THE PREDICTION OF MAXIMAL OXYGEN CONSUMPTION
FROM A SUBMAXIMAL WATER RUNNING TEST

by

DAESUNG ROH, B.S.

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CHAPTER 1
INTRODUCTION

The first open-circuit respirometer was built by Pettenkofer and Voit in 1862 (Lusk, 1928). From these data, oxygen consumption (VO$_2$) was calculated. Their experiments represented the first attempts in analyzing the effects of exercise on metabolism. When concerned with exercise, the predominant application of indirect calorimetry is the measurement of VO$_2$. Computerized indirect calorimetry systems have been able to produce time-average systems, breath by breath systems, and ventilatory hood systems. When referring to gas analysis during maximal exercise, these computerized systems are referred to as the direct measurement of maximal oxygen consumption (VO$_{2\text{max}}$) (Robergs & Roberts, 1996).

The measurement of VO$_{2\text{max}}$ has been broadly accepted as a criterion for the assessment of cardiorespiratory fitness (Astrand & Rodahl, 1986). It represents a measure of aerobic energy transfer. An increase in VO$_{2\text{max}}$ is brought about by three main changes, an increased oxygen delivery to the working muscles, an increased cardiac output (L/min), and an increased oxygen extraction from the blood by skeletal muscle during maximal exercise (arterial-venous oxygen difference, ml O$_2$/L). The attainment of a plateau of maximal work requires the integration of the ventilatory, cardiovascular, and neuromuscular systems even though other factors at the muscular level, such as the number of capillaries, enzymes, and fiber type have an affect on VO$_{2\text{max}}$. VO$_{2\text{max}}$ is also known as aerobic power, maximal oxygen consumption, and cardiorespiratory endurance capacity (Robergs & Roberts, 1996).
Even though the open-circuit calorimetry or direct measurement of VO\textsubscript{2max} has been recognized as the most accurate method of evaluating aerobic capacity, the method is laborious and intricate, and can only be used in a well-equipped laboratory (Baumgartner & Jackson, 1995). These limitations have led to the development of a variety of regression models to predict VO\textsubscript{2max} from a submaximal effort. The advantage of using regression models to predict VO\textsubscript{2max} is that they can be used in large field settings without special equipment.

Variables used to predict VO\textsubscript{2max} are diverse. Kaminsky, Wehrli, Mahon, Robbins, Powers, and Whaley (1993) concluded that a 500-yard shallow water run test could be used to predict maximum oxygen consumption using the variables body fat and height in a multiple regression prediction equation ($R^2 = 0.86$, SEE = 3.19). They did not use the variable gender in the equation because there were no significant differences in either the slope or the intercept between the gender specific equations. Conley, Cureton, Dengel, and Weyand (1991) used a 12-min swimming test to predict aerobic power in young college age students. Comparisons were then made between the same participants using a 12-min run. They found that the swimming test was a valid measurement of aerobic power. However, the 12-min swimming test depended heavily on swimming stroke skill. Gender was not a significant predictor in either the swim or the run model.

Jones (1997) stated that when predicting VO\textsubscript{2max} from submaximal data, it is best to use separate equations for each gender or include a constant correction factor in the equation. An equation derived from a large survey of females indicates a lower VO\textsubscript{2max} compared to males (Jones, 1997). Another way to account for the differences between gender is to include a dummy variable for gender in the equation.
Heart rate (HR) is widely used to predict VO$_{2\text{max}}$ because of the known linear relationship between VO$_{2\text{max}}$ and heart rate response. Using a multiple regression equation for predicting VO$_{2\text{max}}$, Hermiston and Faulkner (1971) reported that heart rate was one of the best predictor variables for VO$_{2\text{max}}$. McArdle, Katch, Pechar, Jacobson, and Ruck (1972) also reported that heart rate response during submaximal exercise is a valid predictor of VO$_{2\text{max}}$. Similarly, Fox (1973) concluded that the relationship between VO$_{2\text{max}}$ and submaximal heart rate was linear.

However, many researchers report differences in heart rate responses following exercise between water and land environments (Avellini, Shapiro, & Pandolf, 1983; Costill, 1966; Whitlay & Schoene, 1987). Gleim and Nicholas (1989) investigated the linear relationship between VO$_2$ and HR with water temperature and depth. Gleim concluded that the relationship between HR and VO$_2$ could be affected by the temperature and depth in water. Furthermore, Butts, Tucker, and Smith (1991) suggested that the formula used to predict maximum heart rate in water should be changed to 200-age rather than 220-age. Butts suggested that maximum heart rate in water can be complicated by the interaction of the duration of submersion and temperature of the water.

It is well accepted that body composition is significantly related to physical performance or VO$_{2\text{max}}$ (Katch, McArdle, Czula, & Pechar, 1973). Using multiple regression equations for predicting VO$_{2\text{max}}$, Hermiston and Faulkner (1971) reported that fat-free weight significantly impacted the variance in VO$_{2\text{max}}$. Kaminsky et al. (1993) also reported that percent body fat accounted for significant additional variance in the
estimation of peak VO₂ when combined with water running time, even though there was a low correlation between percent body fat and water run time.

From the review of literature, it could be hypothesized that VO₂max could be predicted from a submaximal test utilizing significant variables that contribute to the explained variance in VO₂max. The variables should be specific to the study participants and environmental conditions in order to increase the accuracy of prediction (Kaminsky et al., 1993).

**Purpose of the Study**

The purpose of this study was to predict maximal oxygen consumption from a submaximal water running test. Predictor variables included in the model were body fat, height, weight, gender, and heart rate at the end of a 6-min water running test.

**Statement of the Hypothesis**

VO₂max can be predicted from an exercise heart rate at the end of a 6-min water running test. Additional explanatory variables were hypothesized to be percent body fat, height, weight, and gender.

**Delimitations**

This study had the following delimitations to control the participants.

1. This study was delimited to men and women who were enrolled in Texas Tech University between the ages of 18 and 25 years.
2. Participation was delimited to men and women who had level III swimming ability (formerly advanced beginner) as outlined by the American Red Cross.

**Limitations**

This study had the following limitations to minimize the error variance during the experiment.

1. A 7-site skin fold assessment has an error of 1-1.5% compared to hydrostatic weighing.

2. The Bruce Treadmill Protocol might impose a muscular limitation rather than a cardiovascular limitation on the participants because of the increase in grade.

3. Participants might not utilize their full range of motion when performing the water running test.

4. Participants might not follow dietary or exercise recommendations prior to testing which might have an affect on their physiological responses.

**Significance**

Previous research suggests that treadmill and bicycle ergometer tests are commonly used to predict $\text{VO}_{2\text{max}}$ from submaximal tests. Individuals who are obese and have lower extremity injuries or orthopedic limitations may not be able to perform a submaximal weight-bearing test. In the aquatic environment, the most widely used submaximal test is the 12-min swimming test (Conley et al., 1991). In addition to the time constraints imposed by this test, a lap pool is needed for testing, and the test depends heavily on
swimming stroke skill. A water fitness test is needed that is more time-efficient and does not rely so heavily on swimming stroke skill. According to the research literature, a steady pace of at least 5 min is needed to predict VO_{2max}. The duration of the proposed test was 6 min. The movement pattern in the present study was similar to bicycling, an easily taught movement pattern, familiar to most individuals. The assessment tool proposed in this study would provide health and fitness practitioners with a practical submaximal water based fitness test designed to assess cardiovascular fitness level independent of stroke efficiency. This assessment tool would be very useful for physical therapists or other health and fitness practitioners who work with individuals who are overweight, have lower extremity injuries, or orthopedic disabilities. These individuals, particularly, would benefit from a non-weight bearing assessment because of the decreased impact on the joints.
CHAPTER II
REVIEW OF LITERATURE

Estimation of VO$_{2\text{max}}$

There have been many methods to evaluate VO$_{2\text{max}}$. These methods have been widely classified as direct or indirect determination of VO$_{2\text{max}}$. In the direct method, VO$_2$ can be measured by direct gas analysis. Even though the direct measurement of VO$_{2\text{max}}$ is accurate and reliable to evaluate aerobic power, the complexity of the direct method has resulted in the development of several methods by walking, running, or cycling as a field-based submaximal exercise test to predict VO$_{2\text{max}}$ (Fox, 1973).

Since Astrand, and Ryhming (1954) developed a nomogram for estimation of VO$_{2\text{max}}$ using a submaximal exercise test, many researchers have demonstrated that there is no significant difference between estimated VO$_{2\text{max}}$ and measured VO$_{2\text{max}}$ (Cooper, 1968; Fox, 1973; Getchell, Kirkendall, & Robbins, 1977; Glassford, Baycroft, Sedgwick, & Macnab, 1964). Cooper (1968) reported the correlation between the estimated VO$_{2\text{max}}$ from a 12-min performance test and the direct measurement of VO$_{2\text{max}}$ with gas analysis to be $r = .90$, a reasonably high correlation. The results of a study by Fox (1973) also support that prediction of VO$_{2\text{max}}$ from submaximal exercise is valid and accurate.

The correlation coefficients between direct VO$_{2\text{max}}$ testing and submaximal aerobic prediction equations has ranged from $r = .63$ to $r = .82$ (Glassford et al., 1964). This suggests that the VO$_{2\text{max}}$ values between direct method and estimated values are correlated.
Ribisl and Kachadorian (1969) examined the relationship between the measurement of \( \text{VO}_2\text{max} \) and performance times from several running tests using young and middle-aged participants. Study results indicated that there was a high correlation between \( \text{VO}_2\text{max} \) and running time (\( r=0.85 \) for the young and \( r=0.86 \) for middle-aged men). However, the variables to predict \( \text{VO}_2\text{max} \) were different between young and middle-aged participants (Ribisl & Kachadorian, 1969).

Hermiston and Faulkner (1971) reported that the variables for prediction of \( \text{VO}_2\text{max} \) should be determined by the inherent characteristics of the participants. Hermiston suggested that the participants’ age, lean body mass, heart rate, fraction of carbon dioxide in expired gas (\( \text{FE CO}_2 \)), tidal volume (\( \text{TV} \)), and the rate of change of the respiratory exchange ratio (\( \text{RER} \)) during a submaximal walking test should be considered as the variables for an accurate prediction equation. Getchell et al. (1977) also used multiple regression procedures to predict \( \text{VO}_2\text{max} \) from a 1.5 mile running time and several variables related to \( \text{VO}_2\text{max} \). The results indicated that the correlation coefficient was significantly greater after adding the variables body weight, age, and height (\( r = .92 \)).

The results from the studies by Ribisl (1969), Getchell (1977), and Hermiston (1971) indicate that the development of multiple regression equations using multiple variables affecting aerobic power might estimate \( \text{VO}_2\text{max} \) much better than a single variable for predicting maximal aerobic power.

A study by Mastropaolo (1970) provided additional evidence that multiple regression equations using several different variables, such as RER, heart rate, blood pressure, etc., could predict \( \text{VO}_2\text{max} \) significantly better than simple regression equations. In addition, Mastropaolo also found that RER and work rate was significantly correlated
with VO₂max. However, other researchers reported the relationship between these two factors and VO₂max to be low (DeVries & Klafrs. 1965; Rowell, Taylor, & Wang, 1964).

The results from a study by Zwiren, Freedon, Ward, Wilke, and Rippe (1991) showed that the correlation between measured VO₂max and predicted VO₂max using a running submaximal test was high (r = 0.79). Furthermore, the estimated VO₂max from a walking test was also not significantly different from measured VO₂max values. It supports the assumption that estimating VO₂max from a submaximal test is a valid measurement of cardiovascular fitness.

Researchers report that field tests of short distance such as a 600-yard run/walk test showed lower validity than longer running tests (Falls, Ismail, & MacLeod. 1966; Doolittle & Bigbee, 1968). The results of the study by Falls et al. (1966) indicated that the correlation values were considerably low between a 600-yard run/walk test and measured VO₂max (r = .54). Doolittle and Bigbee (1968) also found that the correlation coefficient between a 600-yard run-walk test and measured VO₂max test was low (r = .62).

Katch, Rechar, McArdle, and Weltman (1973) suggested that the prediction of VO₂max using submaximal field tests should include exercise duration of at least 5 min to increase validity. Ribisl and Kachadorian (1969) also reported that the field-based tests of distances beyond a half-mile were significantly better predictors of VO₂max than distances less than a half mile. It was also found that there was not a significant relationship between VO₂max and submaximal tests of less than a half-mile. These findings suggest that even though field tests such as running a short duration evaluated aerobic power to some extent, it appears that other factors such as running speed or skills should be considered during the tests (Getchell et al., 1977).
The accuracy and validity of several field-based submaximal tests have still been questioned even though there has been much support for the estimation of VO$_{2\text{max}}$ from these tests. Recently, a few studies have attempted to examine the validity of the prediction for VO$_{2\text{max}}$ from submaximal tests using standard errors of estimation, cross-validation, or both (Kline et al., 1987; Conley et al., 1991). However, many researchers did not report the standard error of estimation, which explains the accuracy of predicting an individual’s VO$_{2\text{max}}$ (Fox, 1973; Doolittle & Bigbee, 1968; Getchell et al., 1977). While other researchers did not report cross-validation results (Falls et al., 1966; Fox, 1973; Mastropaulo, 1969; Metz & Alexander, 1970). Metz and Alexander (1970) examined the relationship between VO$_{2\text{max}}$ and three submaximal work variables, heart rate, VO$_2$, and RER; while the prediction equation for VO$_{2\text{max}}$ was developed with respective coefficients, it failed to apply to every participant due to cross-validity. It is, therefore, difficult to examine the practicability of field-based submaximal tests for accuracy and validity. An accurate submaximal or field test completed on a group of individuals should have a mean estimated VO$_{2\text{max}}$ and standard deviation similar to measured values, a high correlation with the criterion value, and a low standard error of estimate (Lohman, 1981).

**VO$_2$ and Heart Rate**

From the Fick equation (VO$_2$ = HR * SV * a-v O$_2$ diff), it is obvious that heart rate can directly affect oxygen consumption (McArdle, Katch, & Katch, 1996). The attempt to measure recovery heart rate has led to the development of the well-known Harvard Step Test to predict VO$_{2\text{max}}$ (Horvath & Horvath, 1973). Even though there is a linear increase
in oxygen consumption, Astrand and Ryming (1954) did not state the degree of correlation between submaximal heart rates during exercise and maximal oxygen consumption. Astrand (1954) stated that a participant’s aerobic capacity could be predicted when the intensity of submaximal exercise reaches a steady heart rate of 125 beats per min (bpm) to 170 bpm; this criterion is valid for participants 18 to 30 years old.

McArdle et al. (1972) reported a high degree of correlation between heart rate during submaximal exercise and aerobic power when oxygen consumption was measured. The study by McArdle indicated that several regression equations could be developed for predicting VO$_{2\text{max}}$ by using the length of the time the participant walked before the heart rate reached 150 bpm and 170 bpm. The highest correlations between submaximal heart rate data and aerobic capacity were obtained when the relative VO$_{2\text{max}}$ was expressed (ml/kg/min).

Rowell et al. (1964) found that a single variable, heart rate, during submaximal exercise level underestimated oxygen consumption in a sedentary group. Rowell concluded that the heart rate during submaximal exercise was an unreliable predictor of VO$_{2\text{max}}$ since it could be influenced by several variables such as environmental temperature and mental factors.

Using multiple regression equations for predicting VO$_{2\text{max}}$, Hermiston and Faulkner (1971) reported that age, HR, and fat-free weight had the highest correlations for the prediction of VO$_{2\text{max}}$. Their study indicated that other variables, such as FE CO$_2$, TV, and RER were also correlated to VO$_{2\text{max}}$.

Fox (1973) reported that the relationship between VO$_{2\text{max}}$ and submaximal heart rate was linear. He emphasized the practicality of using a single 5-min submaximal
exercise load and one submaximal variable to predict VO$_{2\text{max}}$. He focused on a simple and practical technique while others utilized several different physiological variables (Hermiston & Faulkner, 1971; Mastropaolo, 1969). However, Mastropaolo suggested that relying on more than a single cardiovascular or respiratory variable, such as HR, increases the accuracy of predicting VO$_{2\text{max}}$.

The Role of Body Composition in Predicting VO$_{2\text{max}}$

Many researchers have reported that body composition was significantly related to both submaximal and maximal VO$_2$ (Barry & Cureton, 1961; Kireilis & Cureton, 1947; Riendeau & Welch, 1958; Wilmore, 1970). Even though total body weight is not an important factor in determining physical performance as described by Cooper (1968), Katch (1973) explained that percent fat and lean body weight were related to physical performance. Data revealed that approximately 24 and 30% of the variation in physical performance was attributed to variation in lean body mass and body fat, respectively.

Hermiston and Faulkner (1971) also suggested that the prediction of VO$_{2\text{max}}$ by a multiple regression equation should involve lean body mass as one of variables related to VO$_2$. The study by Hermiston and Faulkner (1971) showed that the correlation between VO$_{2\text{max}}$ and lean body mass was second only to age among several variables. In contrast, the results of the study by Getchell et al. (1977) indicated that body fat or body weight had little variance for the prediction of VO$_{2\text{max}}$ because all participants were young adult joggers without excess body fat or weight. Nevertheless, when lean body mass and body fat were combined with age, height, and weight, the total variance increased from 83.4\% to 94.2\%. Kaminsky et al. (1993) also reported that percent body fat accounted for
significant additional variance in the estimation of peak VO$_2$ when combined with water running time even though there was a low correlation between percent body fat and water running time.

**VO$_2$ and Gender**

The differences between gender in VO$_{2\text{max}}$ result from considerable variation in the dimensions of the heart and lungs during certain developmental periods (Johns, 1997). There is little difference in population averages of vital capacity and heart volume at ages 14 to 16 years (Berglund, Birath, & Grimby, 1963). At age 18 years, vital capacity of males is 30% higher than that of females. Heart volume of males is 40% greater than that of females at age 18. These differences are maintained through adult life. The differences in VO$_{2\text{max}}$ between gender result from the lower tidal volume and higher frequency of breathing as well as lower stroke volume and higher heart rate at any given VO$_2$ and height.

Kaminsky et al. (1993) reported that multiple variables should be used in addition to gender since gender was not a significant predictor, and there were no differences in slopes or intercepts of gender specific regression equations. Other researchers also reported that there was little or no difference in predicting VO$_{2\text{max}}$ due to gender (Bruce, Kusumi, & Hosmer, 1973; Pollock et al., 1982; Storer, Davis, & Caiozzo, 1990). Conley et al. (1991) reported separate equations for women (1992) and men (1991) to estimate VO$_{2\text{max}}$ even though there were no differences in the slopes of two equations. However, the intercept was 5 ml/kg/min higher in the equation for men (Conley, Cureton, Hinson, Higbie, & Weyand, 1992). Furthermore, Kaminsky suggests that additional researches
investigating the contribution of gender in prediction of $V_{O2max}$ for tests performed in the water are needed.

**VO$_2$ and Heart Rate Between Land and Water**

For individuals who have excess body weight, lower limb joint, and cardiac problems, exercise in water is more feasible than exercise on land. According to a study by Evans, Cureton, and Purvis (1978), the effects of water buoyancy and resistance make possible high levels of energy expenditure with relatively little movement and strain on lower extremity joints.

Oxygen consumption and heart rate were compared between exercises in water and on land (Johnson, Stromme, Adamczyk, & Tennoe, 1977). The results of a study by Johnson et al. (1977) indicated that there were significant differences in mean values for VO$_2$ and heart rate between exercise responses in water and on land at temperatures between 26 and 26.5°C. Furthermore, a decrease in heart rate occurred from 30 to 60s, at the point when all participants entered the water and submerged to the shoulder level. The range of reduction of heart rate in water was from 10 to 15 beats per minute lower than that on land. It resulted from the response of the cardiovascular system to water temperature and the effect of the hydrostatic water pressure exerted against the body (Begin et al., 1976).

Whitley and Schoene (1987) attempted to determine whether the heart rate response to water walking reached a high enough level to show cardiorespiratory training effects. Heart rate response in water was compared with the heart rate response to walking on land. The results indicated that heart rates during water walking at the depth of .92 m and
the water temperature between 25 and 27.2 °C were significantly higher than those during walking on land at the same speed. This suggests that the heart rates during water walking at specific speeds (> 2.55 km/hr) were high enough to show sufficient intensity as a submaximal exercise. As discussed by Whitley and Schoene, slower movement, reduced work efficiency, or the completion of less work due to water resistance and buoyancy made an increase in the metabolic rate based on heart rate and VO₂ compared to land.

According to the study by Butts et al. (1990), VO₂max observed during water running was significantly lower than a treadmill run on land at the same speed and grade. These findings are very similar to the research of McArdle, Magel, Delio, Toner, and Chase (1978), who examined the difference in VO₂max between running and swimming. It was concluded that the lower VO₂max during water exercise was caused by several factors, the hydrostatic forces on the body during immersion, changes of cardiac output, and water temperature. Furthermore, Butts et al. (1991) suggested that lowering maximum HR to 200 – age might be more indicative of the metabolic costs of maximal water running. However, the utilization of maximum HR in water as an indicator for aerobic power may be complicated by the interaction of the length of exercise and temperature of the water.

Kaminsky et al. (1993) evaluated a shallow water running test for the prediction of VO₂max comparing a 500-yard shallow water running test and a 1.5-mile running test on land. The results showed that peak HR and RER means were considerably different between the two tests while there was no significant differences in blood lactate concentration between the 1.5-mile running test on land and the 500 yard- shallow water
run. The results indicated that HR response to exercise in water was considerably lower than HR response on land due to hydrostatic pressure and buoyancy, supporting similar findings from other researchers (Avellini et al., 1983; Johnson et al., 1977).

Costill (1966) examined the effects of water temperature on maximal working capacity during 3 min. The results indicated that water temperatures of 17.8, 25, and 32.2 °C did not significantly affect HR or VO2max during 3 min of maximal exercise. Costill, Cahill, and Eddy (1967) also reported that HR following a 20 minute submaximal exercise bout in 17.4 °C water was lower than that in 26.8 or 33.1 °C. Gleim and Nicholas (1989) reported that when exercising on an underwater treadmill (30.5 °C) at waist depth, the heart rate response was greater for any increase in VO2. Furthermore, as the water temperature was increased to 36.1 °C, this effect was more apparent. Gleim suggested that water temperature affects the relationship of heart rate to VO2 at waist depth, suggesting that water temperature could add a significant thermal load to the cardiovascular system.
CHAPTER III

METHODS

Recruitment of Participants

Following approval from the institutional review board at Texas Tech University (TTU) (see Appendix A), 32 volunteers (n = 19 males, n = 13 females), age 18 – 25 years, were recruited from the general population of college students in the Personal Fitness and Wellness classes. Specifically, the swimming and scuba diving classes offered by the department of Health, Exercise, and Sport Sciences at TTU were targeted to recruit volunteers. The study was explained to potential participants including the purpose, procedures, possible risks, and potential benefits (see Appendix B). Prior to their actual participation in the study, the students were given a form which contained the name and address of the investigators, the purpose of the research, a summary of the eligibility criteria which was used to both admit and exclude participants from the study, a list of benefits to the participants for their participation in the study, the location of the research, and the person to contact for further information. The purpose of this form was to help students decide if they were interested in participating in the study (see Appendix C). After it became clear that potential participants understood these factors and all questions had been answered fully, they were offered the opportunity to read the consent form and became enrolled in the study. They were given the consent form to read (see Appendix D). If they agreed to participate, they signed and dated the consent form.

After obtaining informed consent, three additional stages of screening were used in order to identify qualified participants.
Stage 1

Participants completed a Physical Activity Readiness Inventory (see Appendix E) in order to determine their eligibility to proceed to the next screening step. This form was a widely used screening tool. If participants listed yes to any of these questions, they were excluded from the study.

Stage 2

Participants who passed stage one screening were asked to go to Thompson Hall, Student Health Center, Texas Tech University, to have their cholesterol, blood pressure, and triglycerides checked. They also were responsible for picking up their lab reports from Thompson Hall.

Stage 3

After lab report results were available to them, participants scheduled an appointment with the investigator to answer questions concerning risk factors. The risk categories were those designated by the American College of Sports Medicine (1998) (see Appendix F). Only participants who scored in the apparently healthy risk category were eligible for participation in the full research project (see Appendix G).

Instrumentation

The following instruments were used for a 7-site skin fold assessment, a maximum VO₂ exercise treadmill test, or a 6 min water running test.
1. A Lange skinfold caliper (Cambridge Scientific Industries, Inc.; Cambridge, Maryland) was used to obtain skinfold measurements. Skinfold measurements were taken at seven sites: abdomen, axillary, chest, subscapular, suprailiac, triceps, and thigh (Lohman, 1981).

2. A Polar heart rate monitor (Polar Electro Oy; Finland) was used to determine recovery heart rate following a water running test.

3. Aqua Cal Digital Thermometer (Swim Things; Blue Springs, Mo.) was used to measure the water temperature during a water running test.

4. A Quinton EKG Monitor (Quinton Instrument Company; Seattle, Washington) utilizing limb leads I, II, and III were used to determine HR and ECG changes during the VO$_{2\max}$ test.

5. Quinton treadmill (Quinton Instrument Company; Seattle, Washington) was used for VO$_{2\max}$ testing utilizing the Bruce Protocol (Appendix J)

6. A metabolic measurement system, CPX/D, (Med Graphics Corporation; St. Paul, MN) was used to measure VO$_{2\max}$. The metabolic measurement system was interfaced with the Quinton EKG for heart rate during testing.

7. Seiko Quartz Pendulum Metronome (Seiko Quartz; Timberlake, NC) was used to maintain a water running speed.

8. Aqua Jogger Classic Uni-Sex Belt (Recreonics; Louisville, KY) was used during a 6 min water running test.
Tasks

Participants underwent the following testing procedures: (a) a 7-site skin fold assessment; (b) a maximum VO2 exercise treadmill test; and (c) a 6-min water running test.

Testing Procedures

Following the participants’ eligibility and consent to participate, they scheduled a lab appointment with the investigator to undergo a series of 3 tests over a 2-day period. The VO2max test and the water running test were separated by at least a 24-hour period. The first day of testing consisted of skinfold assessments and a VO2max test. Day 2 consisted of a 6-min water running test.

Participants were asked to refrain from food, alcohol, or caffeine or using tobacco products within 3 hours of testing. Participants were rested for the assessment, avoiding significant exertion or exercise on the day of the assessment. For the VO2max test, clothing permitted freedom of movement and included walking or running shoes. Women brought a loose-fitting blouse with short sleeves that buttoned down the front, and avoided restrictive undergarments. For the water running test, swimming suits were requested.

Skinfold Assessment

Skinfold assessment was taken using standardized procedures. The procedures were as follows: (a) all measurements were made on the right side of the body; (b) the caliper was placed 1 cm away from the thumb and finger, perpendicular to the skinfold, and halfway between the crest and the base of the fold; (c) the pinches were maintained before and while reading the caliper; (d) measurements were taken twice and retested if
measurements were not within 1 to 2 mm; (e) measurements sites were rotated or time
was allowed for skin to regain normal texture and thickness; and (f) the two closest
values were averaged for a final skinfold thickness.

Standardized description of skinfold sites was as follows: (a) abdominal (vertical
fold); (b) triceps (vertical fold); (c) biceps (vertical fold); (d) chest (diagonal fold); (e)
calf (vertical fold); (f) axillary (vertical fold); (g) subscapular (diagonal fold); (h)
suprailliac (diagonal fold); and (j) thigh (vertical fold) (ACSM. 1998). The gender-
specific 7-Site formula for body density using skinfolds can be found in Appendices K
and L. The Siri equation then was used to determine body composition from estimated
body density (see Appendices K and L).

Maximum VO₂ Testing

Following the skinfold assessment, an additional exercise consent form which
included the dialogue used by the exercise tester, was signed prior to maximal exercise
testing (Appendix H). After signing the consent form, standardized procedures for
VO₂max assessment were followed (ACSM. 1994). Equipment was calibrated prior to
testing. Volume calibration of the pneumotach was made utilizing a 3-liter syringe. The
gas analyzers were calibrated with the use of certified reference gas tanks. Oxygen and
trained CPR personnel were available on site during exercise testing. Participants were
informed that if they experienced light-headedness, chest tightness or pain in their arm,
undue fatigue, unwarranted breathlessness or any pain that was increasingly
uncomfortable, they should stop the test. Test end-point criteria and rate of perceived
effort signals during testing were also explained to the participants immediately prior
to the initiation of the test. Resting heart rate and blood pressure were also assessed prior to maximal testing. Participants were asked to stretch their lower extremity muscles particularly their gastrocnemius prior to testing. The Bruce Treadmill Protocol was used for VO$_2$max testing (see Appendix J). Participants' perceived exertion, blood pressure, and heart rate were monitored and recorded at the end of every 3-min stage during the VO$_2$max test (see Appendix I). To be sure that participants reached the maximal capacity for aerobic metabolism during exercise, a leveling-off or peaking-over in VO$_2$ was observed. In addition, the attainment of the age-predicted maximum HR or RER in excess of 1.00 was also observed (McArdle et al., 1996). Mean HR and RER were 196bpm and 1.25 RER, respectively. Absolute and relative indications to stop an exercise test were followed as outlined by ACSM (1994) (Appendix I). Any abnormal rise or fall in blood pressure, or irregular heart rhythms, immediately signified the termination of the test. Recovery heart rate and blood pressure were collected for 8 min or until a baseline was established.

**Water Testing**

On the second day of testing, participants took part in a submaximal water running test (WRT). Testing was conducted in the Applied Physiology Lab in the Men's Gym. The WRT occurred in a fiberglass weighing tank 128 cm in diameter and 402 cm in circumference. The depth of the tank was 165 cm. A bar (287 cm in length and 26 cm in circumference) was placed on top of the tank. Water temperature was recorded from the Aqua Cal Digital Thermometer and was kept constant within the range from 33.4 to 34.4°C. The participants were asked to wear an Aqua Jogger Classic Uni-Sex Belt and a
Polar heart rate monitor during the water running test. During the water running test, the participants' head, shoulders, hips and feet were vertically aligned, using a modified running/bicycle motion. The participants were instructed to alternately move each hip joint to a flexed position of 45° and hyperextended position of 10° (Brown, Chitwood, Beason, & McLemore, 1997). This same motion was used throughout the entire protocol. The participants were asked to touch the bar during WRT in order to prevent forward movement. The water running motion was practiced prior to the test. The protocol consisted of three 2-min stages. A metronome was used to keep the steps/min (spm) constant during each stage. During the first 2-min stage of the protocol, the participants were asked to run at a cadence of 100 spm. During the second 2-min stage, the cadence increased to 108 spm. The rate of cadence increased to 116 spm during the last 2-min stage (Brown et al., 1997; Whitley & Schoene, 1987). HR was taken at 6 min using the Polar Heart Rate Monitor. HR at the end of the 6 min period was the variable of interest and was used as the predictor variable in the proposed equation.

Data Analyses

The mean and standard deviation for all variables were calculated to find the central tendency and variability of the participants’ scores. Descriptive statistics included gender, age, weight, height, body composition, HRWRT, and VO_{2max}. The matrix of correlation among independent variables included in the predictor equation (HRWRT, body fat, height, weight, and gender) was used to quantify the independence of the predictor variables. All predictor variables with a correlation of .5 or higher were scrutinized by the researcher before being included in the full model (George & Mallery, 2000). The
criterion variable in the equation was the participants' measured VO$_{2\text{max}}$. The predictor variables included in the equation were the participants' HRWRT, body fat, height, weight, and gender. A full multiple regression model was used to predict VO$_{2\text{max}}$ from the hypothesized predictor variables. Only variables that contributed to the variance in VO$_{2\text{max}}$ were included in a restricted model. A test of R squared change was used to determine the most parsimonious model.
CHAPTER IV

RESULTS

The purpose of this chapter is to provide descriptive data for the participants and to detail the statistical procedures followed in order to analyze study results. Specifically, the statistical methods used to determine the most parsimonious regression equation will be revealed.

Descriptive Data

Descriptive data for age, height, weight, body fat, VO₂ max and HRWRT were collected and analyzed for each participant. Mean and standard deviation values are presented in Table 4.1.
Table 4.1: Descriptive Data for the Participants (N=32)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Men</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>M</td>
<td>SD</td>
<td>N</td>
<td>M</td>
<td>SD</td>
<td>N</td>
</tr>
<tr>
<td>Age (yrs)</td>
<td>20.84</td>
<td>1.68</td>
<td>19</td>
<td>20.77</td>
<td>1.79</td>
<td>13</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>180.32</td>
<td>5.74</td>
<td>19</td>
<td>169.24</td>
<td>8.51</td>
<td>13</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>76.56</td>
<td>13.38</td>
<td>19</td>
<td>64.93</td>
<td>12.29</td>
<td>13</td>
</tr>
<tr>
<td>VO₂max</td>
<td>45.11</td>
<td>6.69</td>
<td>19</td>
<td>38.71</td>
<td>4.23</td>
<td>13</td>
</tr>
<tr>
<td>HRWRT (bpm)</td>
<td>155.79</td>
<td>16.64</td>
<td>19</td>
<td>149.46</td>
<td>13.82</td>
<td>13</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>12.66</td>
<td>6.97</td>
<td>19</td>
<td>18.02</td>
<td>2.99</td>
<td>13</td>
</tr>
<tr>
<td>RER</td>
<td>1.29</td>
<td>6.24</td>
<td>19</td>
<td>1.20</td>
<td>8.84</td>
<td>13</td>
</tr>
<tr>
<td>BSA m²/kg</td>
<td>1.95</td>
<td>.18</td>
<td>19</td>
<td>1.74</td>
<td>.19</td>
<td>13</td>
</tr>
</tbody>
</table>

All variables included in the regression model with the exception of gender and age were approximately normally distributed with skewness and kurtosis values between ±1 as listed in Table 4.2. (George & Mallery. 2000)
Table 4.2: Skewness and Kurtosis for the Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td>.40</td>
<td>-1.97</td>
</tr>
<tr>
<td>Age</td>
<td>.06</td>
<td>-1.23</td>
</tr>
<tr>
<td>Height</td>
<td>-.21</td>
<td>-.407</td>
</tr>
<tr>
<td>Weight</td>
<td>-.39</td>
<td>-.60</td>
</tr>
<tr>
<td>VO(_2) max</td>
<td>.25</td>
<td>-.87</td>
</tr>
<tr>
<td>HRW</td>
<td>-.00</td>
<td>-.50</td>
</tr>
<tr>
<td>Body fat</td>
<td>.30</td>
<td>-.40</td>
</tr>
<tr>
<td>RER</td>
<td>-.06</td>
<td>-.96</td>
</tr>
<tr>
<td>BSA m(^2)/kg</td>
<td>.47</td>
<td>-.83</td>
</tr>
</tbody>
</table>

Correlation

A Pearson Product Moment Correlation (see Table 4.3) was used to determine the extent of any relationships between the predictor variables for this specific sample. This was done in an attempt to prevent multicollinearity, which creates a problem only when it leads to inflated estimates of the standard error of the parameter estimate, thus deflating the absolute value of the t statistic (George & Mallery, 2000). All predictor variables with a correlation of .5 or higher were scrutinized by the researcher before being included in the full model (George & Mallery, 2000). Gender and height (r = .63) and height and weight (r = .56) were examined for theoretical inclusion in the model. Based on the review of literature, a decision was made by the researcher to include all variables in the
model. Kline et al. (1987) found that the best prediction equation for $V_02_{max}$ included gender, weight, age, running time, and HR after a submaximal exercise bout. Similarly, Kaminsky et al. (1993) also found that the adjusted $R^2$ increased with the addition of the variable height in their multiple regression analyses to predict $VO_2_{max}$.

Table 4.3: Intercorrelations between the Variables for Participants

<table>
<thead>
<tr>
<th>Variables</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Participant (N=32)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Gender</td>
<td>--</td>
<td>-.63</td>
<td>-.41</td>
<td>-.49</td>
<td>-.20</td>
<td>.43</td>
</tr>
<tr>
<td>2. Height</td>
<td>--</td>
<td>.56</td>
<td>.40</td>
<td>.10</td>
<td>.31</td>
<td></td>
</tr>
<tr>
<td>3. Weight</td>
<td>--</td>
<td>-.27</td>
<td>.04</td>
<td>.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. $VO_2_{max}$</td>
<td>--</td>
<td>-.09</td>
<td>-.87</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. HRWRT</td>
<td>--</td>
<td></td>
<td>.06</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Body Fat</td>
<td>--</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Regression Analyses

Full model

The researcher made an assumption based on the review of literature that all the variables in the model could increase the explained variance in the participants' $VO_2_{max}$ (Kaminsky et al., 1993; Kline et al., 1987). All 5 variables were entered into the regression analysis. The values for the full model are listed in Table 4.4.

Table 4.4: Full Multiple Regression Analysis Model
### Restricted Model

Based on the information from the full model, a restricted model was conducted using only the variables that significantly contributed to the variance in VO$_2$ max. A t-value that refuted the null hypothesis (H0: $b_1 = 0$) that the predictor variable would not contribute to the explanatory variance in the criterion variable was used to determine the significance of the predictor variables ($p < .05$). Only the variable, body fat, was included in the restricted model. The values for the restricted model are listed in Table 4.5.
Table 4.5: Restricted Model

<table>
<thead>
<tr>
<th>Variable</th>
<th>Beta coefficient</th>
<th>t-value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body Fat</td>
<td>-0.92</td>
<td>-9.76</td>
<td>.00</td>
</tr>
</tbody>
</table>

Intercept = 56.14

R-squared = .76

Adjusted R-squared = .75

Standard Error of Estimation = 3.27

The Significance of Multiple R

Table 4.6 lists F values and the R-squared values for the restricted and full model.

Table 4.6: Results of the Full and Restricted Models

<table>
<thead>
<tr>
<th>Source of Variation</th>
<th>Df</th>
<th>F</th>
<th>R-squared</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Full</td>
<td>5</td>
<td>19.26</td>
<td>.79</td>
<td>.00</td>
</tr>
<tr>
<td>Restricted</td>
<td>1</td>
<td>95.22</td>
<td>.76</td>
<td>.00</td>
</tr>
</tbody>
</table>

The researcher tested the difference between the multiple R for the full model and the multiple R for the restricted model (Hinkle, Wiersma, & Jurs. 1997).
The formula used for this computation is as follows:

\[
F = \frac{(R_1^2 - R_2^2)/(k_1 - k_2)}{(1 - R_1^2)/(N - k_1 - 1)}
\]

where \( R_1^2 \) is the square of the multiple \( R \) for the full model with the predictor variables \( (k_1) \) and \( R_2^2 \) is the square of the multiple \( R \) for the restricted model with the predictor variable \( (k_2) \). Data for this formula is as follows:

\[
F = \frac{(.79 - .76)/(5-1)}{(1 - .79)/(32-5-1)} = .94.
\]

The critical value of \( F \) for 4 and 26 degrees of freedom was 2.74 in order to reject the null hypothesis that there was no difference in the explanatory variance between the two models (\( \alpha = .05 \)). Since the computed value (0.94) did not exceed the critical value (2.74), the conclusion was that the addition of gender, height, weight, and HRW did not result in a statistically significant increase in the multiple \( R \). The most parsimonious model was the one variable model (Adjusted R-squared = .75). The regression equation for the restricted model was: Predicted VO\(_{2\text{max}}\) = 56.14 - .92 (% Body Fat).
CHAPTER V
DISCUSSION AND CONCLUSIONS

The purpose of this study was to predict VO₂max from a submaximal water running test utilizing the HRWRT response. Additional predictor variables included in the model were body fat, height, weight, and gender. Based on the correlation coefficient, body fat accounted for 76% of the variance in VO₂max. No other variable significantly contributed to the explained variables in VO₂max.

The studies for a submaximal test in water to predict VO₂max have been limited (Conley et al., 1991). In addition, even though there have been a few studies to develop prediction equations utilizing a submaximal test in water for VO₂max, the HR responses to exercise in water have not been used for a significant predictor variable (Kaminsky et al., 1992; Conley et al., 1991, 1992). Predictions of VO₂max from submaximal exercise are based on the assumption that a linear relationship exists among VO₂, workload, and HR. Other studies have been reported that HR responses during water exercise are correlated to VO₂, which is similar to the relationship between HR and VO₂ during exercise on land (Whitley & Schoene, 1987; Kame & Pendergast, 1995; Gleim & Nicholas, 1989). Nevertheless, Kaminsky et al. (1993) reported that the coefficient correlation between VO₂max and the HR after the 500-yard water run was r = .06. However, there have been no additional studies to support or refute this finding.

An inverse relationship between HRWRT and VO₂max was expected in the present study, but this was not the case. This assumption was based on the linear relationship between heart rate and VO₂max on land. In the present study, there was no correlation
between VO\textsubscript{2max} and HRWRT (r = -.09). The average HRWRT during this study was 153 bpm or 77% of maximum HR. This heart rate should be of sufficient intensity to meet the requirements for predicting VO\textsubscript{2max}. Astrand (1954) stated that a participant’s aerobic capacity could be predicted when the intensity of submaximal exercise reached a steady heart rate of 125 bpm to 170 bpm for participants 18 to 30 years old on land. Fox (1973) also reported that the relationship between VO\textsubscript{2max} and submaximal heart rate was linear, emphasizing the practicality of using a single 5-min submaximal exercise load and one submaximal variable to predict VO\textsubscript{2max}. In addition, the study by McArdle et al. (1972) indicated that several regression equations could be developed for predicting VO\textsubscript{2max} by using the length of the time the participant walked before the heart rate reached 150 bpm and using the length of the time the participant walked before the heart rate reached 170 bpm. Based on McArdle et al.’s study, the HRWRT of the present study (155.79 bpm for male and 149.46 bpm for female) should have been of a sufficient magnitude to predict VO\textsubscript{2max}. Why the different findings between water and land?

Both the present study and the study by Kaminsky et al. (1993) used submaximal field tests in water while other researchers used the submaximal field tests on land to develop regression equations for VO\textsubscript{2max}. The hydrostatic pressure of water pushes equally on all body surfaces and helps the cardiovascular system circulate blood by aiding venous return to the heart. This assistance to the heart accounts for lower heart rates during the exercise in water than on land at water temperatures below 36.1°C (Whitley et al., 1987; Kame & Pendergast, 1995). Butt et al. (1991) stated that these alterations to facilitate venous return maintained the required cardiac output more efficiently with higher stroke volumes and lower heart rates during submaximal exercise.
in water. In addition, McMurray, Fieselman, Avery, and Sheps (1988) reported that cardiac outputs during low intensity water exercise were slightly greater than in response to land exercise with lower heart rate, but these differences were not evident as the exercise intensity increased.

Another possible factor to consider when examining the different HR responses to the exercises in water and on land is water temperature. Water temperature could affect the heart rate during water running tests. Craig and Dvorak (1969) reported that head-out underwater arm and leg cycling at 25°C produced a lower HR response for similar exercise on land. Costill et al. (1967) reported that heart rate following a 20 min submaximal exercise bout in 17.4 °C water was lower than that in 26.8 or 33.1°C. The observation from these studies is that heart rate decreased with a decrease in water temperature (Costill et al., 1967: Craig & Dvorak, 1969).

In the present study, the water temperature was held constant at approximately 34°C. Gleim and Nicholas (1989) reported that when exercising on an underwater treadmill (30.5 °C) at waist depth, the heart rate response was greater for any increase in VO₂ compared to dry land at room temperature of 24-26°C. Furthermore, as the water temperature was increased to 36.1°C, heart rate increased more rapidly for any change in VO₂. The slope of the line for heart rate to VO₂ was significantly different between dry land, underwater treadmill walking at 30.5°C, and underwater treadmill walking at 36.1°C. It is apparent from this study that water temperature has an effect on heart rate.

The tremendous variability between HRWRT and VO₂max could be related to the variability in surface-area-to-body-mass-ratio (BSA m²/kg) among the participants. BSA m² can be calculated using the formula (([Height*Weight]/3600)½. This value is then
divided by the individual's body weight in kg to obtain BSA m$^2$/kg. BSA m$^2$/kg for the study participants ranged from 1.39 to 2.22. BSA m$^2$/kg is one of the most important variables in heat transfer (McComb, 1999). However, BSA m$^2$/kg was not correlated to the HR responses at the end of each stage during the exercise. At the end of the first, second and third stages, the correlation coefficients between HR responses and BSA m$^2$/kg were $r = .15$, .19, and .06, respectively.

The increase in HR in water temperatures $> 24^\circ$C, as found in the study by Gleim and Nicholas (1989), could be related to an increase in peripheral blood flow to aid in cooling the skin and regulating body temperature. The decrease in central blood volume for peripheral cooling would be compensated for by an increase in HR to maintain an adequate cardiac output to meet oxygen demands (Wilmore & Costill, 1994). There would be variability in blood flow to the skin to regulate body temperature because of the inconsistency in BSA m$^2$/kg among the participants. Heat transfer in water is approximately 4 times faster than on land because of the combined effects of radiation, conduction, and convection (Wilmore & Costill, 1994).

Another postulate that must be examined when trying to understand the HRWRT in the present study is the assumption that there is a linear relationship between workload and HR. If HR does not increase as workload increases, the protocol in the water running test may be flawed and invalid. HR responses at the end of each 2-min spm increments (100, 108, & 116) were plotted to see if there was a linear increase in HR as workload increased (see Appendix O). The average HRs at the end of 100, 108, and 116 spm were 131, 145, and 153 bpm, respectively. Based on these results, it seems that HR was responding to an increase in workload appropriately. However, even though the
relationships between workload and HR response during the water exercise test was linear, there was tremendous variability between HRWRT and VO\textsubscript{2max} in the present study. This finding is different from land studies which used HR at the end of submaximal exercise bout to predict VO\textsubscript{2max} (Horvath & Horvath, 1973; Fox, 1973).

In order to use submaximal HRs to predict VO\textsubscript{2max} a steady state HR must be reached at the end of each stage. In order to test this assumption, HR values should not differ by more than 5 bpm between the last 2 min of the stage. If HR differs by more than 5 bpm, an additional min should be added to the stage until a steady state is reached (Astrand & Rodahl, 1986; Golding, Myers, & Sinning, 1989). This procedure to assure a steady state was not followed in the present study. It is not known whether a steady state was reached during each stage. If a steady state was not reached, this would violate the assumption that is needed to use submaxial HRs to predict VO\textsubscript{2max} (Astrand & Rodahl, 1986; Golding, Myers, & Sinning, 1989).

Kaminsky et al. (1993) reported that heart rate responses to exercise in water might differ from those on land depending on a variety of factors and the lack of familiarity with the exercise in water. Furthermore, there might be the influence of the water on the mechanical factors involved when running in the water. Due to the body’s buoyancy in water, less work is required for the antigravity muscles to maintain body posture during water running. This decreases the active muscle mass normally involved when running on land (Butt et al., 1991).

Rowell (1964) mentioned that the HR during submaximal exercise was an unreliable predictor of VO\textsubscript{2max} since it could be influenced by several variables such as temperature and mental factors. Therefore, the tremendous variability in the HR response...
during water running in 34°C in this study sample is not unprecedented. Other studies have reported similar findings (Kaminsky et al., 1993; Butt et al., 1991; Rowell et al., 1964).

The correlation coefficient of VO2max and percent body fat was r = -.87. This was similar to the correlation coefficients of VO2max and percent body fat from other studies. Kaminsky et al. (1993) reported a correlation coefficient of -.82 between VO2max and percent body fat in 43 volunteers (28 male, 15 female) from several university aqua-aerobics classes. The study by Getchell et al. (1977) also showed that the correlation coefficient between VO2max and percent body fat for similar age groups (20.1 years, 21 female) was r = -.75. According to a study by Harrison, Bruce, Brown, and Cochrane (1980), the correlation coefficient between VO2max predicted from body fat and actual VO2max was r = -.79 for males (N=9) with a M age of 31 years. These results support the findings of the present study that body fat significantly contributes to the explanatory variance in VO2max. Appendix P lists the measured VO2max values and those obtained from the prediction equation developed in this study (56.14 - .92 * (% Body Fat)). The M difference in percent between the measured and predicted values was 6.15% (SD, 4.76).

Height accounted for 16% of the variance in VO2max in this study. The correlation coefficient of VO2max and height was r = .40. Other researchers reported that the correlation coefficient between VO2max and height was not high enough to be considered as a predictor variable for VO2max, accounting for approximately 27% of the variance in VO2max (Katch et al., 1973; Getchell et al., 1977; Kaminsky et al., 1993). However, other researchers (Conley et al., 1991) have stated that it is possible for height to influence VO2max with respect to mechanical factors and running economy.
Gender accounted for 24% of the explained variance in VO_{2max} in the present study ($r = -0.49$). Jones (1997) stated that the differences in VO_{2max} between genders largely disappeared when other factors, such as lean body mass, hemoglobin level, and levels of habitual activity, were taken into account. Other researchers also reported that there was little or no difference in predicting VO_{2max} due to gender (Pollock et al., 1982; Storer et al., 1990). Conley et al. reported separate equations for women (1992) and men (1991) to estimate VO_{2max} even though there were no differences in the slopes of the two equations. Previous researchers have stated that the examination of the variable gender is warranted in predicting VO_{2max} (Conley et al., 1991). However, similar to the present study, gender has not been found to be a significant predictor variable in VO_{2max} (Kaminsky et al., 1993; Conley et al., 1991).

Implications

Based on the findings of the present study, implications include the following for the practitioner and for the researcher.

Practitioner

The practitioner can use the findings of the present study as one of the assessment tools.

1. The practitioner should be aware that the prediction equation using percent body fat may be utilized for individuals who cannot perform other field tests due to orthopedic limitations.
2. The practitioner should be aware that the HR during water exercise may be affected by several factors including but not limited to water temperature, BSA m²/kg, mental factors, and lack of familiarity with exercise in water. Therefore, the HR should be carefully considered for the prescription of water exercise.

**Researcher**

The researchers are needed to conduct a similar type of study in order to utilize the findings of this study for several populations.

1. A similar type of study should be designed to understand HR responses to exercise in water since the HR responses to exercise in water seem to differ from those to exercise on land.

2. This type of study should be carried out on other populations that vary in age and gender. The current study was limited to college-aged males and females.

3. This type of study should be conducted on patients with lower extremity injuries, orthopedic limitations, and obesity to determine VO₂max from a submaximal water running test utilizing significant predictor variables.

4. The assumption that a steady state HR is reached in a 2-min stage must be tested by the researcher. HR should be checked between the last two min of each stage to make sure that a steady state HR is reached. If HR differs by more than 5 bpm, an additional min should be added to the stage until a steady state is reached. If this assumption is not met, HR cannot be used to predict VO₂max from a submaximal water running test.
Conclusions

The results of this study warrant the following conclusions.

1. VO₂max is highly correlated to body fat. This finding is very similar to other findings in the literature (Kaminsky et al., 1993; Getchell et al., 1977; Harrison et al., 1980).

2. HRWRT in the present study did not contribute to explained variance in VO₂max. Another study has similarly reported that HR may not be a significant predictor variable for VO₂max due to low correlation coefficients between HR response in water and VO₂max (Kaminsky et al., 1993). However, other studies have reported that HR responses during water exercise are correlated to VO₂, which is similar to the relationship between HR and VO₂ during exercise on land (Whitley & Schoene, 1987; Kame & Pendergast, 1995; Gleim & Nicholas, 1989).

3. Height was not considered to be a significant predictor variable in this study. Other researchers reported that the correlation coefficient between VO₂max and height was not high enough to be considered as a predictor variable for VO₂max (Katch et al., 1973; Getchell et al., 1977; Kaminsky et al., 1993).

4. Gender was not considered to be a significant predictor variable in the regression analyses. Other researchers also reported that there was little or no difference in predicting VO₂max due to gender (Pollock et al., 1982; Storer et al., 1990).


APPENDIX A

FULL COMMITTEE PROPOSAL

I. Title of Research Project:
The Prediction of Maximal O₂ Consumption from a Submaximal Water Running Test

II. Rationale:
A submaximal water based fitness test that is useful in predicting cardiovascular fitness has not been developed which excludes swimming stroke skill. The most widely used swimming test takes 12-min and depends heavily on swimming stroke skill. There is a need for a fitness test that would be more time-efficient and that does not rely heavily on swimming. The proposed assessment instrument will be non-invasive and submaximal. The test only takes 6-min and uses a pattern similar to walking. This test may be used in fitness centers and health care settings as a screening or assessment tool.

The assessment tool proposed in this study will provide health and fitness educators with a practical submaximal water based fitness test designed to assess cardiovascular fitness level independent of stroke efficiency. This assessment tool would be very useful for physical therapists or other health and fitness professionals who work with individuals who are overweight or have lower extremity injuries because of the decreased impact on the joints. These individuals, particularly, would profit from non-weight bearing assessment tools.

Participants involved in this study will benefit in the following ways: they will accrue extra credit at the same rate given for other extra credit assignments in the class, the results of the assessments of their fitness level and body composition will be shared with them (an $280.00 market value); and the health and fitness results may serve as a motivator for increased fitness. If students wish to receive extra credit but are not eligible for the study or do not wish to participate in this particular study, alternative extra credit points will be made available by the researcher. Students will be asked to fill out a 7-day dietary recall and enter their information in the program entitled the "Executive Diet Helper". They will also be required to develop an exercise plan using the program entitled 'Weight Loss Planner Exercise Program Development' on the same computer. A summary will be printed out for them. They will have to turn in this summary to receive extra credit. This program is found on the Power Mac in the Men's Gym Computer Lab. This lab is open from 8 until 5 o'clock M-F.

III. Participants
Volunteers will be recruited from the general population of college students in the Personal Fitness and Wellness classes, and specifically, the swimming and scuba diving classes offered by the Department of Health Exercise and Sport Science at TTU. The study will be explained to potential participants covering the purpose, procedures, possible risks, and potential benefits. Prior to their actual participation in
the study, the students will be given a form which will contain the name and address of the investigators, the purpose of the research, a summary of the eligibility criteria which will be used to both admit and exclude participants from the study, a list of benefits to the participant for their participation in the study, the location of the research, and the person to contact for further information. The purpose of this form is to help students decide if they are interested in participating in the study. After it becomes clear that potential participants understand these factors and all questions have been answered fully, they will be offered the opportunity to sign the consent form and become enrolled in the study. They will then be given the consent form to read. If they agree to participate, they will then each read, sign, and date the consent form (see Appendix D).

IV. Protocol
There are three stages of the screening process in order to qualify for participation in this study following the signing of the consent form.

Stage 1
Participants will complete a Physical Activity Readiness Inventory in order to determine their eligibility to proceed to the next screening step. This form is a widely used screening tool. If participants list yes to any of these questions they will be excluded from the study. Alternative extra credit points offered by the investigator can be used.

Stage 2
Participants that pass the stage one screening will be asked to go to Thompson Hall to have their cholesterol, blood pressure, and triglycerides checked. They will also be responsible for picking their lab reports up from Thompson Hall.

Stage 3
After lab report results are available to them, participants will schedule an appointment with the investigator to answer questions concerning risk factors. The risk categories are those designated by the American College of Sports Medicine (see Appendix F). Only participants who score in the apparently healthy risk category will be eligible for participation in the full research project (see Appendix G). If students wish to receive extra credit but are not eligible for the study or do not wish to participate in this particular study, alternative extra credit points will be made available by the researcher. Students will be asked to fill out a 7 day dietary recall (see Appendix N) and enter their information in the program entitled the "Executive Diet Helper". They will also be required to develop an exercise plan using the program entitled 'Weight Loss Planner Exercise Program Development' on the same computer. A summary will be printed out for them. They will have to turn in this summary to receive extra credit. This program is found on the Power Mac in the Men's Gym Computer Lab. This lab is open from 8 until 5 o'clock M-F.

Participants will then undergo the following exercise tests over a period of a few days: a) a maximum VO\textsubscript{2} exercise treadmill test; b) a water running test (a Polar
Heart Rate Monitor will be used to determine heart rate: and c) a 7 site skin fold assessment.

Oxygen and trained CPR personnel will be available on site during all aerobic exercise testing. Participants will be informed that if they experience light-headedness, chest tightness or pain in their arm, undue fatigue, unwarranted breathlessness or any pain that is increasingly uncomfortable they should stop the test. An additional exercise consent form, which includes the dialogue used by the exercise tester, will be signed prior to maximal exercise testing (see Appendix H). Participants perceived exertion, blood pressure, and heart rate will be continually monitored (every 3-min) during maximal testing. Absolute and relative indications to stop an exercise test will be posted on the wall and adhered to (see Appendix I). Any abnormal rise or fall in blood pressure, irregular heart rhythms, will immediately signify the termination of the test. Cardiac arrest is rare during exercise testing (1 in 20,000) and even rarer in healthy individuals in this age category. Should any of these symptoms begin to appear, the trained personnel administering the tests will stop the test and take appropriate action.

IV. Arrangements for Handling Liability for Unexpected Injuries to Participants

Arrangements for handling liability for unexpected injuries to participants are addressed in the consent form.

‘If this research project causes any physical injury to participants in this project, treatment will be supplied in accordance with the participant’s insurance. There is not necessarily any treatment available at Texas Tech University, nor is there necessarily any insurance carried by the University or its personnel applicable to cover any such injury. Financial compensation for any such injury must be provided through the participant’s own insurance program. Further information about these matters may be obtained from Dr. Robert M. Sweazy, Vice Provost for Research, 742-3884, Room 203, Holden Hall, Texas Tech University, Lubbock, Texas, 79409.’
Hello, my name is _________. I am a graduate assistant in the Department of Health, Exercise and Sport Science. Dr. McComb and I are conducting a study for which we are seeking volunteers.

The purpose of the study is to develop a sub-maximal water exercise test, which will serve as a predictor of one’s cardiovascular fitness level. We are using a sample of college students enrolled in PF&W swimming and scuba classes. The methods of the study are as follows. Should you volunteer to participate in the study, you will be given a consent form to read and sign. You will be given a form to keep which will contain the names and addresses of the investigators, the purpose of the research, a summary of the eligibility criteria which will be used to exclude participants from the study, a list of benefits to you for your participation in the study, the location of the research, and the person to contact for further information. If you are pregnant we do not recommend that you participate in this study since it will require you to increase your working heart rate above 140.

Once you have signed the consent form and given these papers, you will go through three stages of screening in order to qualify for participation in the study. The first stage is for you to complete a self-report data form (PAR-Q) indicating your health status and eligibility for inclusion in the study. If you pass this screening you will then go to Thompson Hall to have your cholesterol, blood pressure, and triglycerides checked. You will bring the results of the lab test to the investigators, who will determine your risk category for the exercise testing, as defined by the American College of Sports Medicine. Only persons who are within the “Apparently Healthy” category and are younger than age 40 for men and 50 for women will be included in the study. The results of each of these screening forms will be kept on file and will be strictly confidential.

If included in the study sample, you will undergo the following exercise tests over a period of 2 days: (1) a symptom-limited maximum exercise test on a treadmill with stress level being monitored via a limb-lead EKG, (2) a water running test while wearing a Polar Heart Rate Monitor, and (3) a 7 site skinfold assessment of body composition. On the treadmill you will continue walking or running until you tell us you have reached your maximum physical exertion. During the water test you will simply tread water for 6 min and we will get your heart rate from a heart rate monitor that you wear on your wrist. We will be determining body composition by assessing the thickness of your subcutaneous skinfold fat.

Your participation in the study will cost you your time and energy. We anticipate the time cost to be a few hours, given the time required for the blood work and the exercise tests. The time involved for exercise tests will be about a half an hour each, over a period of 2 days.

The benefits to you from your participation in the study are the following. You will gain accurate information about your cardiovascular fitness, body composition, cholesterol, blood pressure, and triglycerides. The information has a market value of $280. Also, you will earn extra credit points for this class by participating in this study.
Alternative extra credit points can be earned by doing a 7-day dietary recall and exercise program development plan. If you volunteer for the study and become eliminated at the first stage after completing the Par-Q preliminary written screening form or you advance on to the second or third stage, and then are eliminated, you can earn extra credit points by participating in the dietary analysis and exercise program development. You will be asked to fill out a 7-day dietary recall (see Appendix N) and enter their information in the program entitled the "Executive Diet Helper". You will also be required to develop an exercise plan using the program entitled 'Weight Loss Planner Exercise Program Development' on the same computer. A summary will be printed out for you. You will have to turn in this summary to receive extra credit. This program is found on the Power Mac in the Men's Gym Computer Lab. This lab is open from 8 until 5 o'clock M-F. This computerized program can be found in the computer lab at the Men's Gym and is open from 8-5 M-F.

Thank you for your attention. I will now respond to your questions, and accept volunteers for the study.
APPENDIX C

PARTICIPANT'S INFORMATION FORM

Participant: _______________________

Investigators: Dr. Jacalyn McComb Mr. Daesung Roh
742-3371 (work) 742-3333 (work)
tmjjr@ttacs.ttu.edu daesungr@hotmail.com
office: Men’s Gym 203 office: SRC #5

Purpose of the Research: To develop a sub-maximal water exercise test that predicts one’s cardiovascular fitness level.

Summary of Eligibility Criteria to Admit and Exclude Participants:
You may be excluded from the study in one of two ways: (a) if you answer yes to any one of the below questions; or (b) if you have more than one major coronary risk factor as determined by your lab tests and personnel interview.

1. Has your doctor ever said you have heart trouble? Yes No
2. Do you frequently suffer from pains in your chest? Yes No
3. Do you often feel faint or have spells of severe dizziness? Yes No
4. Has a doctor ever said your blood pressure was too high? Yes No
5. Has a doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise? Yes No
6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to? Yes No
7. Are you over age 65 and not accustomed to vigorous exercise? Yes No
8. Is there a possibility that you could be pregnant? Yes No

Participation Benefits: You will gain accurate information about your cardiovascular fitness, body composition, cholesterol, blood pressure, and tryglycerides. Also, you will earn extra credit points for this class by participating in this study. Alternative extra credit points can be earned by doing a 7-day dietary recall and exercise program development plan. If you volunteer for the study and become eliminated at the first stage after completing the Par-Q preliminary written screening form or you advance on to the second or third stage, and then are eliminated, you can earn extra credit points by participating in the dietary analysis and exercise program development. This computerized program can be found in the computer lab at the Men’s Gym and is open from 8 to 5 o’clock M-F.
Research Location: The laboratories at the Department of Health, Exercise and Sport Science located in the Men’s Gym on the main campus of Texas Tech University.

For further information, contact the primary investigators listed at the top of this form.
APPENDIX D

CONSENT FORM

I hereby give my consent for my participation in the project entitled: The Development of a Prediction Equation for Maximum Oxygen Consumption: Significant Predictor Variables in an Aquatic Environment. I understand that the people responsible for this project are: Dr. Jaclyn McComb; Telephone number (806) 742-3371, and Daesung Roh; Telephone number (806) 724-7227.

The investigators have explained that the purpose of this study is to develop a sub-maximal exercise test in the water that will serve as a predictor of one’s cardiovascular fitness level. I give my consent for the release of the information from the lab reports to the investigator in order to determine the appropriateness from a safety standpoint of maximal exercise testing for me. The investigators or their authorized representatives have explained the procedures as follows: My participation will involve a total of approximately 3 hours. This will consist of a pre-study pencil and paper questionnaire, followed by cholesterol and blood pressure screening assessment at Thompson Hall, and lastly meeting with the investigator to determine my risk category. The actual testing time following screening is as follows: (a) a maximum VO₂ consumption treadmill test (approximately 9-18 min); (b) a 6 min water test; and (c) a 7-site skin fold assessment (approximately 10 min). Information concerning payment for my participation in this study has been explained to me as extra credit points to be applied toward my grade in the PF&W class. I may also choose to participate in an alternative extra credit assignment. I will be asked to fill out a 7-day dietary recall (see Appendix N) and enter the information in the program entitled "Executive Diet Helper". I will also be required to develop an exercise plan using the program entitled 'Weight Loss Planner Exercise Program Development' on the same computer. A summary will be printed out for me. I will have to turn in this summary to receive extra credit. This program is found on the Power Mac in the Men's Gym Computer Lab. This lab is open from 8 until 5 o'clock M-F.

Based on my cardiovascular risk factors, I am considered to be low risk for coronary heart disease. However, there are risks with any activity. The risks have been explained to me as follows. Possible risks include light-headedness, abnormal rise in blood pressure, irregular heart rhythms, and in rare (1 in 20,000), cardiac arrest. I have been informed that if I experience any of the above mentioned symptoms while undergoing the exercise testing, I should inform the trained personnel administering the test, and they will stop the test for my safety and take appropriate action.

Oxygen and trained CPR and first aid personnel will be available on site during all testing. I have been informed that if I am pregnant, I must not participate in this testing.
It has further been explained to me that only the investigators will have access to the records and/or data collected for this study, and that all data associated with this study will remain strictly confidential.

Dr. McComb and Mr. Roh have agreed to answer any inquiries I may have regarding the procedures and have informed me that I may contact the Texas Tech University Institutional Review Board for the Protection of Human Subjects by writing them in care of the Office of Research Services, Texas Tech University, Lubbock, Texas. 79409, or by calling 742-3884. If this research project causes any physical injury to participants in this project, treatment will be supplied in accordance with the participant’s insurance. There is not necessarily any treatment available at Texas Tech University. Financial compensation for any such injury must be provided through the participant’s own insurance program. Further information about these matters may be obtained from Dr. Robert M. Sweazy, Vice Provost for Research, 742-3884, Room 203, Holden Hall, Texas Tech University, Lubbock, Texas, 79409-1035.

I understand that I may not derive therapeutic treatment from participation in this study. I understand that I may discontinue this study at any time I choose without penalty.

Signature of Participant

Date

Signature of Parent/Guardian or Authorized Representative (if required)

Date

Signature of Project Director or her Authorized Representative:

Date
APPENDIX E

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE

For most people, physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable.

1. Has your doctor ever said you have heart trouble? Yes__ No__
2. Do you frequently suffer from pains in your chest? Yes__ No__
3. Do you often feel faint or have spells of severe dizziness? Yes__ No__
4. Has a doctor ever said your blood pressure was too high? Yes__ No__
5. Has a doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise? Yes__ No__
6. Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to? Yes__ No__
7. Are you over age 65 and not accustomed to vigorous exercise? Yes__ No__

If a person answers yes to any question, vigorous exercise or exercise testing should be postponed. Medical clearance may be necessary.

## APPENDIX F

### ACSM’S RISK FACTORS FOR CARDIAC DISEASE

<table>
<thead>
<tr>
<th>Positive Risk Factors</th>
<th>Defining Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Age</td>
<td>Men &gt; 45 years; women &gt; 55 or premature menopause without estrogen replacement therapy</td>
</tr>
<tr>
<td>2. Family history</td>
<td>MI or sudden death before 55 years of age in father or other male first-degree relative, or before 65 years of age in MI or sudden death before 55 years of age in father or other male first-degree relative, or before 65 years of age in</td>
</tr>
<tr>
<td>3. Current cigarette smoking</td>
<td>Blood pressure ≥ 140/90 mm Hg, confirmed by measurements on at least 2 separate occasions, or on antihypertensive medication</td>
</tr>
<tr>
<td>4. Hypertension</td>
<td>Total serum cholesterol &gt; 200 mg/dL (5.2 mmol/L) (if lipoprotein profile is unavailable) or HDL &lt; 35 mg/dL (0.9 mmol/L)</td>
</tr>
<tr>
<td>5. Hypercholesterolemia</td>
<td>Persons with insulin dependent diabetes mellitus (IDDM) who are &gt; 30 years of age, or have had IDDM for &gt; 15 years, and persons with noninsulin dependent diabetes mellitus (NIDDM) who are &gt; 35 years of age should be classified as patients with disease</td>
</tr>
<tr>
<td>6. Diabetes mellitus</td>
<td>Persons comprising the least active 25% of the population, as defined by the combination of sedentary jobs involving sitting for a large part of the day and no regular exercise or active recreational pursuits</td>
</tr>
<tr>
<td>7. Sedentary lifestyle/ inactivity</td>
<td></td>
</tr>
</tbody>
</table>

### SIGNS AND SYMPTOMS OF POSSIBLE CARDIOVASCULAR DISEASE

1. Do you have pains in your chest, neck, or jaw?  
   - Yes  
   - No

2. Do you often feel faint or have spells of severe dizziness?  
   - Yes  
   - No

3. Do you have a known heart murmur?  
   - Yes  
   - No

4. Do you have ankle edema?  
   - Yes  
   - No

5. Do you have shortness of breath at rest or with mild exertion?  
   - Yes  
   - No

6. Do you become unusually fatigued or have shortness of breath with usual activities?  
   - Yes  
   - No

Comments:
APPENDIX G

HEALTH SCREENING AND RISK STRATIFICATION

Table G.1 Intial Risk Stratification

<table>
<thead>
<tr>
<th>Level</th>
<th>Defining Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Apparently healthy</td>
<td>Individuals who are asymptomatic and apparently healthy with no more than one major coronary risk factor</td>
</tr>
<tr>
<td>2. Increased risk</td>
<td>Individuals who have signs or symptoms suggestive of possible cardiopulmonary or metabolic disease and/or two or more major coronary risk factors</td>
</tr>
<tr>
<td>3. Known disease</td>
<td>Individuals with known cardiac, pulmonary, or metabolic disease</td>
</tr>
</tbody>
</table>
APPENDIX H

INFORMED EXERCISE CONSENT

In order to assess cardiovascular function, body composition, and other physical fitness components, the undersigned hereby voluntarily consents to engage in the following tests: (a) a graded exercises stress test, (b) a water fitness test, and (c) a body composition test.

Explanation of the Tests

The graded exercise stress test is performed on a motor-driven treadmill. The workload is increased every few minutes until exhaustion or until other symptoms dictate termination of the test. We may stop the test at any time because of fatigue or discomfort. During the exercise test we want you to pay close attention to how hard you feel the exercise work rate is. This feeling should reflect your total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort, and fatigue. We will be asking you to rate your exertion based on a standardized scale, which is called the scale for Rating Perceived Exertion. Perceived exertion is the overall effort or distress of your body during exercise. The number 0 represents no perceived exertion or leg discomfort and the number 10 represents the greatest amount of exertion that you have ever experienced. At various times during the exercise test you will be asked to point to a number, which indicates your rating of perceived exertion at the time. Don’t concern yourself with any one factor such as leg pain, shortness of breath or exercise intensity, but try to concentrate on your total, inner feeling of exertion. One of the technicians will say the number out loud in order to make sure that we understand your selection. Try not to underestimate or overestimate your feeling of exertion, be as accurate as you can. Do you have any questions?

The body composition procedure involves assessment of subcutaneous fat at seven sites using skinfold calipers. This test provides an accurate assessment of your body composition.

For water fitness testing, you will run in water for 6-min using a modified running motion kick. You will be wearing a heart rate monitor on your wrist that will give us an accurate count of your heart beats per min at the completion of your 6 min test. A lifeguard will be on deck for your safety.

Risks and Discomforts

During the graded exercise stress test, certain changes may occur. These changes include abnormal blood pressure responses, fainting, irregularities in heartbeat, and heart attack (1 in 20,000). Every effort is made to minimize these occurrences. Emergency equipment and trained personnel are available to deal with these situations if they occur.

There is a slight possibility of pulling a muscle or spraining a ligament during the muscle fitness testing. In addition, you may experience muscle soreness 24 to 48 hours after testing. Performing warm-up exercises prior to taking the tests can minimize these risks. If muscle soreness occurs, appropriate stretching exercises to relieve this soreness will be demonstrated.
Expected Benefits from Testing

These tests allow us to assess your physical working capacity scientifically and to appraise your physical fitness status clinically. You will also receive free education about your cholesterol and lipid profile. The results can be used as a motivation to continue or increase your present exercise program. Records are kept strictly confidential unless you consent to release this information.

Inquiries

Questions about the procedures used in the physical fitness tests are encouraged. If you have any questions or need additional information, please ask us to explain further.
APPENDIX I

ABSOLUTE AND RELATIVE INDICATIONS FOR TERMINATION OF AN EXERCISE TEST

Absolute Indications

1. Acute myocardial infarction or suspicion of a myocardial infarction
2. Onset of moderate-to-severe angina
3. Drop in SBP with increasing workload accompanied by signs or symptoms or drop below standing resting pressure
4. Serious arrhythmias (e.g., second- or third-degree atrioventricular block, sustained ventricular tachycardia or increasing premature ventricular contractions, atrial fibrillation with fast ventricular response)
5. Signs of poor perfusion, including pallor, cyanosis, or cold and clammy skin
6. Unusual or severe shortness of breath
7. Central nervous system symptoms, including ataxia, vertigo, visual or gait problems, or confusion
8. Technical inability to monitor the ECG
9. Patient's request

Relative Indications

1. Pronounced ECG changes from baseline [>2mm of horizontal or downsloping ST-segment depression, or >2mm of ST-segment elevation (except in aVR)]
2. Any chest pain that is increasing
3. Physical or verbal manifestations of severe fatigue or shortness of breath
4. Wheezing
5. Leg cramps or intermittent claudication (grade 3 on 4-point scale)
6. Hypertensive response (SBP>260 mm Hg; DBP>115 mm Hg)
7. Less serious arrhythmias such as supraventricular tachycardia
8. Exercise-induced bundle branch block that cannot be distinguished from ventricular tachycardia
APPENDIX J

BRUCE TREADMILL TEST

Name ___________________________ Max HR (220-age) ________
Age_____ Gender_____ Weight _____ 85% of Max HR________
Time___Test Administrator (s) _____________________________

I. Preliminary Data

   Participant ___________________________
   Resting Heart Rate _________ Resting Blood Pressure _____ / _____
   Resting FVC ________________ Resting MVV ___________

II. Graded Exercise Test

<table>
<thead>
<tr>
<th>Stage</th>
<th>Duration (minutes)</th>
<th>Time (Minutes)</th>
<th>Speed (mph &amp; m/min)</th>
<th>Grade (%)</th>
<th>METs</th>
<th>RPE</th>
<th>HR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3</td>
<td>1-3</td>
<td>1.7 45.6</td>
<td>10</td>
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<td>2</td>
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<td>2.5 67.0</td>
<td>12</td>
<td>7.0</td>
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<td>&quot;</td>
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<td>10.2</td>
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<td>5</td>
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<td>13-15</td>
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<td>18</td>
<td>14.9</td>
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<td>6</td>
<td>&quot;</td>
<td>16-18</td>
<td>5.5 147.5</td>
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<td>17.0</td>
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<tr>
<td>7</td>
<td>&quot;</td>
<td>19-21</td>
<td>6.0 160.9</td>
<td>22</td>
<td>19.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Recovery

   2 minutes  Sitting
   4 minutes  "
   6 minutes  "
   8 minutes  "

61
### APPENDIX K

#### SKINFOLD DATA COLLECTING SHEET FOR WOMEN

**7-site formula for women**

<table>
<thead>
<tr>
<th>Site</th>
<th>Value 1</th>
<th>Value 2</th>
<th>Value 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midaxillary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triceps</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subscarpular</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdomen</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Suprailliac</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thigh</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Density Formula for Women**

\[
\text{Body Density} = 1.0970 - (0.00046971*Σ7) + (0.00000056*Σ7^2) - (0.00012828*age)
\]

**Siri Equation (universally accepted)**

\[
\% \text{ Fat} = \frac{4.95}{\text{BD} - 4.65} \times 100
\]

\[
\% \text{ Fat} = ________________
\]
APPENDIX L

SKINFOLD DATA COLLECTING SHEET FOR MEN

7-site formula for men

<table>
<thead>
<tr>
<th>Site</th>
<th>Measurement 1</th>
<th>Measurement 2</th>
<th>Measurement 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chest</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Midaxillary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Triceps</td>
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<td>Thigh</td>
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Body Density Formula for Men

Body Density = 1.0970 - (0.00046971*Σ7) + (0.00000056*Σ7²) - (0.00012828*age)

Siri Equation (universally accepted)

% Fat = (4.95/BD - 4.65) X 100

% Fat = __________
# APPENDIX M

## DATA SHEET FOR WATER RUNNING TEST

<table>
<thead>
<tr>
<th>Name</th>
<th>Gender</th>
<th>Class</th>
<th>Age</th>
<th>MHR (220 - \text{age})</th>
<th>(H_2O) Temp</th>
<th>85% MHR W</th>
<th>Polar HR at end of 6 min water run</th>
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APPENDIX N

FOOD HISTORY QUESTIONNAIRE

If you wish to receive extra credit but are not eligible for the study or you do not wish to participate in the fitness tests, alternative extra credit points can be earned. You will be asked to fill out a 7-day dietary recall (see Appendix I) and enter this information in the program entitled the "Executive Diet Helper". You will also be required to develop an exercise plan using the program entitled 'Weight Loss Planner Exercise Program Development' on the same computer. A summary will be printed out for you. You will have to turn in this summary to receive extra credit. This program is found on the Power Mac in the Men's Gym Computer Lab on the TTU campus. This lab is open from 8 until 5 o'clock M-F.

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**Day Six:**

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**Day Seven:**

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APPENDIX O

MEAN HR RESPONSE TO WATER RUNNING EXERCISE

Figure O.1 Mean HR Response to Water Running Exercise

Figure O.2 HR Response to Water Running Exercise

Table O.1 Mean HR Response

<table>
<thead>
<tr>
<th>Speed</th>
<th>M</th>
<th>SD</th>
<th>N</th>
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<tr>
<td>100 spm</td>
<td>130.63</td>
<td>16.02</td>
<td>32</td>
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<tr>
<td>108 spm</td>
<td>144.54</td>
<td>15.25</td>
<td>32</td>
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<tr>
<td>116 spm</td>
<td>153.22</td>
<td>15.64</td>
<td>32</td>
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### APPENDIX P

**MEASURED AND PREDICTED $\text{VO}_{2\text{max}}$**

Table P.1 The Differences between Measured and Predicted $\text{VO}_{2\text{max}}$

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<tr>
<th></th>
<th>Measured $\text{VO}_{2\text{max}}$</th>
<th>Predicted $\text{VO}_{2\text{max}}$</th>
<th>% Differences</th>
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