A cross-validation of the Marshall University step test on college males and females age 18-24

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A Cross-Validation of the Marshall University Step Test
on College Males and Females Age 18-24

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Table of Contents

CHAPTER I

INTRODUCTION

Positive health entails more than the absence of disease; it is a state of physical, mental, and social well-being (Hartung, Krock, Crandall, Bisson, & Myhre, 1993; Payne & Hahn, 1995). Physical fitness, as described by Francis (1987), is the potential for making adequate functional adjustments to increased metabolic demands. Cardiorespiratory fitness (aerobic fitness) is believed to be the single best indicator of physical fitness (Astrand & Rodale, 1985). The standard index of cardiorespiratory fitness is maximum oxygen uptake (VO_{2max}), or the maximum rate at which oxygen can be consumed. VO_{2max} is dependent upon the cardiovascular system's ability to deliver blood to working muscles and the cellular ability to take up and utilize this oxygen in energy production (Hartung et al., 1993; Siconolfi, Cullinane, Carleton, & Thompson, 1982). As a growing body of scientific research links cardiorespiratory fitness to health and well-being, a growing number of studies have investigated cardiorespiratory fitness in large and varying populations (Anderson, 1992).

The American College of Sports Medicine (ACSM) (1995) states that cardiorespiratory endurance is considered health related because (a) low levels of fitness have been associated with a markedly increased risk of premature death from all causes and specifically from cardiovascular disease, and (b) higher fitness is associated with higher levels of habitual physical activity, which is, in turn, associated with many health benefits.

The increased awareness of exercise and its benefits has stimulated the public to become more involved with physical fitness testing. Parallel interest has resulted in the development of measurement tools which determine cardiorespiratory fitness.

Direct measurement of VO_{2max} is a laboratory procedure involving specialized equipment and knowledgeable technicians. The procedure entails maximal performance on a treadmill or cycle ergometer while analyzing expired air. This procedure is expensive, time consuming, and requires the subject to work until exhaustion. Due to the level of exertion involved, directly measuring VO_{2max} comes with a certain medical risk in unscreened and older individuals. Also, the time necessary to administer a VO_{2max} test precludes testing large numbers of subjects using direct measurement. Therefore, alternate methods of easily and accurately estimating VO_{2max} are valuable adjuncts to health and fitness evaluations (Hartung et al., 1993).

Several indirect sub-maximal exercise tests have been developed to help physical educators, coaches, and exercise scientists to predict VO_{2max} (Anderson, 1992). The mode of exercise (cycle ergometer, bench stepping, treadmill, one mile run, shuttle run, etc.) and the protocol (single stage, multi-stage, etc.) are the two main variables in sub-maximal testing (Fitchett, 1985).

There are generally two methods of predicting VO_{2max} (Hartung et al., 1993). The first is the extrapolation of heart rate response to a standard sub-maximal exercise on a cycle ergometer, treadmill, or stepping bench. This method is based on the assumption that a linear relationship exists between heart rate and VO_2 or workload (Hartung et al., 1993). Dependent upon the sub-maximal test, heart rate can be taken at different time intervals during or following (heart rate recovery) a standardized exercise.

The second method is based on performance: distance run in a specified time or the time required to a run a set distance (Hartung et al., 1993). This method ignores heart rate response to exercise and is based on the known oxygen requirement for running at a given speed or the workload completed. The results from performance related sub-maximal tests, however, are confounded by climate, motivation, pacing skill, and running efficiency (Hartung et al., 1993; Willis, 1998). Also, performance is not the same construct as fitness. A performance test requires and assumes that the subject is giving a maximal effort. If they do not, the relationship between performance and fitness deteriorates.

Sub-maximal tests may be single stage or multistage, with continuous or discontinuous work loads and predetermined, arbitrary end points (Francis, 1987). The end point may be the number of trips on a standardized step, work load, oxygen requirement, or a target heart rate based on a percentage of the estimate maximal heart rate obtained from age and activity status and is then compared with average values of "normal persons" (Francis, 1987). Continuous protocols are progressive stages with no set rest intervals. Discontinuous protocols have altering work and rest intervals. As a result, a plateau in VO_2 with increasing exercise intensity occurs more often, in part because the subject does not experience the degree of local muscular fatigue as with continuous protocols (ACSM, 1995).

Predicting VO_2 from sub-maximal tests allows for the assessment and quantification of a primary component of health related fitness (Anderson, 1992). It also serves as a method of monitoring improvement, assessing training methods, and allowing for motivation toward improving one's physical fitness.

Researchers at the Marshall University exercise physiology laboratory have developed a step test that is designed to predict VO_{2max} (Gwyther, Cappert, Willis, & Shepherd, 1998). This test used a regression equation that includes variables of steady state heart rate, work in kg-m/min, body weight, sex, and the sum of skinfold measurements. The equation yields a pearson *r* of 0.87 and a standard error of estimate (SEE) of 4.75 ml/kg/min. However, the equation was developed using 11-14 year old subjects. Since the equation includes fitness variables of the heart rate response to a given external load and subcutaneous fat measurements, the investigators suggested that this test best measures the construct of "fitness". Yet, this test has not been validated for other populations and other age groups. The purpose of this study is to test the correlation between VO_{2max} as measured by gas analysis on a treadmill and the predicted VO_{2max} obtained from the Marshall Step Test for college males and females 18 to 24 years old.

Statement of the Problem

The Marshall University (MU) Step Test has not been validated for any population or age group other than 11-14 year old school children. Therefore, this study will investigate the correlation between VO_{2max} as measured by gas analysis on a treadmill and the predicted VO_{2max} obtained from the MU Step Test.

Null Hypothesis

The null hypothesis for this study maintains that there will be no significant correlation between predicted VO_{2max} obtained from the Marshall University step test and VO_{2max} obtained from maximal treadmill exercise with indirect calorimetry.

Basic Assumptions

1. The subjects participating in this study were apparently healthy.

2. The subjects did not take any medications, which would alter heart rate, prior to the testing session.
3. All subjects exhibited maximum effort during the maximal treadmill test.
4. A linear relationship exists between heart rate, workload, and maximum maximum oxygen uptake.

Limitations

1. Only thirty-nine subjects participated in the study.
2. The college age subjects were limited to Marshall University students.
3. Body composition measurements were limited to skindfold assessment.
4. There was no control for diurnal variations.

CHAPTER II

REVIEW OF LITERATURE

This review of literature will examine several sub-maximal cardiorespiratory fitness tests. Cycle ergometry, running and walking, and step tests are the three primary modes of exercise that will be reviewed.

Cycle Ergometry to Predict VO_{2max}

Astrand - Ryhming Bicycle Test

The Astrand-Ryhming bike test (A-R test) is a widely used fitness test. However, it is not practical to use for group testing due to the need for numerous bicycle ergometers. It predicts VO_{2max} based upon the steady-state heart rate of a person exercising at a single stage submaximal power level for 6 minutes (Adams, 1990.) Pedal rate is set at 50 rpm and work rate is selected based on gender and an individual's activity status: males-unconditioned, 50 or 100 watts, or conditioned, 100 or 150 watts; females-unconditioned, 50-75 watts, or conditioned, 75 or 100 watts (ACSM, 1995). The heart rate is measured during the 5th and 6th minutes of work, with the average of the two heart rates being used to estimate VO_{2max} from a nomogram (Astrand & Ryhming, 1954). The value obtained from the nomogram is then corrected for age differences using a correction factor (ACSM, 1995).

The nomogram Astrand and Ryhming (1954) derived is based on weight, age, and heart rate elicited by a submaximal work test. Therefore, the test is dependent upon the direct relationship between power level, oxygen consumption, and heart rate (Adams, 1990.)

The validity of the Astrand bike test as a predictor of maximal oxygen consumption varies. In reviewing thirteen studies, Kasch (1984), reported validity coefficients ranging from as low as 0.34 to as high as 0.94, the average being 0.64. Kasch also reported low validity coefficients (approximately 0.60), with respect to age, between the A-R bike test and directly measured maximal oxygen consumption of middle-aged men. With respect to fitness, Astrand and Rodahl (1985), claimed that untrained persons are more likely to be underestimated by the A-R bike test, whereas the highly trained are more likely to be overestimated in their maximal oxygen consumption (Adams, 1990).

A study by Williams (1975) looked at the reliability of the Astrand bike test in predicting aerobic fitness and found that the estimated reliability for a single trial was low (0.64) and a total of 3 trials over 3 days was needed to estimate reliability above 0.90.

The Astrand and Ryhming nomogram was developed in 1954 on individuals who differed in their ability, sex, age, and ethnicity . Due to the differences these characteristics can make on VO_2, a study was conducted by Legge and Banister (1986) to look at developing a new nomogram based on the Astrand-Ryhming protocol. The study consisted of 5 trained, 5 untrained, and 4 moderately trained caucasian males, ranging in age from 20 to 29. They found the correlation measured between VO_{2max} values and those predicted from the new nomogram were significantly better (r = 0.98) than predictions made for the A-R nomogram (r = 0.80) (Legge & Banister, 1986).

Siconolfi, et al.(1982) conducted a study to modify the Astrand-Ryhming Protocol. The researchers suggested the A-R test was to difficult for inactive adults. The study consisted of two groups: a test group of 50 subjects (ten for each decade between 20 and 70) and a validity group of 63 subjects. Initial exercise rates for the original A-R protocol was 49.0 W for women and 98.1 W for men. These initial work loads were changed so that the initial exercise rate for women of all ages and men 35 or older was 24.5 W and increased by 24.5 W every 2 minutes until the subject acheived the target heart rate (70% predicted max heart rate). The initial exercise rate for men 35 or younger was 49.0 W and increased by 49.0 W every 2 minutes until the subject achieved the target heart rate (70% predicted maximum heart rate). Steady state heart rate was achieved when consecutive heart rates were within 5 beats. Multiple regression equations were derived from the data obtained from the test group:

Males: $Y = 0.348 (X_1) - 0.035 (X_2) + 3.011$

$(R = 0.86;\ SEE = 0.359\ l/min)$

Females: $Y = 0.302 (X_1) - 0.019 (X_2) + 1.593$

$(R = 0.97;\ SEE = 0.199\ l/min)$

where $Y = VO_2$ (ml/kg/min); $X_1 = VO_2$ (L/min) (from A-R nomogram not corrected for age); and X_2 is the age

Siconolfi, et al. (1982) conclude that the results demonstrate that this protocol provides accurate and safe estimates of cardiorespiratory fitness over a wide age range.

YMCA Cycle Ergometry Protocol

Unlike the single stage Astrand and Ryhming protocol, the YMCA protocol uses two to four, 3-minutes stages of continuous exercise, designed to raise the steady state heart rate of the subject to 110 to 150 beat per minute for two consecutive stages (ACSM, 1995). Each work rate is performed for 3 minutes, with heart rates recorded during the final 15 to 30 seconds of the second and third minutes. If the recorded heart rates are not within 5 beats/min, then the work rate is continued for an additional minute. Heart rate measured during the last minute of each stage is plotted against work rate. Then a line is generated and extended to the age-predicted maximal heart rate (ACSM, 1995). A VO_{2max} and maximal work rate can then be estimated using nomograms and charts similar to the A-R test. The A-R test and YMCA protocol both use the extrapolation of heart rate method, but other cycle ergometry tests have been developed based on performance.

Cycle Ergometry Graded Exercise Test

The cycle ergometry graded exercise test is a performance test which predicts Vo_{2max} using the maximal work rate achieved as the primary prediction variable (Storer, Davis, & Caiozzo, 1990). Healthy sedentary males and females (N=115 and N=116 respectively) aged 20-70 years old participated in the study. Each subject was given a graded exercise test with increasing work rate of 15 W/min^{-1} and a maintenance of 60 revolution per minute pedal rate. Multiple linear regression equations which predict VO_{2max} (ml/min) from the independent variables of maximum work (W), body weight (kg), and age (yr) were derived from the data (Storer et. al., 1990):

Males $Y = 10.51\ (W) + 6.35\ (kg) - 10.49\ (yr) + 519.3\ ml/min^{-1}$

Females $Y = 9.39\ (W) + 7.7\ (kg) - 5.88\ (yr) + 136.7\ ml/min^{-1}$

The equation was cross-validated internally and externally, which yielded r values ranging from 0.920 and 0.950 for the male and female regression equations, respectively. The researchers conclude that the use of the equations generated from this study, for a 15 W/min^{-1} cycle ergometry graded exercise test, provide accurate estimates of VO_{2max} (Storer et al., 1990).

Run / Walking Tests to Predict VO_{2max}

Although cycle ergometry is usually the mode of exercise most commonly chosen in a laboratory setting, its use in the field where a large number of subjects must be tested is not practical. Therefore, other modes of exercise have been used to predict VO_{2max}. Several tests in the literature predict VO_{2max} based on running or walking performance or the extrapolation of heart rate during or after a running or walking event.

Shuttle Run Test

A study conducted by Paliczka, Nichols, and Boreham (1987) assessed the validity of a 20 meter multi-stage shuttle run as a predictor of maximal oxygen uptake. Nine male subjects (35 ± 5.8 years) participated. The 20 meter multi-stage test involved running between two lines set 20 meters apart at a pace dictated by a cassette recorder emitting tones at appropriate intervals (Paliczka et al., 1987). The first minute velocity was set at 8.5 $km.hr^{-1}$, increasing by 0.5 $km.hr^{-1}$ every minute thereafter. The score achieved is based on the number of 20 meter laps completed before the subject fails to be within 3 meters of the end lines on two consecutive tones, or the subject withdraws voluntarily. The results revealed high correlations between the predicted VO_{2max} from the 20 meter multi-stage shuttle run and direct measurement of VO_{2max} (r = 0.93). Therefore, the researchers conclude that the multi-stage shuttle run test is a valid field test of cardio-respiratory endurance (Palickza et al., 1987).

Another study involving the shuttle run was conducted on seventy-four volunteers (36 men, 38 women), age 19 to 34, to determine the validity of using a 20 meter progressive shuttle run test to estimate maximal oxygen uptake (Ramsbottom, Brewer, & Williams, 1988). The test consisted of shuttle running between two markers placed 20 meters apart at increasing fast speeds. The speed increased 0.14$m.s^{-1}$ each minute; the change in running speed was described as a change in level. Performance was described as the final level in which the subject obtained. The final running speed was compared to the directly determined VO_{2max} values and resulted in a coefficient of $r = 0.82$ for men and $r = 0.85$ for women. The researchers concluded that maximal oxygen uptake values can be predicted from the level attained on a 20 metre progressive shuttle run test (Ramsbottom et al., 1988).

Cooper 12 Minute Test

The Cooper 12 minute test is another performance based test, in which the distance covered in the allotted time is used to estimate maximal oxygen consumption. Cooper (1968) developed the test using 115 men (17 to 52 yr) and distance covered was correlated to maximum aerobic capacity. The test is easy to administer, but the subjects' level of motivation and pacing ability may have an impact on the test results. Validation of this field test on more homogeneous groups and/or different populations has yielded correlations ranging form $r = 0.13$ to $r = 0.90$ (Kline, 1987).

A study by Grant, Corbett, Amjad, Wilson, and Aitchison (1995), compared three methods of predicting VO_{2max}. The comparison was made between direct measurement of VO_{2max} on a treadmill; the Cooper run/walk test, a submaximal cycle test, and the 20 m multi-stage shuttle run test used by Ramsbottom et al. (1988). Twenty-two males (age 22.1 ± 2.4 years) performed each of the three sub-maximal tests on separate days. The mean VO_2 in ml/kg/min for each test was as follows: gas analysis on a treadmill 60.1(8.0), Cooper run/walk test 60.6(10.3), multi-stage shuttle run test 55.6(8.0), and submaximal cycle test 52.0(8.4). The findings indicate that, for the population assessed, the Cooper walk/run test is the best predictor of VO_{2max} among the three tests (Grant et al., 1993).

One-Mile Run / Walk Test

As opposed to measuring the distance covered in an allotted time the one-mile run walk measures the time it takes an individual to cover one-mile. Kline, et al. developed the one mile run as an alternative field test to estimate VO_{2max}. The study consisted of 343 healthy adults (males = 165, females = 178) aged 30 to 69. The subjects were assigned to a validation group (N = 174) or cross-validation group (N = 169). The validation group was used to develop equations for estimating VO_{2max}. The equations were then cross-validated using the cross-validation group. VO_{2max} was determined using a progressive treadmill protocol. The subjects performed two, one mile track walks as fast as possible. The two finishing times had to be within 30 seconds or further trials were done. The subject's heart rate was recorded every one quarter mile. Multiple regression analysis to estimate VO_{2max} (L/min^{-1}) yielded the following predictor variables: track walk time (T1); fourth quarter heart rate for track walk (HR 1-4); age (yr); weight (lb.); and sex (male = 1, female = 0) (Kline, 1987). The equation with the highest correlation (r = 0.93, SEE=0.325 L/min^{-1}) was as follows (N = 174):

$$V0_{2max} = 6.9652 + (0.0091*WT) - (0.0257*AGE) + (0.5955*SEX) - (0.2240*T1) - (0.0115*HR1\text{-}4)$$

Comparing observed and estimated VO_{2max} values in the cross-validation group (N =169) resulted in a correlation of r = 0.92 and SEE = 0.355 L/min^{-1}. Cross-validation in ml/kg^{-1}/min^{-1} resulted in r = 0.88 and SEE = 4.4ml/kg^{-1}/min^{-1}. The researches conclude that the one-mile walk test protocol provides a valid sub-maximal assessment for VO_{2max} estimation (Kline, 1987).

Maximum oxygen consumption can also be estimated due to the linear relationship which exists between heart rate and VO_2 and the known oxygen cost of submaximal walking and running (workload). Latin and Elias (1993) developed a submaximal treadmill test using this method.

Submaximal Treadmill Testing

Latin and Elias (1993) performed a study to determine if VO_{2max} could be predicted with the Astrand-Ryhming method in conjunction with the ACSM equations, which estimate the oxygen cost of submaximal walking and running. The study consisted of fifty-three participants (28 males and 25 females), age 19 - 40. Testing was done on two separate occasions. The first session consisted of direct measurement of VO_{2max} using a progressive treadmill test. The second session consisted of two bouts: walking at 50% VO_{2max} and running at 70% $V0_{2max}$, until steady-state heart rate was achieved for each intensity. VO_{2max} was determined using the equations published the ACSM for running and walking. Results showed a high correlation between actual and predicted VO_{2max} for walking (r = 0.82) and running (r = 0.86). The authors conclude that when ACSM estimates of the oxygen cost of walking and running were used with the AR method, reasonably accurate predictions of VO_{2max} were obtained for the present group of subjects (Latin & Elias, 1993).

Single-Stage Submaximal Treadmill Walking Test

Ebbeling, Ward, Puleo, Widrick and Ripppe (1991), estimated VO_{2max} based on a single submaximal stage of treadmill walking. The study consisted of 67 males and 72 females aged 20-59 years old. Each participant completed 4 minute stages at 0, 5, and 10% grades walking at a constant speed (2.0, 3.0, 4.0, or 4.5 mph), and then continued to walk or run while the grade of the treadmill was increased 2.5% every 2 minutes until the subject was no longer able to continue. Through multiple regression analysis the researchers developed the following model from the 4-min stage at 5% grade:

VO_{2max} = 15.1 + 21.8 * speed(mph) - 0.327 * heart rate(bpm) - 0.2638 * speed * age(yr) + 0.00504 * heart rate * age = 5.988 * gender (0=Female; 1=Male)

A cross-validation (N = 22) of the regression equation showed high correlations between observed and estimated VO_{2max} (r = 0.93 to 0.96). The researchers concluded that this submaximal walking test based on a single stage of a treadmill protocol provides a valid and time-efficient method for estimating VO_{2max} (Ebbeling, et al.).

Step Tests to Predict VO_{2max}

Another mode of exercise suitable for mass testing is the step test. Several step tests have been developed to estimate VO_{2max}. There are primarily two categories of step tests: single stage (one work period) and multi-stage (two or more work periods) (Watkins, 1984). The work on the step is determined by the height of the step and the step frequency. VO_2 is usually based on one or a combination of the following: heart rate during submaximal exercise; heart rate during recovery (one or more pulse counts) the duration of stepping; and body weight.

Single Stage Tests

Harvard Step Test.

The Harvard Step Test is one of the earliest reported step tests (Brouha, 1943). The single stage step test was tested at Harvard University using 8000 male undergraduate students. The test involves stepping on a 20-in (50.8 cm) bench at a rate of 30 steps per minute for five minutes or until the subject becomes exhausted, whichever occurred first. To predict fitness an individual's fitness level recovery heart rate is taken from 1 to 1.5, 2 to 2.5, and 3 to 3.5 minutes after the work has stopped. To obtain the score, the duration of the exercise and the sum of the pulse counts in recovery are put into the following formula:

$$\text{Index} = \frac{\text{duration of exercise in seconds} \times 100}{2 \times \text{sum of pulse counts in recovery}}$$

The subjects fitness score was determined as follows:

< 54	=	poor condition
54 to 67	=	low average
68 to 83	=	high average
83 to 96	=	good
above 96	=	excellent

The protocol is thought by some investigators too strenuous and therefore limited in its usefulness with untrained or older individuals (Francis & Brasher, 1992; Francis, 1987). Datta, Chatterjee, and Roy (1974) did a study on a group of 12 young adults and found only 4 could achieve the maximum stepping time of 5 minutes, and indicated that the subjects were forced to stop the test due to local fatigue rather than a result of maximal cardiorespiratory stress. It is for these reasons that modifications have been made to the Harvard Step Test.

In an attempt to modify the Harvard step test, Tuxworth and Shahnawaz (1977) reduced the height of the bench to 15.7 inches (40cm) and reduced the stepping frequency to 25 steps/minute, and included body weight in the equation for predicting VO_{2max} from heart rate response. Of the 400 subjects, not one was unable to finish the five minutes of stepping. The index was the sum of the three-minute recovery heart rate (30 second intervals, divided by the weight of the subject. VO_{2max} was estimated using the following formula:

$$VO_{2max}\,(L/min) = -\,0.378A + 4.57$$

where A = the modified Harvard Step Test index

The predicted VO_{2max} corrrelated highly ($r = 0.876$) with VO_{2max} measured on a cycle ergometer (Francis, 1987).

Forestry Step Test.

As a modification of the original Harvard step test, the single stage Forestry Step Test developed (Sharkey, 1977). The step test was originally designed as a screening test for safety and emergency personnel (firefighters). It was adopted in 1975 by all federal and many state agencies as the national standard for firefighters. It is used for apparently healthy persons. However, if individuals are much shorter than average, inefficient stepping may lead to an unfair underestimation (Adams, 1990).

The protocol consists of stepping on a 40 cm (15.75 in) and 33 cm (13 in) step for men and women, respectively. The rate was set at 22.5 steps per min (90 beats per min.) for a period of 5 minutes. Immediately after the test the subject sits down and a pulse is counted 15 seconds after completion to 30 seconds after completion. VO_{2max} can then be estimated using a regression equation which is charted using pulse count and body weight (Adams, 1990). The value obtained must then be corrected for age.

Skubic and Hodgkins Step Test.

The Harvard step test also brought about the development of another single stage step test, by Skubic and Hodgkins (1963). This test consists of stepping at a rate of 24 step per minute on an 18 inch bench for 3 minutes. The study consisted of 96 females between the ages of 13 and 24. To determine cardiorespiratory fitness a 30-second pulse count was taken after one minute of rest. The results showed a correlation of 0.79 between the five minute Harvard Step Test and the three minute Skubic and Hodgkins Step Test. Looking at test-retest a reliability coefficient of $r = 0.820$ was found.

Kent State University Test.

In a study by Harvey and Scott (1970) the Kent State University Step Test (K.S.U.) was validated using the Skubic and Hodgkins Step Test. The K.S.U.

step test consists of stepping on a 30 inch bench for one minute at a step rate of 30 steps per minute. Thirty-two freshmen women between the ages of 17 and 20 (14 athletes) participated in the study. The subjects performed both the Kent State University test and the Skubic-Hodgkins test prior to the fall quarter. At the end of the nine week quarter the subjects were retested using the K.S.U. test. A correlation was made between the Skubic-Hodgkins test and several methods of scoring the K.S.U. Step Test. The highest correlation was at one minute post exercise (r = 0.71). The authors also looked at the efficiency of the self-reported pulse count as opposed to a pulse count taken by stethoscope. They concluded that students are reasonably accuate in ascertaining their true resting pulses (r = 0.77 for K.S.U test and r=0.90 for Skubic- Hodgkins test) (Harvey & Scott, 1970). The authors conclude that the K.S.U. test was a valid and reliable test when using the one minute post-exercise pulse count.

Height Adjusted, Rate Specific, Single Stage Test.

Many single stage tests have been developed modifiying Brouha's (1943) original Harvard step test. However, none had been designed to accommodate differences in stature (Francis, 1990). To modify the problem Francis and Culpepper (1989) developed a height-adjustable platform to normalize the height of steppping for individuals of varying stature (Francis, 1990). The height of the platform used for testing was derived by the following equation:

Step Height = Subject height in cm. X (0.189)

The protocol consisted of the subject stepping on a height-adjusted platform for 3 minutes at 26 step per minute for adults and 22 step per minute for children. Immediately following stepping the subject remains standing and a pulse rate is determined for 15 seconds starting 5 seconds into recovery. Maximal oxygen consumption is then estimated by the following equation (Francis, 1990):

Adults (Males 18 - 47 years old and females 18 - 34 years old):

VO_{2max} = 71.97 - (0.776 x 15 - second recovery heart rate)

Children and adolescents (6 -17 years old):

VO_{2max} = 103.42 - (1.588 x 15 - second recovery heart rate)

To validate the height-adjusted platform protocol, Francis and Culpepper tested 17 students aged 19 to 33 using the, 3-minute 22 step per minute, step test of McArdle (1972). However, the test was adapted using the "variable step height" determined and they added two additional stepping frequencies of 26 and 30 steps per minute. Testing took place on two separate occasions. In the first testing session the subject performed one of three step tests. On the second session the subject performed a maximal treadmill test. The reliability of test-retest measurement of maximal exertion on the treadmill and the step tests resulted in coefficients of 0.91 and 0.89, respectively. The standard error of estimates were 2.59, 2.87, and 3.09 ml/kg/min for the stepping frequencies of 30, 26, and 22 steps per minute, respectively (Francis and Culpepper, 1989).

To validate the mathematical model used to standardize the height of stepping for individuals of various stature, Francis and Brasher (1992), tested forty three males aged 18 to 47 (10 used for cross validation). Maximal oxygen consumption was determined on a treadmill and correlated with a 15 second recovery heart rate after stepping at 22, 26, and 30 steps per minute. The correlation coefficients were 0.77, 0.81, and 0.81 at the $p<0.01$ level, respectively. The researchers conclude that the single stage height adjusted step test provides an effective predictor of VO_{2max} in males and can be used when more complex methods of obtaining VO_{2max} are unavailable (Francis & Culpepper, 1989).

Multi-Stage Tests

Mulit-stage are based on the same requirements as those of the single-stage test with the exception that the multistage test provides a gradual increase in work rate and a termination level that often exceeds the exertional level experienced in a single-stage test (Francis, 1987).

Gradational step tests.

Nagle, Balke, and Naughton (1965) developed a multi-stage step test in which the platform was adjustable. The platform could be raised vertically from 2.0 cm to 50 cm to increase the external work load (Francis, 1987). In the study by Nagle et al., two testing procedures were described to assess subjects with chronic illnesses to trained athletes. The first testing procedure consisted of 38 presumably healthy men (age 18-49) stepping to a cadence of 30 steps per minute. The platform height began at 2.0 cm and was increased 2 cm every minute thereafter. The test was stopped when the subject could no longer maintain the required rhythm or the pulse pressure began declining at pulse rates considered near maximum (Nagle et al., 1965). The second testing procedure consisted of 22 healthy men (age 29-68) with apparently low physical work capacity. The test was similar to above with the following modifications: step rate was reduced to 24 steps per minute, initial platform height was 3.3 cm, the level of the platform was raised 1.7 cm/min every minute. The oxygen cost of the negative and the positive work components of stepping were determined in both procedures. To predict the metabolic costs of stepping at various rates and platform levels the researchers derived an equation:

$$\text{Total } VO_2 = \text{standing } VO_2 + 1.33 \times \text{horizontal } VO_2 = 2.4 \times \text{vertical ascent}$$

The researchers conclude that the energy costs of stepping at reasonable rates and heights can be closely predicted (Nagle et al., 1965). However, it is also noted that the 30 cm step test will accommodate all presumbly "healthy" individuals with the exception of trained sportsmen with superior cardiorespiratory capacity (Nagle et al., 1965).

Canadian Home Fitness Test.

In terms of equipment and ease of operation the Canadian Home Fitness Test (Canadian Aerobic Fitness Test) is one of the simplest multi-stage tests (Watkins, 1984). The test was originally designed for use in Canadian homes as a motivational tool. The protocol consists of repeatedly stepping on a double 20.3 cm step. The CHFT is graded in two, progressively harder, work stages; the first consists of stepping at a rate of 114 beat cadence for 3 minutes followed immediately by a second stage at the rate of 132 beat cadence for 3 minutes (Morgan, Hughes, & Philipp, 1984). Immmediately post-exercise, the subject takes his or heart rate which is put into a multiple regression equation (Jette', Campbell, Mongeon, & Routhier (1976):

$$\text{Predicted } VO_{2max} = 42.5 + 16.6\ (VO_2) - 0.12\ (Wt) - 0.12\ (HR) - 0.24\ (Age)$$

Where VO_2 = estimated oxygen uptake at the last completed stage of the step test (L/min), Wt = kg, HR = heart rate after the last stage of exercise (b/min)

Weller, Thomas, Cox, and Corey (1992) conducted a study to validate the Canadian Aerobic Fitness Test (CAFT). The study consisted of 129 males and females, 58 and 71 respectively, aged 15 to 69 years. The subjects performed the CAFT once on each of two visits. Maximal oxygen consumption was obtained using a treadmill. A correlation coefficient of 0.83 resulted when comparing VO_{2max} obtained from the treadmill and VO_{2max} predicted from the CAFT. The original study by Jette' et al. (1976) resulted in a correlation of 0.71. Weller et al. (1992) also noted that there is a 40% chance of correctly classifying someone whose measured VO_{2max} is in the excellent range. Whereas someone who is classified as poor has a 96% chance of being correctly predicted in terms of his or her VO_{2max}.

Another study conducted by Anderson (1992) compared three sub-maximal fitness tests: the Canadian Aerobic Fitness test; a 20 m shuttle run; and a 1.5 mile run. Thirty-seven males and 26 females took part in the study. Tests were done on alternate days over a one week period. Results were analyzed over the entire group (N = 63) and by gender. Anderson found that significant differences in the prediction of aerobic capacity was found in the male sub-sample. It was noted by the investigator that the results indicate that the choice of sub-maximal test will ultimately infleunce the predicted VO_{2max} of college age male subjects, but the choice of sub-maximal test will not influence the predictive capacity of female subjects (Anderson, 1992). The results also showed an underestimation of VO_{2max} in females between the ages of 20 and 29 as well as subjects having superior cardiorespiratory fitness.

CHAPTER III

METHODOLOGY

Subjects

Thirty eight male and female college aged individuals enrolled at Marshall University volunteered to take part in this study. Mean demographic data for all subjects are shown on Table 1. The subjects were asked a series of questions concerning their medical history (risk factor analysis). The test was not performed if an individual answered yes to two or more questions (American College of Sports Medicine Guidelines). The subjects were also asked to sign an informed consent which explains the test, the risks and discomforts, the responsibilities of the participant, and the freedom of consent (see Appendix A).

Testing Procedures

Explanation of the MU Step Test.

The Marshall University step test is a sub-maximal exercise test which uses adjustments in step height (0.2, 0.3, and 0.4 meters) and/or step rate (steps per minute) to elicit a steady state heart rate (HRss) response of between 150 - 160 beats per minute (approximately 70% of maximal oxygen consumption). The beginning step height is determined by noting the physical stature of the individual and his or her physical activity level. The step rate is defined as the number of times an individual ascends and descends in one minute. The beginning step rate was set at twenty-two steps per minute. The heart rate of the individual was measured using a POLAR heart rate monitor. During the first two minutes of the exercise the step rate and step height was kept constant and

Table 1

Demographic Data

	N	Mean	SD	Low	High
Age	37	19.78	1.42	18	24
Height (inches)	37	68.03	3.94	61	75.5
Weight (kg)	37	73.92	14.42	42	108
Sum SF (mm)	37	29.88	14.11	10.5	62
% Body Fat	37	16.92	9.07	6.1	36.1
Subjects	37				
Male	21				
Female	16				

the heart rate was recorded every minute. The workload is then adjusted (increasing step rate or step height) to obtain a HRss of 150-160 beats per minute. The HRss is attained when HR did not increase or decrease five beats or more in two consecutive minutes. The examiner notes the final step height, step rate and HRss. The subject then cools down at a slower step rate and step height.

Body composition measurements.

Skinfold measurements were taken prior to the exercise bouts. The measurement sites for females were the suprailiam, thigh, tricep, and calf. For males the sites were the thigh, abdomen, chest, tricep and calf. The measurements were taken using a Lange skinfold caliper and according to the ACSM Guidelines for Exercise Testing and Prescription (ACSM, 1995). The calf and tricep sites were added and used as the sum of skinfold in the MU step test regression equation. All other sites were used in the Jackson-Pollock equation to determine the percent fat for all subjects (Pollock & Jackson, 1984)

Step test.

Students performed the MU step test in the laboratory on a scheduled date. Prior to arrival on the day of testing the subjects were instructed to wear comfortable clothing, take no medication that would affect their heart rate, and do no other type of physical exercise. Before performing the exercise tests the subjects' resting heart rates were taken after having them sit for 15 minutes. The lowest recorded heart rate in the fifteen minutes was used as the resting heart rate (RHR).

The steps were placed in ascending order at 90 degrees from each other, representing an open-ended square (see appendix B). This arrangement allowed the subject to change step height while staying in rhythm with the metronome. Step rate was kept constant using a metronome. Time was kept by an electric timer. The Polar telemetry heart rate monitor was used to record the heart rate every minute of exercise.

VO_{2max} was predicted using the regression equation established by Gwythers et al. (1998):

VO_{2max}= 69.85 + 7.75 (sex) - 0.34 (Wt) - 0.024 (kg-m/min) - 0.096 (HRss)- 0.144 (Sum of SF)

where:

1.) Sex is entered by the numerical zero and one for female and male, respectively
2.) Weight in kilograms
3.) Work rate is calculated by multiplying the step height in meters by step rate and body weight.
4.) Steady state heart rate (HRss) in beats per minute
5.) Sum of skinfold measurement (SF) is expressed in mm and is the calf and tricep added together.

VO_{2max} test.

Once the step test was completed, the subject cooled down by stepping on the lowest step and at a slower step rate. The subject then sat in a chair until the heart rate returned to below 100 beats per minute. Once RHR was achieved the subject then began the treadmill test. The treadmill test was used to directly measure VO_{2max}. The protocol selected depended on personal preference, physical stature, activity history, and the predicted VO_{2max} of the subject (from step test).. Oxygen consumption, ventilation, and other metabolic indexes were measured or calculated using a SensorMedics 2900 metabolic cart.

Protocol one. Protocol one consists of the individual walking on the treadmill (see Table 2). Two minutes of baseline data were taken with the

Table 2

Progressive Treadmill Exercise Protocol 1

Walking Protocol

	Stage	Duration (min:sec)	Speed (mph)	Grade (%)
Baseline	1	1:00	0	0
	2	1:00	0	0
Warm-up	3	1:00	2	0
	4	1:00	3	0
Exercise	5	1:00	4	0
	6	1:00	4	2
	7	1:00	4	4
	8	1:00	4	6
	9	1:00	4	8
	10	1:00	4	10
	11	1:00	4	12
	12	1:00	4	14
	13	1:00	4	16
	14	1:00	4	18
	15	1:00	4	20
	16	1:00	4	24
	17	1:00	4	26

subject seated in a chair on the treadmill. Then the subject was asked to straddle the treadmill while the examiner removed the chair. The subject was then asked to walk at 2 mph and 0% grade the first minute of warm-up and then 3 mph and 0% grade the second minute of warm-up. The exercise protocol began with the subject at 3 mph and 0% grade. The speed was then increased 0.5 or 1 mph every minute until the individual was at a comfortable walk. After the appropriate speed was obtained the grade was then increased by 2% every minute thereafter until the subject stops the test or the examiner reads an r value of greater than 1.2 after a plateau in VO_2 was observed.

Protocol two.

Protocol two consists of the individual jogging on the treadmill (see Table 3). Two minutes of baseline data were taken with the subject seated in a chair on the treadmill. Then the subject was asked to straddle the treadmill while the examiner removed the chair. The subject walked at 2 mph and 0% grade the first minute of warm-up and then 3 mph and 0% grade the second minute of warm-up. The exercise protocol began and the subject remained at 3 mph and 0% grade. The speed was then increased 0.5 or 1 mph every minute until the individual was at a comfortable jog. This was determined from feedback from the subject using hand signals that indicate that they were comfortable at that speed. After the appropriate speed was obtained the grade is then increased by 2% every minute thereafter until the subject stops the test or the examiner reads an r value of greater than 1.2 after a plateau of VCO2 was observed. Maximum oxygen consumption VO_{2max}, VE, RER, VCO2, and heart rate were measured and recorded every 20 seconds during the exercise protocol.

Table 3

Progressive Treadmill Exercise Protocol 2

Running Protocol

	Stage	Duration (min:sec)	Speed (mph)	Grade (%)
Baseline	1	1:00	0	0
	2	1:00	0	0
Warm-up	3	1:00	2	0
	4	1:00	3	0
Exercise	5	1:00	4	0
	6	1:00	5	0
	7	1:00	5.5	0
	8	1:00	6	0
	9	1:00	6	2
	10	1:00	6	4
	11	1:00	6	6
	12	1:00	6	8
	13	1:00	6	10
	14	1:00	6	12
	15	1:00	6	14
	16	1:00	6	16
	17	1:00	6	18

Statistical Analysis.

A pearson product moment correlation coefficient and a standard error of estimate was calculated using a Microsoft Excel computer program. A pearson r value and SEE were constructed for the VO_{2max} measured by open circuit spirometry (metabolic cart) and the VO_{2max} predicted by the Marshall University step test. All graphs and tables presented in the results were developed using the Microsoft Excel computer program.

CHAPTER IV

RESULTS

Subject Data

All thirty-seven subjects tested in the Marshall University Laboratory achieved an RER value of 1.10 during VO_{2max} determination. Demographic characteristics are presented in Table 1 (refer to page 23). These data suggest that the subjects were heterogeneous with respect to weight and height. Weight ranged from 42 kg to 108 kg (M = 73.92) and height ranged from 61 inches to 75.5 inches (M = 68.03). The sum of skinfold and percent body fat showed ranges from 10.5 mm to 63 mm (M = 29.88) and 6.1% to 36.1% (M = 16.92), respectively. Age ranged from 18 - 24 years old with a mean of 19.78.

MU Step Test Results

Data from indirect measurement during the MU Step Test are shown in Table 4. The average VO_2 derived from the MU step test was 42.7 ml/kg/min. (SD = 7.98), ranging from 55.98 to 25.41 ml/kg/min. Step rate ranged from 20 to 30 steps per minute (M = 22.94, SD = 1.99) while step heights ranged from 0.20 to 0.40 meters (M = 0.32, SD = 0.07). The amount of external work to achieve the HRss averaged 547.14 +/- 164.4 with a range of 193.2 to 962.4. This wide range is consistent with the large range demonstarated for the variable of VO_{2max}. The mean heart rate steady state was 156.3 bpm (SD = 4.72), which was within the operationally defined target heart rate for the MU Step Test.

Table 4

MU Step Test Data

Variable	N	Mean	SD	Low	High
Step rate (spm)	37	22.94	1.99	20	30
Step height (cm)	37	0.32	0.07	0.2	0.3
Kg-m/min	37	547.14	164.41	193.2	962.4
HRss (bpm)	37	156.31	4.72	148	165
Predicted VO2max ml/kg/min	37	42.67	7.98	25.4	55.98

Treadmill (VO_{2max}) Test Results

The respiratory exchange ratio (RER) was used as a marker for maximal effort during the treadmill test. By covention, an RER of > 1.1 is accepted as an indicator of maximal effort by the subject. The subjects yielded a mean RER value of 1.23, with a range from 1.13 to 1.4 (SD = 0.07). The maximum heart rate achieved during direct measurement of VO_{2max} ranged from 171 to 207 beats per minute (M = 191.22, SD = 9.58). The VO_{2max} obtained from the two protocols, of running and walking on the treadmill, ranged from 29.29 to 66.51 ml/kg/min. (M = 44.09, SD = 7.96). Results for the treadmill test are displayed in Table 5. The mean VO_{2max} obtained from the treadmill and the mean VO_{2max} obtained using the MU Step Test are shown in Figure 1 and in Table 6. A correlation coefficient of 0.83 (0.0001 level) with a SEE of 4.12 ml/kg/min demonstrates a strong relationship between VO_{2max} obtained from the treadmill and VO_{2max} obtained using the MU Step Test.

Table 5

Maximal Treadmill Test Data

Variable	N	Mean	SD
VO2max (ml/kg/min.)	37	44.09	7.96
HRmax (bpm)	37	191.22	9.58
RER	37	1.23	0.07

Table 6

Comparison of VO_2

	VO2max (ml/kg/min)
VO2max Treadmill	44.09
Predicted MU Step Test VO2max	42.67

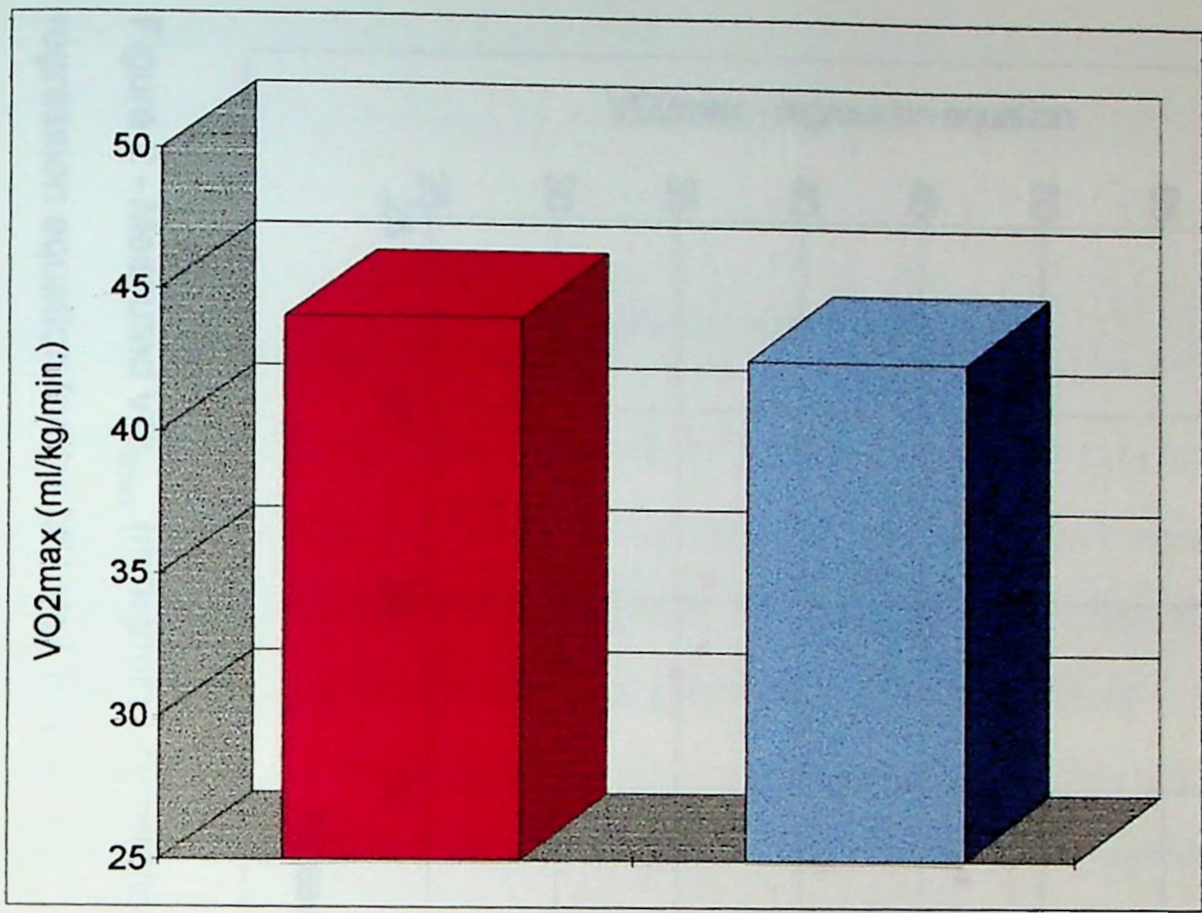


Figure 1 - Mean VO_{2max} (ml/kg/min) (N = 37) obtained from Marshall University Step Test and direct measurement on treadmill, where the SD was 7.98 and 7.96, respectively.

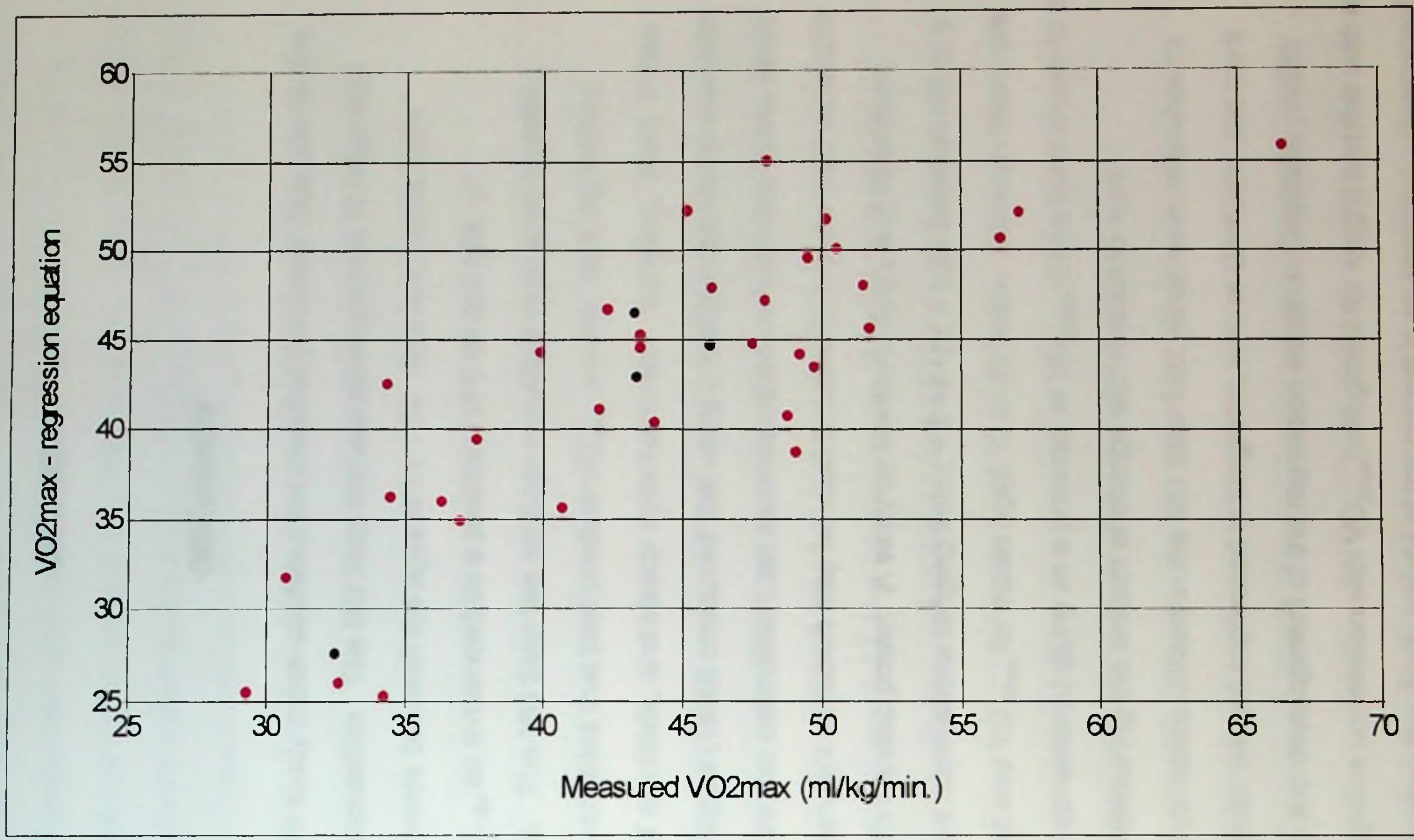


Figure 2 - Measured VO_{2max} (ml/kg/min.) correlation to VO_{2max} (ml/kg/min.) determined using the established regression equation for the MU step test.

CHAPTER V

DISCUSSION

The present study cross-validated the Marshall University Step test for the college-age population. The MU Step test was developed on 77 male and female participants between the ages of 11 - 14. This test successfully predicted VO_{2max} as evidenced by a pearson r of 0.83 and SEE of 4.12 ml/kg/min. The MU Step test employs a mulitple regression equation. Independent variables that best predicts VO_{2max} are sex, work (kg-m/min), weight, sum of skinfolds, and steady state heart rate. Ebbeling, Ward, Puleo, Widrick, and Rippe (1990) concurred that using a multiple regression equation may provide greater estimation than methods based on heart rate alone, since several independent variables may be used to account for individual variations associated with aerobic power. A study by Montoye, Ayen, and Washburn (1986) reported correlations ranging from $r = 0.16$ to $r = 0.62$ between HR at a fixed work load and VO_{2max} for males aged 10 to 39 years. Although heart rate should not be considered alone as a predictor of VO_{2max}, it has been shown to be useful when measuring the amount of change with respect to work.

Of the five variables utilized in the MU Step Test, three have reference to body composition: weight expressed in kilograms, sum of skinfolds, and work (kg-m/min). In the development of the regression equation Gwythers (1998) reported a negative correlation with VO_{2max}(ml/kg/min) for weight and the sum of skinfolds. Including the body weight of the subject is an essential independent variable which allows for the determination of aerobic power. The sum of skinfolds also resulted in a negative correlation with respect to VO_{2max} in developing the regression equation. The sum of skinfolds reflects adiposity, which has shown to lower the respective relative VO_{2max}. In the present study, four subjects presented with greater than 30% fat (greater than 55 sum of SF), with resultant VO_{2max} (from treadmill) ranging from 29-34 ml/kg/min which is significantly below the mean (44ml/kg/min) for the sample group.

Sex is the fifth variable used in the regression equation. It was found by Gwyther et al. (1998) to be a significant contributor to the determination of VO_{2max}. This is confirmed by other investigators (McArdle, Katch, & Katch, 1996). McArdle et al., stated that difference in VO_{2max} between sexes has generally been ascribed to differences in body composition and hemoglobin concentration.

Age did not prove to be a significant contributor and was not used as a variable in the regression equation. However, further research needs to be done using this regression equation on other age groups since VO_{2max} declines steadily at a rate of about 1% per year so that, by age 55, it is about 27% below values reported for 20 year olds (McArdle et al., 1996).

Most sub-maximal tests use a combination of independent variables. However, it is the belief of Gwyther et al. (1998) that by including several independent variables allows for a greater range of anthropomorphic measurements, as well as a better assessment of physical fitness rather than the performance based constructs.

Several sub-maximal testing modes have been utilized in the prediction of VO_{2max} for the college age individual. However, which test is most suitable is continually debated. Each sub-maximal test generally has presents its inconveniences and error for a specific population. However, a submaximal test that yeilds an assessment of functional capacity while being safe, portable, uncomplicated, time efficient, can be used in the field, and does not require maximal effort and self-motivation would be optimal.

Cycle Ergometer Test Versus the MU Step Test

Cycle ergometry, although widely used in the clinical setting, is not practical for field testing, due to the need for muliple cycle ergometers and ease of transporting. In comparison, the MU Step Test requires only three steps of varying heights, a metronome, and heart rate monitor all of which could be transported easily and used with minimal training. Dependening on the protocol, cycle ergometry may be inappropriate in some test settings because of the time required to administer the test.

Run / Walk Tests Versus MU Step Test

Run/walk tests which predict VO_{2max} are typically performance based tests and therefore are effort dependent. The presence of confounding extraneous variables such as climate, running efficiency, motivation, and pacing skill has resulted in confounding results (Hartung, Blancq, Lally & Krock, 1995). A study by Willis (1998) determined the validity of the one mile run when conducted under field and controlled field conditions. The study found that under field conditions (one mile run conducted by physical education teacher) a correlation coefficient of -0.66 resulted when compared with direct measurement of VO_{2max}. When comparing the controlled field condition (effort was controlled) to direct measurement of VO_{2max} a r of -0.86 resulted.

One of the more common run/walk tests for the college age individual is the Cooper 12 Minute Test. Validity coefficients for Cooper's 12 Minute Test have resulted in coefficients ranging from 0.28 to as high as 0.94 (Adams, 1990). McArdle et al. (1986) noted that when the original Cooper data was confined to college men the correlation was 0.59. With performance based testing, like the

Cooper run/walk test there is no way to ensure that the subject is giving maximal effort. However when you require a subject to give maximal effort you create a helath risk (Grant, et al., 1995). The MU Step Test, however, is independent of effort and does not require the individual to give maximal effort to be valid.

Other Step Tests Versus MU Step Test

The Forestry Step Test is similar to that of the MU Step Test in that it is portable, inexpensive, and safe. Also, both can also be administered in approximately 5 - 7 minutes. However, the Forestry Step Test consists of one step rate (22.5 spm) and one step height, 40 and 33 cm, for men and women respectively as opposed to three heights of 20, 30, and 40 centimeters and altering the step rate as in the MU step test. This allows the examiner to adjust for individual differences in height and weight by using a steady state heart rate and making adjustments accordingly. The Forestry Step Test has resulted in underestimation of short stature people, due to the efficiency of stepping (Adams, 1990). Therefore, allowing the subject to utilize a shorter step and increase the workload by increasing the step rate would be advantageous. The Harvard Step Test resulted in the same criticism. The single stage step height of 0.5m and fast step rate of 30 spm, it is thought by investigators to be too strenuous for untrained and older individuals (Francis & Basher, 1992; Francis, 1987; Benerjee & Chatterjee, 1983). Both the Foresty and Harvard step tests use recovery heart rate to determine VO_{2max}. With the advent of telemitry heart rate monitoring, which allows for real time measurement, sub-maximal step tests are more practical. Thus eliminating the error which arises from taking a pulse count.

Other step tests have been developed which correct for the height of the individual. One such test is the height adjusted, rate specific, single stage test by Francis and Culpepper (1989). Although it resulted in high correlation coefficients (0.91 and 0.89, men and women respectively) for individuals 19 - 33 years of age, it would be expensive to purchase the Exer-Stepper to do sub-maximal fitness testing when another less expensive test, such as the MU Step Test, could be done with similar accuracy. Another disadvantage is that the Exer-Stepper is not portable therefore it limits testing to the laboratory.

Correlating the MU Step Test to directly measured VO_{2max}, resulted in a coefficient of 0.83 between the predicted and measured values. This is similar to that found by Gwythers et al. (0.873) which evaluated boys and girls age 7 to 14. The standard error of estimate (4.12 ml/kg/min) is also similar to that found by Gwythers et al., (4.75 ml/kg/min). The similarity of the estimates and the regression coefficients indicates that the MU Step Test is stable across the college age population. The test is also safe, portable, uncomplicated, time efficient, can be used in the field, and does not require maximal effort and self-motivation.

Conclusion

The investigator concludes that the MU Step Test and its established regression equation is a valid predictor of VO_{2max} (ml/kg/min) on college males and females age 18 to 24. Therefore, the author rejects the null hypothesis.

Improvements, Problems, and Suggestions

It is the suggestion of the author that cross validation be done on other populations, especially the extremely fit and unfit. As well as the population between the ages of 14 to 18 years of age. One subject showing superior cardiorespiratory fitness (66.5 ml/kg/min) was underestimated by 10.5 ml/kg/min using the MU step test. The number of subjects may have been greater with a greater coordinated effort from the study administrators.

References

Adams, G. M., (1990). Exercise physiology laboratory manual (2nd ed.). Madison, Wisconsin: Brown & Benchmark.

American College of Sports Medicine, (1995). ACSM's guidelines for exercise testing and prescription. 5th Ed. Baltimore: Williams & Wilkins.

Anderson, G.S., (1992). A comparison fo predictive tests of aerobic capacity. Canadian Journal of Sport Science, 17, (4), 304-308.

Astrand, P. O., & Rodahl, K. (1985). Textbook of work physiology. New York: McGraw - Hill.

Astrand, P. O., & Ryhming, I., (1954). A nomogram for the calculation of aerobic capacity (physical fitness) from pulse rate during submaximal work. Journal of Applied Physiology, 7, 218-221.

Brouha., L., (1943). The step test: A simple method of measuring physical fitness for muscular work in young men. Research Quarterly for Exercise and Sport, 14, 34-38.

Cooper K. H., (1968). A means of assessing maximum oxygen intake. Journal of the American Medical Association, 203, 135-138.

Datta, S., Chatterjee, B., & Roy, B., (1974). An improved simple exercise test for evaluation of physical fitness. Ergonomics, 17, 105-112.

Ebbeling, C. B., Ward, A., Puleo, E. M. Widrick, J., & Rippe, J. M., (1991). Development of a single-stage submaximal treadmill walking test. Medicine and Science in Sports and Exercise, 23, (8), 966-973.

Fitchett, M. A., (1985). Predictability of VO_{2max} from submaximal cycle ergometer and bench stepping tests. British Journal of Sports Medicine, 19 (2), 85-88.

Francis, K. T., (1987). Fitness assessment using step tests. Comprehensive Therapy, 13 (4), 36-41.

Francis, K. T., (1990). A new single-stage step test for the clinical assessment fo maximal oxygen consumption. Physical Therapy, 70, (11), 734-738.

Francis, K., & Brasher, J., (1992). A height-adjusted step test for predicting maximal oxygen consumption in males. The Journal of Sports Medicine and Physical Fitness. 32, (3), 282-287.

Francis, K., & Culpepper, M., (1989). Height adjusted, rate-specific, single-stage step test for predicting maximal oxygen consumption. Southern Medical Journal. 82, (5), 602-606.

Grant, S., Corbett, K., Amjad, A. M., Wilson, J., & Aitchison, T., (1995). A comparison of methods of predicting maximum oxygen uptake. British Journal of Sports Medicine. 29, (3), 147-152.

Gwyther B., Cappert T., Willis J. M., and Shepherd T., (1997). Development of an effort dependent step test. Unpublished master's thesis Marshall University, Huntington, WV.

Harley, G. H., Krock, L. P., Crandall, C. G., Bisson, R. U., & Myhre, L. G., (1993). Prediction of maximal oxygen uptake from submaximal exercise testing in aerobically fit and nonfit men. Aviation. Space. and Environmental Medicine. 64. 735-740.

Hartung, GT.H., Blanco, R. J., Lally, D. A., & Krock, L. P., (1995). Estimation of aerobic capacity from submaximal cycle ergometry in women. Medicine and Science in Sports and Exercise. 27 (3), 452-457.

Harvey, V. P., & Scott, G. D., (1970). The validity and reliability fo a one minute step test for women. Journal of Sports Medicine and Physical Fitness. 10, 185-192.

Jette', M., Campbell, J., Mongeon, J., & Routhier, R., (1976). The Canadian home fitness test as a predictor of aerobic capacity. Canadian Medical Association Journal. 114. 680-682.

Kasch, F. W., (1984). The validity of the Astrand and Sjostrand submaximal tests. The Physician and Sports Medicine. 12. (8), 47-52.

Kline, G. M. Porcari, J. P. Hintermeister, R., Freedson, P. S., Ward, A., McCarron, R. F., Ross, J., & Rippe, J. M., (1987). Estimation of VO_{2max} from a one-mile track walk, gender, age, and body weight. Medicine and Science in Sports and Exercise. 19. (3), 253-259.

Latin, R. W., & Elias, B. A., (1993). Predictions of maximum oxygen uptake from treadmill walking and running. The Journal of Sports Medicine and Physical Fitness. 33, 34-39.

Legge, B. J., & Banister, E. W., (1986). The Astrand-Ryhming nomogram revisited. Journal of Applied Physiology, 61, (3), 1203-1209.

McArdle, W. D., Katch, F. I., & Katch V. L., (1996). Exercise physiology (4tth ed.). Baltimore, Maryland: Williams & Wilkins.

McArdle, W., Katch, F., Pechar G., et al., (1972). Reliability and interrelationships between maximal oxygen intake, physical work capacity and step-test scores in college women. Medicine and Science in Sports and Exercise, 4, 182-186.

Montoye, H. J., Ayen, T., & Washburn, R. A., (1986). The estimation of VO_{2max} from maximal and sub-maximal measurements in male, age 10-39. Research Quarterly for Exercise and Sport, 57, 250-253.

Morgan, K., Hughes, A. O., & Philipp, R., (1984). Reliability of a test of cardiovascular fitness. International Journal of Epidemiology, 13, (1), 32-37.

Nagle, F. J., Balke, B., & Naughton, J. P., (1965). Gradational step tests for assessing work capacity. Journal of Applied Physiology, 20, (4), 745-748.

Paliczka, V. J., Nichols, A. K., & Boreham, C. A. G., (1987). A multi-stage shuttle run as a predictor of running performance and maximal oxygen uptake in adults. British Journal of Sports Medicine, 21, (4), 163-165.

Payne, W. A., & Hahn, D. B., (1995). Understanding your health (4th ed.). Muncie, Indiana: Mosby.

Pollock, M. L., & A. S. Jackson. (1984). Research progress in validation of clinical methods of assessing body compostion. Medicine and Science in Sports and Exercise 16, (6), 606-613.

Ramsbottom, R., Brewer, J., & Williams, C (1988). A progressive shuttle run test to estimate maximal oxygen uptake. British Journal of Sports Medicine, 22, (4), 141-144.

Sharkey, B. J., Fitness and work capacity. (Report FS-315) Washington, D.C.: U.S. Department of Agriculture

Siconolfi, S. F., Cullinane, E. M., Carleton, R. A., & Thompson, P. D., (1982). Assessing V_{O2max} in epidemiologic studies: modification of the Astrand-Ryhming test. Medicine and Science in Sports and Exercise, 14, (5), 335-338.

Skubic, V. , Hodgkins, V., (1963). Cardiovascular efficiency tests for girls and women. Research Quaterly, 34, 191-198.

Storer, T. W., Davis, J. A., & Caiozzo, V. J., (1990). Accurate prediction of VO_{2max} in cycle ergometry. Medicine and Science in Sports and Exercise, 22, (5), 704-712.

Tuxworth, W., & Shahnawaz, H., (1977). The design and evaluation of a step test for the rapid prediction of physical work capacity in an unsophisticated industrial force. Ergonomics, 20, 181-191.

Watkins, J., (1984). Step tests of cardiorespiratory fitness suitable for mass testing. British Journal of Sports Medicine, 18, (2), 84-89.

Weller, I. M. R., Thomas, S. G., Cox, M. H., & Corey, P. N., (1992). A study to validate the Canadian Aerobic Fitness Test. Canadian Journal of Public Health, 83 (2), 120-124.

Williams, L., (1975). Reliability of predicting maximal oxygen intake using the Astrand-Ryhming nomogram. Research Quarterly, 46, (1), 12-16.

Willis, J. M. (1998). External validity of a controlled versus an uncontrolled 1-mile run. Unpulished master's thesis, Marshall University, Huntington, WV.

Appendix A

Informed Consent to Participate in Research for the Exercise Physiology Laboratory

1. **Procedure**

   I realize that in order to be a subject in this study I must participate in a battery of fitness tests.

   To examine the fitness of my heart and lungs, I will perform a step test that lasts approximately 7 minutes. This test will require me to perform at 70% of my best effort. I understand that my heart rate will be monitored by a wireless heart monitor. I will also be tested on a treadmill at 100% of my best effort. The treadmill will gradually increase speed and grade until I am unable to continue. It is important that I realize that I am in control of this testing session. I may quit at any time due to discomfort or any other reason.

   To measure my body fat, I understand that skinfold calipers will be placed on the back of my arm, on the top of my thigh, on the inside of my calf, one inch from my navel, or on top of my hip bone. These locations do not require the removal of any articles of clothing. I also know that my height and weight will be measured.

2. **Risks and Discomforts**

   I realize that there are risks involved with any type of fitness testing. There is the possibility for dizziness, syncope, joint injury, nausea, and in the rare instances heart attack, stroke or sudden death. The investigators will do everything possible to avoid any unwanted occurrences while performing these tests with as minimal amount of risk as possible. Emergency equipment, personnel, and protocols will be in place to deal with any emergency situation.

3. **Benefits**

   I will benefit from this study by obtaining information about my current level of fitness.

4. **Inquiries**

   I am encouraged to ask questions at any time. Also concerns I may have will be welcomed.

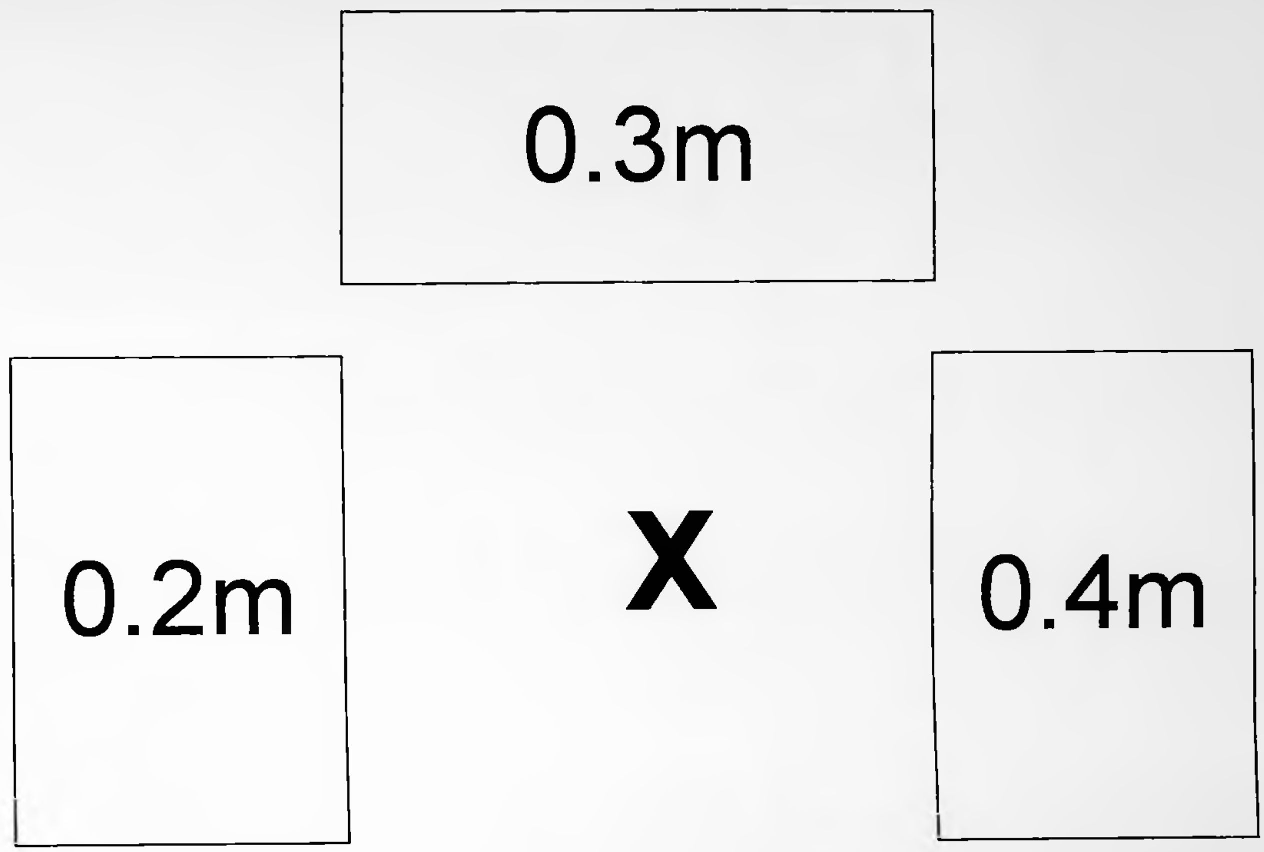
__________________________ ____________________

Subjects Signature Date

__________________________ ____________________

Witness Date

Appendix B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