that it is not age-generalized. Since the

population consisted of only college aged participants, the N-EX model is not

generalizable to a broad population. Thus, there is a need to evaluate PFA as an

independent variable in predicting CRF in a more diverse age group.

Chapter 3

Methods

Participants

One hundred participants, 50 females and 50 males, aged 18-65 years will

volunteer for this study. This study will recruit employees from the LDS Hospital and

participants of the Brigham Young University Y-Be-Fit Program. Participants will be

classified as either low risk or moderate risk according to ACSM (2000) guidelines. Low

risk participants will be tested at BYU while moderate risk participants will be tested at

the LDS Hospital. Participants will read and sign an informed consent document which

contains written instructions explaining testing procedures, benefits, and risks of the test.

Participants will also complete a Physical Activity Readiness Questionnaire (PAR-Q)

(see Appendix A-1) and a non-exercise questionnaire. All participants will receive $25

compensation for their time and efforts. The study will be approved by the BYU

Institutional Review Board for Human Subjects.

Procedures

All participants will complete a maximal treadmill GXT. Prior to testing,

participants will be instructed to wear comfortable clothing, acquire an adequate amount

of sleep the night before the test (6-8 hours), and avoid exercise or strenuous physical

activity the day of the test (ASCM, 2000). Participants will be instructed to drink plenty

of fluids 24-hours prior to testing, and avoid food, tobacco, alcohol, and caffeine 3 hours

before the test (ACSM).

Participants' height and body mass will be measured and recorded while wearing lightweight clothing and no shoes using a stadiometer and balance beam scale, respectively. Information pertaining to the maximal exercise test such as the electronic heart rate monitor, head-gear, mouth piece, nose-clip, and RPE scale (Borg, 1982) (see Appendix A-1) will be explained prior to testing.

Maximal Treadmill Graded Exercise Test

Participants will perform a maximal GXT using a slightly modified version of the ASU maximal protocol (George, 1996). The maximal exercise test will begin with a 4-12 minute warm up on a treadmill at level ground. The warm up will consist of participants' completing up to three, four-minute stages until a steady state heart rate of 75% of age predicted heart rate max is achieved. During the first four-minute stage participants will walk at a brisk pace, 3-4 mph. If 75% of heart rate max is not achieved in this stage, participants will progress to the second stage, and speed will increase to a self-selected jogging pace between 4 and 6 mph. A third stage will be performed if heart rate criteria have not been met by the end of the second stage, and speed will increase to speeds of 6 mph or greater. Following the warm-up, participants will rest for approximately 5 minutes, while the test administrator explains the test procedures for the maximal GXT and fits participants with a mouthpiece and nose clip. The ending speed of the warm-up will serve as the necessary pace for the maximal GXT. Thereafter, the grade will increase 1.5% each minute, while pace remains the same, and continue until participants reach volitional fatigue and are no longer able to continue.

During the maximal GXT, metabolic gases will be collected using the TrueMax

2400 metabolic measurement system (Consentius Technologies, Sandy, UT).

Participants' heart rate, VO_2, and respiratory exchange ratio (RER) will be averaged and

analyzed by the computer every 15 seconds. The participants will give an RPE at the end

of each stage to estimate the exercise intensity. VO_{2max} is considered valid when at least

two of the following three criteria are met (ACSM, 2000; Howley, Bassett, & Welch,

1995):

1. Maximal heart rate within 15 beats of age predicted maximal heart rate.

2. Respiratory exchange ratio equal to or greater than 1.10.

3. Plateau in VO_2 despite an increase in work load.

Participants who fail to meet at least two of these criteria will be dropped from the study.

Non-exercise Questionnaires

Prior to exercise testing participants will complete the PFA (George et al., 1997)

(see Appendix A-1) and a modified PA-R non-exercise questionnaire (Jackson et al.,

1990; George et al., 1997) (see Appendix A-1). The PFA includes two questions that

ascertain how fast participants feel they can cover a 1 and 3 mile distance at a

comfortable pace (George et al., 1990). The participant's sum total of both 13-point

questions is counted as the PFA score (range 2-26).   The original PA-R questionnaire has

individuals rate their level of activity on a 7-point scale over the past month. However

Kolkhorst and Dolgener (1994) noted that an extended time reference might represent

participants' overall average physical activity level more accurately. Thus, the PA-R

questionnaire was modified with a longer 6-month time reference and expanded 10-point scale.

Statistics

Data from the maximal GXT and non-exercise questionnaires, along with BMI, gender and age will be combined with previously collected data in college-aged men and women (from prior studies conducted in the Human Performance Research Center at Brigham Young University) to develop a regression equation to predict VO_{2max} in a sample of men and women aged 18-65 years old. The data collected from this study will be cross validated with the N-EX regression equation developed by Jackson et al. (1990).

Multiple linear regression will be used to create a VO_{2max} regression model using age, gender, BMI, PFA, and modified PA-R. To determine the validity of the VO_{2max} equation, we will assess the statistical significance of independent variables, correlation coefficients, and standard error of estimates (SEEs). Predicted residual sum of squares (PRESS) statistics (Holiday, Ballard, & McKeown, 1995) will be computed to estimate the degree of shrinkage one could expect when the VO_{2max} prediction equation is used across similar, but independent samples. The statistical significance level will be set at p $<.05$.

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Appendix A-1

Consent for Participation in Research Form

1. **Purpose.** The purpose of this study is to generate a Non-exercise (N-EX) regression equation based on N-EX independent variables to predict VO_{2max} in an older population, aged 18-65. Using simple questionnaires, self-reported N-EX predictor variables can be assessed and used in regression equations to predict VO_{2max}. N-EX predictor variables include age, gender, BMI, percent body fat, self-reported physical activity rating (PA-R) and perceived functional ability (PFA). The PFA questionnaire has only been validated in a sample of college aged men and women. This study will evaluate PFA as a predictor variable in estimating cardiorespiratory fitness with a more diverse age range.

2. **Test Protocols.** I will perform one maximal graded treadmill test (GXT) to obtain measured VO_{2max}. The test administrator may stop the test at anytime she notices any abnormal responses to the exercise. I may also stop the test at any time for any reason. The treadmill test is a graded maximal test that will last 10-15 minutes. It will require that I exercise as hard as I can.

As a participant I will be subject to the following measurements, assessments, or procedures: 1) Completion of graded maximal exercise test (GXT). 2) Measurement of height and weight. 3) Completion of Physical Activity Rating (PA-R) and Perceived Functional Ability (PFA) Questionnaires.

3. **Risks and Discomforts.** There is the possibility of certain responses occurring during the tests. These include fainting, irregular heart beat, and in rare cases heart attack, stroke, or death. Extensive efforts are made to minimize these risks through pre-test screening and information regarding my medical history concerning my health and fitness, and through careful observations during the test. Trained personnel and emergency equipment are immediately available to deal with any unusual occurrences. The maximal test is very difficult, it may cause muscular fatigue and pain.

4. **Participant Responsibilities.** Any past or current health related symptoms that I am aware of (including shortness of breath, pain, tightness/heaviness in the chest, neck, jaw, back and/or arms) with physical effort may affect my safety during the test. It is imperative that I promptly report any of these symptoms if they occur during the test. It is my responsibility to fully disclose pertinent medical history as requested in the pre-test screening. It is important that I report medications I am currently taking to the test administrator.

5. **Expected Benefits.** The results of the test may be useful in determining my current level of fitness. This information can be used to modify or design a fitness program to help me meet my goals and needs. I will find out where I am physically compared to national standards.

6. **Inquiries.** Any question, concerns and comments regarding procedures or use of results are encouraged. I will ask for any further clarification and explanation if needed.

7. **Use of Results.** The information obtained from the test will be treated with confidentiality. Results will be analyzed using multiple linear regression. Participants will not be identified with their results at anytime, except when discussing personal results with the respective individual.

8. **Freedom of Consent.** I hereby consent to voluntarily engage in exercise testing to determine my exercise capacity and state of cardiovascular health. My permission to perform this exercise test is given voluntarily. I understand that I am free to stop the test at any point, if I so desire.

I have read this form, and I understand the test procedures that I will perform and the attendant risks and discomforts. Knowing these risks and discomforts, and having had an opportunity to ask questions that have been answered to my satisfaction, I consent to participate in this test.

_____   _____

Date   Signature of Participants

_____   _____

Date   Signature of Witness

Physical Activity Readiness Questionnaire(PAR-Q)

Please respond to the following by checking one of the boxes (☐ Yes, ☐ No) for each question.

YES	No	
☐	☐	Has your doctor ever said that you have a heart condition and should only do physical activity recommended by a doctor?
☐	☐	Do you feel pain in your chest when you do physical activity?
☐	☐	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	Do you ever lose consciousness or lose your balance because of dizziness?
☐	☐	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	Do you have an immediate male family member (father, son, or brother), who before the age of 55 or immediate female family members (mother, daughter, sister) who before the age of 65 suffered from a myocardial infarction, coronary revascularization, or sudden death?
☐	☐	Do you get more than 30 minutes of moderate physical activity on most days of the week?
☐	☐	Do you currently smoke cigarettes or have quit in the last 6 months?
☐	☐	Do you have shortness of breath during physical activity?
☐	☐	Do you (or have you had) have swelling of the ankles?
☐	☐	Do you have a. heart murmur?
☐	☐	Do you experience unusual fatigue or shortness of breath with usual activities?
☐	☐	Do you have difficulty breathing when reclined, lying down or sleeping?
☐	☐	Have you had sensations of rapid or irregular heart beats?
☐	☐	Do you have pain, tension or weakness in your legs during walking which intensifies to produce lameness, and is relieved by rest?
☐	☐	Do you have a thyroid disorder (or are you taking medication for a thyroid disorder)?
☐	☐	Are you currently taking any medications to control blood pressure?
☐	☐	Have you ever been told you are diabetic (Type 1 or 2)?
☐	☐	Do you have a pacemaker?
☐	☐	Do you have asthma?
☐	☐	Do you take insulin?

☐	☐	Are you currently taking medications for a renal (kidney) disease, or have you been told you have a renal disease?
☐	☐	Do you have chronic obstructive pulmonary disease (COPD), interstitial lung disease, or cystic fibrosis?
☐	☐	Are you pregnant?
☐	☐	Are you anemic?
☐	☐	Have you been diagnosed with anorexia or bulimia?
☐	☐	Have you ever had a resting or exercise ECG?
☐	☐	Have you ever had you blood lipids measured?
☐	☐	Have you ever had a glucose tolerance test?
☐	☐	Are you currently under a doctor's care for any reason?
☐	☐	Have you ever been told not to participate in any particular kind of physical activity?
☐	☐	Have you had any recent injuries?
☐	☐	Have you had any surgeries in the past 6 months?
☐	☐	Are you currently taking any medications?
☐	☐	Do you know of any other reason why you should not participate in physical activity or this exercise test?
		If YES, please explain:

_____

I have read, understood, and completed this questionnaire. Any questions which I had were answered to my full satisfaction.

Name:_____   Signature:_____ Date:_____
     (Subject)   (Subject)

Name:_____   Signature:_____ Date:_____
     (Witness)   (Witness)

Rating of Perceived Exertion (RPE) Scale

6
7 Very, very light
8
9 Very light
10
11 Fairly light
12
13 Somewhat Hard
14
15 Hard
16
17 Very hard
18
19 Very, very hard
20

(Borg, 1982)

Perceived Functional Ability (PFA) Questions

Suppose you were going to exercise continuously on an indoor track for **1 mile**. Which exercise pace is just right for you—not too easy and not too hard?

Circle the appropriate number (any number, 1 to 13).

1.   Walking at a *slow* place (18 minutes per mile or more)
2.
3.   Walking at a *medium* pace (16 minutes per mile)
4.
5.   Walking at a *fast* pace (14 minutes per mile)
6.
7.   Jogging at a *slow* pace (12 minutes per mile)
8.
9.   Jogging at a *mediu*m pace (10 minutes per mile)
10.
11.   Jogging at a *fast* pace (8 minutes per mile)
12.
13.   Running at a *fast* pace (7 minutes per mile)

How fast could you cover a distance of **3-miles** and NOT become breathless or overly fatigued? Be realistic.

Circle the appropriate number (any number, 1 to 13).

1.   I could walk the entire distance at a *slow* pace (18 minutes per mile or more)
2.
3.   I could walk the entire distance at a *mediu*m pace (16 minutes per mile)
4.
5.   I could walk the entire distance at a *fast* pace (14 minutes per mile)
6.
7.   I could jog the entire distance at a *slow* pace (12 minutes per mile)
8.
9.   I could jog the entire distance at a *mediu*m pace (10 minutes per mile)
10.
11. I could jog the entire distance at a *fast* pace (8 minutes per mile)
12.
13. I could run the entire distance at a *fast* pace (7 minutes per mile or less)

Source: George et al., (1997). Non-exercise VO_{2max} estimation for physically active college students. *Medicine and Science in Sports and Exercise, 29*(3), 415-423.

Physical Activity Rating (PA-R) Questions

Select the number that best describes your overall level of physical activity for the previous 6 MONTHS:

0 =   avoid walking or exertion; e.g., always use elevator, drive when possible instead of walking

1 =   **light activity:** walk for pleasure, routinely use stairs, occasionally exercise sufficiently to cause heavy breathing or perspiration

2 =   **moderate activity:** 10 to 60 minutes per week of moderate activity; such as golf, horseback riding, calisthenics, table tennis, bowling, weight lifting, yard work, cleaning house, walking for exercise

3 =   **moderate activity:** over 1 hour per week of moderate activity as described above

4 =   **vigorous activity:** run less than 1 mile per week or spend less than 30 minutes per week in comparable activity such as running or jogging, lap swimming, cycling, rowing, aerobics, skipping rope, running in place, or engaging in vigorous aerobic-type activity such as soccer, basketball, tennis, racquetball, or handball

5 =   **vigorous activity:** run 1 mile to less than 5 miles per week or spend 30 minutes to less than 60 minutes per week in comparable physical activity as described above

6 =   **vigorous activity:** run 5 miles to less than 10 miles per week or spend 1 hour to less than 3 hours per week in comparable physical activity as described above

7 =   **vigorous activity:** run 10 miles to less than 15 miles per week or spend 3 hours to less than 6 hours per week in comparable physical activity as described above

8 =   **vigorous activity:** run 15 miles to less than 20 miles per week or spend 6 hours to less than 7 hours per week in comparable physical activity as described above

9 =   **vigorous activity:** run 20 to 25 miles per week or spend 7 to 8 hours per week in comparable physical activity as described above

10 =   **vigorous activity:** run over 25 miles per week or spend over 8 hours per week in comparable physical activity as described above

Source: Modified from Jackson et al., (1990). Prediction of functional aerobic capacity without exercise testing. *Medicine and Science in Sports and Exercise, 22*(6), 863-870.