COMPARISON OF OXYGEN CONSUMPTION ON DIFFERENT BRANDS

OF ELLIPTICAL TRAINERS IN THE DEVELOPMENT OF

A METABOLIC PREDICTION EQUATION

by

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ABSTRACT

COMPARISON OF OXYGEN CONSUMPTION ON DIFFERENT BRANDS

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   Purpose: The primary purpose of this study was to determine the effect of elliptical trainer brand on gas exchange data as well as to develop separate equations that are specific to certain brands. **Methods:** Twenty-three healthy volunteers participated in the study (22.3 ± 4.6 yrs, 172 ± 8.2 cm, 67.5± 9.3 kg). Subjects completed a treadmill VO_{2max} test to determine fitness level, followed by two testing sessions on two different brands of elliptical trainers, the Precor EFX 576i® and the TRUE TS1®. Subjects exercised at the same watt level on each elliptical trainer as determined by resistance and cadence. Elliptical trainers and testing sessions were randomly assigned so that each subject was measured on each machine for six 5-minute stages for a total exercise time of 30 minutes per session. Oxygen consumption (VO_2), heart rate, rating of perceived exertion (RPE), and caloric cost of the exercise were measured during each session. A 2 (machine) x 3 (workload) repeated measures ANOVA was used to analyze differences

between machines. Stepwise multiple nonlinear regression analysis was used to develop

metabolic equations for submaximal elliptical trainer exercise on both the Precor and

TRUE. **Results:** Significant differences were found between elliptical trainer brands for

all variables analyzed ($p < 0.001$), with the TRUE eliciting higher values than the Precor

for equivalent watt output readings. Oxygen consumption values at the same watt output

reading were 6.85 ± 4.4 ml/kg/min higher on the TRUE for watt levels between 107 and

131 watts. Two separate metabolic equations were developed for submaximal elliptical

trainer exercise on the TRUE ($R^2 = 0.95$, SEE = 2.6), and the Precor ($R^2 = 0.92$, SEE =

2.4). **Conclusion:** Differences exist in physiological responses to submaximal elliptical

trainer exercise at the same machine-given watt levels. These differences may require the

acceptance of a metabolic prediction equation that is specific to a particular brand of

elliptical trainer.

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CHAPTER 1

INTRODUCTION

One calculates the energy requirements of physical activity by measuring or estimating the oxygen requirements of a particular activity. Under steady-state conditions, oxygen consumption provides a measure of the energy cost of exercise (1). Direct measurement of oxygen consumption during different forms of steady-state exercise is one way to derive the energy cost of exercises. In contrast, metabolic prediction equations closely estimate or predict the energy cost of those same physical activities. Metabolic prediction equations are regression equations that include variables such as height, weight, age and workload. Makers of commercial aerobic training equipment integrate these equations by programming them into their products. In a health and fitness setting an individual enters the values of each variable and the machine calculates the estimated metabolic cost of the workout. Fitness professionals use metabolic prediction equations to prescribe exercise for their clients. The amount of time needed to lose a certain amount of weight can be determined based on the frequency, intensity, and mode of exercise. In a laboratory setting, clinicians use metabolic prediction equations to estimate oxygen consumption rather than directly measuring it.

In recent years, elliptical trainers have become a popular tool used for aerobic exercise in public health and rehabilitation settings (11). Elliptical trainer exercise provides a low-impact alternative to treadmill exercise by eliminating the foot strike that occurs with each step. Despite the growing popularity of these products, the American College of Sports Medicine (ACSM) has not published elliptical trainer metabolic prediction equations. Limited elliptical trainer research may be a limiting factor in the lack of an ACSM-based equation. Elliptical trainer exercise is known to elicit similar heart rate responses as treadmill exercise at equivalent RPE (11).

To date, only two studies have resulted in the development of a metabolic prediction equation for elliptical trainer exercise. Mier et al. (20) developed two prediction equations that estimate the metabolic cost of leg only as well as combined arm-leg exercise on the elliptical trainer. Dalleck et al. (6) also developed a prediction equation that estimates the metabolic cost of leg only exercise on the elliptical trainer. One problem standing in the way of the development of an accurate metabolic prediction equation is the possible variability of metabolic cost at similar workloads between brands of elliptical trainers. Both of the above studies used a Precor brand elliptical trainer, but other brands are popular in health and fitness settings as well. If fitness professionals and clinicians desire to use these equations to prescribe exercise, it is important to develop an equation that is accurate across brands. Therefore, the purpose of this study was to determine the effect of elliptical trainer brand on gas exchange data.

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1.1 Hypotheses

Hypothesis 1) Oxygen consumption, heart rate, caloric cost, and rating of perceived exertion quantified on each brand of elliptical trainer would be significantly different. Hypothesis 2) machine-estimated caloric cost of elliptical trainer exercise would be significantly different from actual caloric cost. Hypothesis 3) the metabolic prediction equations developed for each brand of elliptical trainer would predict different energy costs for an individual despite the use of similar workloads. Hypothesis 4) influential variables in the prediction equations would be cadence, level of resistance, and body weight.

1.2 Definition of Terms

Elliptical Trainer – A stationary exercise machine used to simulate walking or running without causing excessive pressure to the joints, hence decreasing the risk of impact injuries.

Maximal Oxygen Consumption (VO_{2max}) – The maximal rate at which the body can consume oxygen during exercise.

Metabolic Equivalent (MET) – A physiologic equivalent of oxygen consumption used to express energy expenditure, where 1 MET = 3.5 ml/kg/min.

Metabolic Prediction Equation – Regression equation that uses the metabolic cost of carrying body weight in a vertical and horizontal direction for purposes of estimating oxygen consumption.

Muscular Efficiency – The fraction of energy liberated within the human machine that appears as external work.

Oxygen Consumption – An expression of the rate at which oxygen is used by the tissues, usually expressed in liters of oxygen consumed per minute.

Standard Error of the Estimate (SEE) – A numerical value that indicates the amount of error in the prediction of a *Y* value in bivariate or multivariate regression.

Steady State – A condition where certain bodily functions have attained dynamic constancy at a level different from homeostasis.

1.3 Delimitations

The delimitations of this study included males and females between the ages of 18 and 40 from the University of Texas at Arlington. Second, subjects met the minimum level of fitness based on their VO_{2max} test. Third, subjects had sufficient experience using elliptical trainers before participating in the testing sessions. Last, subjects were able to reach steady state on each of six 5-minute workload stages.

1.4 Assumptions

The first assumption made in this study was that the subjects filled out the health history questionnaire accurately. Second, we assumed that subjects gave maximal effort during their VO_{2max} test. Third, we assumed that subjects were exercising at the watt levels expressed by each machine during the elliptical trainer testing sessions.

1.5 Limitations

Because VO_{2max} tests are effort-dependent, not knowing if the subjects attained their true VO_{2max} was a limitation to the study. Second, the regression equations developed in this study only apply to individuals at a similar age and fitness level to subjects in this study. Third, lack of elliptical trainer watt and calorie output formulas, which are under the proprietary control of the makers.

CHAPTER 2

REVIEW OF LITERATURE

2.1 Background and Significance

Early research on this topic was primarily concerned with quantifying the

oxygen costs of various daily activities (22), walking, and running (9, 10, 19, 22, 26).

Many of these researchers were able to determine the approximate oxygen consumption

per step during treadmill walking and running. Soon equations were being developed

with the intent of allowing individuals to predict the energy demands of exercise (21,

26). ACSM published metabolic prediction equations for four modes of exercise, which

made the equations available for practical use in research and exercise prescription (see

Table 2.1). Despite the widespread popularity of elliptical trainers, ACSM has yet to

publish an elliptical trainer metabolic prediction equation. If fitness professionals and

clinicians desire to utilize an elliptical trainer metabolic prediction equation to prescribe

exercise, it is important to develop an equation that is accurate across brands. If it is

determined that one universal equation is not plausible due to differences between

elliptical trainer brands, it may be necessary to develop separate equations that are

specific to certain brands.

Table 2.1 Current ACSM metabolic prediction equations

Leg Cycling	VO_2 (ml/kg/min) = 1.8(work rate)/(body mass) + 3.5 + 3.5
Walking	VO_2 (ml/kg/min) = (0.1*speed) + (1.8*speed*grade) + 3.5
Running	VO_2 (ml/kg/min) = (0.2*speed) + (0.9*speed*grade) + 3.5
Stepping	VO_2 (ml/kg/min) = (0.2*frequency) + (1.33*1.8*height*frequency) + 3.5

where work rate = kgm/min, body mass = kg, speed = m/min, frequency = steps/min, and height = step height in m

2.2 Metabolic Prediction Equations

2.2.1. Development of Metabolic Prediction Equations

Researchers began investigating the oxygen cost of exercise in order to formulate metabolic prediction equations in the early 1960's. Goldman et al. (10) developed a metabolic prediction equation for treadmill walking with a load. The equation used three variables: speed in miles per hour, load (0-30 kg), and grade as a percentage. The researchers calculated actual energy expenditure (kcal/min/kg) as a function of rate of progression, load carried, and grade.

Workman et al. (26) produced a metabolic prediction equation for treadmill walking from one to four miles per hour based on speed (steps/min) and oxygen consumption (L/step). Although the equation was cumbersome to use, it only required two variables: speed in miles per hour and body weight in pounds. The correlation coefficient between the measured and predicted oxygen consumption was $r = +0.94$, while the SEE was 0.22 L/min. This equation only describes the oxygen consumption of walking done to conserve energy. The investigators pointed out that the equation

was not suited for untrained subjects who walked poorly, but rather, healthy trained individuals.

Margaria et al. (19) measured and quantified the energy cost of walking and running on a treadmill at different speeds and inclines. Based on their measurements, the net cost of running is approximately 1 kcal/kg/km when running on the level. They found that this energy cost is independent of speed and increases linearly. The researchers developed a nomogram based on speed (km/h) and grade (%). These findings are limited due to the small sample size (2 subjects).

Dill (9) measured and quantified the energy cost of horizontal and grade walking and running on a treadmill. His results were closely comparable to those of Margaria et al at the different speeds and grades. These findings are also limited by the inclusion of only three subjects.

Nagle et al (21) produced a metabolic prediction equation for stepping while taking into account all components of the movement. The researchers developed an equation based on oxygen requirements for standing, stepping horizontally forward and vertically upward, and the negative work for stepping downward. The energy expenditure of stepping was then estimated during all even test minutes and compared to measured values. During the 30-step test, the equation was accurate, but predicted oxygen intakes were slightly overestimated for the 24-step test. Unfortunately, the significance of this difference is unknown. The authors deemed the equation accurate because the differences between predicted and measured values were generally within one standard deviation.

2.2.2. Accuracy of Metabolic Prediction Equations

  The metabolic prediction equations published by ACSM are highly accurate due to studies that were carried out to improve their accuracy through revisions. Lang et al. (14) found differences between actual and predicted oxygen consumption using the cycle ergometry equation that was current at the time of the study. The researchers developed a new equation based on their data and found reductions in Total Error (TE), and mean differences at each power output. TE ranged from 2.9 to 4.0 ml/kg/min in the original equation, and from 1.5 to 2.7 ml/kg/min in the revised equation. Mean differences ranged from -2.0 to -3.7 ml/kg/min in the original equation, and from -0.8 to 0.5 ml/kg/min in the revised equation. Interestingly, correlations and SEE at each power output did not improve with the revised equation. The SEE ranged from 1.4 to 2.8 ml/kg/min in the original equation, and from 1.3 to 2.6 ml/kg/min in the revised equation. The authors did not report an R^2 value associated with the revised equation. This was the first equation to account for the oxygen cost of unloaded cycling, leading to its inclusion in the ACSM metabolic prediction equation for cycle ergometry that is used today (Table 2.1).

  Latin el al. (17) validated the equation developed in the previous study by replicating its methods and comparing the newly measured oxygen consumption values to values predicted by the recently developed equation. TE ranged from 1.1 to 2.0 ml/kg/min, and SEE ranged from 1.0 to 2.0 ml/kg/min. The prediction equation overestimated oxygen consumption at five of the six workloads (0.5 to 1.2 ml/kg/min), with the only underestimation (-1.4 ml/kg/min) occurring during unloaded cycling. The

correlation across all workloads was $r = 0.97$. Based on improved statistical findings from the original group, the authors deemed the equation valid and a better predictor for cycle ergometry exercise than the ACSM equation.

Berry et al. (4) developed a cycle ergometry equation for females. The researchers reported an $R^2 = 0.89$, and SEE = 2.0 ml/kg/min. A seemingly more important finding, however, was a positive correlation between body mass and oxygen consumption ($r = 0.64$ to 0.80 across four workloads). By contrast, body mass was negatively correlated with exercise efficiency ($r = -0.55$ to -0.69). Body mass of the fifty subjects ranged from 41.5 to 98.9 kg. Gross exercise efficiency was defined as work performed/energy expended x 100. Variables included in the equation were work rate (Watts), pedal rate (rpm), and body mass (kg). Leg muscle volume (ml) was also a good predictor, but was left out of the equation because it did not improve the R^2 value enough warrant its measurement in each individual desiring to use the equation. These results validated the role of body mass in cycle ergometry exercise.

Latin et al. (16) also assessed the accuracy of the ACSM cycle ergometry equation in relation to a new equation developed for young women. The correlation between actual and predicted values was $r = 0.96$, while SEE ranged from 1.3 to 2.6 ml/kg/min for the ACSM equation that was current at the time of the study. TE ranged from 1.8 to 4.5 ml/kg/min, and mean differences ranged from -4.1 to 1.0 ml/kg/min. The authors did not report an R^2 value associated with the revised equation. The revised equation did not change the correlation coefficient or SEE. TE ranged from 1.6 to 2.9

ml/kg/min, and mean differences ranged from -1.3 to 0.6 ml/kg/min. The researchers greatly improved the accuracy of the ACSM cycle ergometry equation for women.

Anderson et al. (2) compared the accuracy of two equations to predict oxygen consumption of obese women during cycle ergometry exercise. The ACSM equation that was current at the time of the study significantly underestimated oxygen consumption at 0, 50, and 100 Watts (-5.0, -2.5, and -1.5 ml/kg/min respectively). The equation developed by Latin et al. (17) only significantly underestimated oxygen consumption at 0 Watts (-2.3 ml/kg/min). SEE was 2.0, 2.1, and 2.4 ml/kg/min for both equations at each workload. The investigators concluded that the ACSM equation was inaccurate obese individuals, and validated the accuracy of the equation developed by Latin et al. (17).

Stanforth et al. (24) also developed a metabolic prediction equation for cycle ergometry and compared it to previously developed equations. The authors reported an R^2 value of 0.94 and an SEE of 1.9 ml/kg/min with the revised equation. The researchers reported an overall mean difference of 1.1 ml/kg/min between measured and predicted oxygen consumption values. The major finding in this study was the development of an equation that used only power output as an independent variable. The researchers were able to develop a seemingly equally accurate equation with the use of fewer independent variables.

Ruiz et al. (23) evaluated the accuracy of the ACSM metabolic prediction equation for treadmill running that was current in 1999. The researchers reported an overestimation of oxygen consumption by an average of 4.7 ml/kg/min during steady

state running between 50 and 85% of VO_{2max}. The measured oxygen consumption

values were moderately correlated with predicted values ($r = 0.77$). The authors did not

report an R^2 value associated with the revised equation. This was one of numerous

studies in which the ACSM equation overestimated oxygen consumption. However,

continual validation such as the one carried out by these investigators led to the revised

and highly accurate equation being supported by ACSM today.

Latin et al. (15) compared actual and predicted oxygen consumption using the

newly published ACSM stair-stepping equation in 2000. The researchers found TE

values ranging from 1.3 to 2.5 ml/kg/min, and similar SEE values. The calculated

correlation across all workloads between actual and predicted oxygen consumption was

$r = 0.95$. Mean differences ranged from -0.2 to -1.1 ml/kg/min. These differences were

judged not meaningful from a practical standpoint because they were less than 1 MET.

The researchers did not produce a revised equation because the researchers found the

current equation to be an accurate predictor of oxygen consumption during stepping

exercise at workloads used in the study.

2.3 Muscular Work

2.3.1. Muscular Efficiency

Calculation of muscular efficiency has been a controversial topic over the years

as researchers have examined it from many different angles. Whipp et al. (25)

quantified muscular efficiency during steady-state cycle ergometry. The researchers

were the first to calculate muscular efficiency while accounting for resting oxygen

consumption *and* unloaded cycling. Subtraction of unloaded cycling effectively

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increased muscular efficiency from 20% to 30%. Only eight subjects volunteered to participate in this study, yet it was a crucial step in the development of accurate measures of muscular efficiency.

Chen et al. (5) assessed efficiency of walking and stepping by simultaneously measuring minute-by-minute energy expenditure and muscular work through the use of a whole-room indirect calorimeter and a force platform system. The researchers found a negative correlation between the efficiency of walking at normal speed and body fatness in both men and women. Consequently, the use of an energy expenditure equation to predict oxygen cost of walking on a treadmill would underestimate an obese individual's oxygen cost. Therefore, it may be advantageous to control for body fatness or level of fitness when attempting to develop an energy expenditure equation.

2.3.2. Oxygen Cost of Different Amounts of Exercising Muscle

Oxygen consumption is higher during combined arm-leg exercise when compared to leg only exercise. Bergh et al. (3) found that combined arm-leg exercise elicits a higher VO_{2max} than leg only (cycle ergometry) exercise. These researchers used an apparatus that measured arm versus leg work. When arm work accounted for 20% of maximal leg workload, VO_{2max} was 98% of running VO_{2max}. The authors also reported higher heart rates when arm work accounted for 20% of maximal leg workload.

Similarly, Hoffman et al. (13) determined that combined arm-leg exercise elicits minimally higher, but statistically significant, oxygen consumption than leg only exercise at the same external power output. This was the first study to use the same

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apparatus to measure the leg only as well as the arm and leg exercise. This ensured that the external work rates were identical for the two exercise conditions. Combined arm-leg exercise elicited an average of 0.04 L/min higher than leg only exercise.

Elliptical trainers are manufactured one of two ways, with leg only capabilities, or with arm handles that accompany the leg movement. There may be high variability of arm contributions to elliptical trainer exercise between brands, thus limiting the use of one universal equation for all brands.

2.4 Measurement of Oxygen Consumption on an Elliptical Trainer

2.4.1. Prediction of VO_{2max}

In general, elliptical trainers and treadmills elicit similar physiological responses during both submaximal and maximal exercise. Dalleck et al. (8) developed and compared specific elliptical trainer VO_{2max} protocols to the modified Balke treadmill VO_{2max} protocol.   All subjects met minimum health and activity thresholds. According to the pre-screening interview, subjects completed either the "recreationally active" or the "trained" protocol, with different protocols for males and females. Elliptical trainer VO_{2max} (ml/kg/min) = 47.3 ± 6.4, and treadmill VO_{2max} (ml/kg/min) = 47.9 ± 6.8, with no significant difference between the two modalities.

Dalleck et al. (7) used the same protocols in the development of a method to administer submaximal tests for estimating VO_{2max} on an elliptical trainer. The authors developed a prediction equation that estimates VO_{2max}:

$$VO_{2max} \text{ (ml/kg/min)} = 73.676 + 7.383(gender) - 0.317(weight) +$$
$$0.003957(age*cadence) - 0.006452(age*heart\ rate\ at\ stage\ 2)$$

$$R^2 = 0.73, \text{ SEE} = 3.9 \text{ ml/kg/min}$$

This is a useful way to predict VO_{2max} for those that are unable to exercise to maximal levels, especially obese individuals and individuals with joint limitations.

Unfortunately, the researchers controlled for percent body fat (18.6 ± 7.2), meaning that the equation is not accurate for those that fall out of the percent body fat ranges used in this study. The researchers also stated that the R^2 value compared favorably with other studies. Yet when the value (0.73) was compared to five walking tests for prediction of VO_{2max}, the other five R^2 values ranged from 0.84 to 0.93. The R^2 value for bench stepping (0.75) was the only comparable prediction test.

2.4.2. Oxygen Cost of Exercising on an Elliptical Trainer

Recent studies have resulted in the production of equations that predict submaximal steady state oxygen cost on elliptical trainers. Mier et al. (20) measured the effects of stride rate, resistance, and combined arm-leg use on energy expenditure. This group used a Precor Elliptical Fitness Crosstrainer (EFX) 534i for this study. The protocol consisted of six 5-minute stages on two separate days; leg only on one day, and combined arm-leg on the other. Subjects carried out three stages at 110 strides per minute and three at 134 strides per minute. Subjects exercised against resistance levels of 2, 5, and 8 at each cadence to mimic common workloads for the average patron of the fitness center. Two prediction equations that estimate the oxygen cost of leg only as well as combined arm-leg exercise on the elliptical trainer were developed. Both regression equations can be found in Table 2.2. The researchers did not control for body composition or fitness level, limiting the study. A second limitation was their lack

of control for level of experience with elliptical trainer exercise. The energy

expenditure equations developed were strong, despite these limitations. The authors,

however, discouraged the use of their equations to predict energy expenditure when

prescribing elliptical trainer exercise. They suggested using the data as a guide to

prescribe changes in exercise intensity.

Similarly, Dalleck et al. (6) examined the effects of leg only stride rate,

resistance, and incline on energy expenditure. The researchers used a Precor EFX 544

for this study. The protocol consisted of nine 5-minute stages on two separate days.

Subjects maintained a randomly assigned cadence throughout each testing session while

changes in levels of resistance and incline altered the workload. A prediction equation

estimating the oxygen cost of leg only exercise on the elliptical trainer was developed

and can also be found in Table 2.2.

The researchers controlled for percent body fat (17.8 ± 6.6), meaning that the

equation was not accurate for those that fall out of the percent body fat ranges used in

this study. The researchers reported a high correlation coefficient (r=0.89) between

predicted and measured oxygen consumption values. Mean differences averaged -0.3

ml/kg/min across all workloads. While the authors reported that this equation seemed

to accurately predict oxygen consumption during exercise on a Precor EFX 544, it is

unknown if it would produce accurate predictions for a different brand of elliptical

trainer at the same workloads.

Therefore, the purpose of this study was to determine the effect of elliptical trainer brand on gas exchange data. Furthermore, if differences do exist, it may be necessary to develop separate equations that are specific to certain brands.

Table 2.2 Elliptical trainer metabolic prediction equations

Mier et al.	Leg only	VO_2 (ml/kg/min) = (0.097*stride rate) + (0.678*resistance) + 3.48 ml/kg/min $R^2 = 0.90$, SEE = 1.9 ml/kg/min
Mier et al.	Arm - Leg	VO_2 (ml/kg/min) = (0.101*stride rate) + (0.713*resistance) + 3.34 ml/kg/min $R^2 = 0.95$, SEE = 1.8 ml/kg/min
Dalleck et al.	Leg only	VO_2 (ml/kg/min) = (1.5*cadence) + (1.22*resistance) − (0.11*weight) + 3.5 ml/kg/min $R^2 = 0.78$, SEE = 2.8 ml/kg/min

where stride rate and cadence = strides per minute, resistance = level, and weight = kg

CHAPTER 3

METHODS

3.1 Subjects

Twenty-three healthy males and females volunteered for this study (22.3 ± 4.6

yrs, 172 ± 8.2 cm, 67.5 ± 9.3 kg). During the first visit to the laboratory, each subject

provided informed consent and completed a health history questionnaire in addition to

performing a VO_{2max} test. Subjects were excluded if they indicated health risks due to

cardiopulmonary, metabolic, or coronary heart disease. No subjects with a VO_{2max}

below 40 ml/kg/min (female) or 45 ml/kg/min (male) were included in the study. This

study was approved by the University of Texas at Arlington Institutional Review Board

for Human Subject Research.

3.2 Instrumentation

All subjects used two elliptical trainers of different brand over two testing

sessions. One was the Precor EFX 576i® (Precor Incorporated, Woodinville, WA), and

the other was the TRUE TS1® (TRUE Fitness Technology, St. Louis, MO). During the

preliminary VO_{2max} tests and testing sessions a three-way valve mouthpiece (Hans

Rudolph Inc., Kansas City, MO) was worn. Gas exchange data was recorded breath-by-

breath and analyzed using a ParvoMedics TrueOne 2400® metabolic cart

(ParvoMedics, Sandy, UT). Heart rate was measured using telemetry (Polar™, Lake

Success, NY). Each subject's height and weight was obtained using a Detecto Scale®

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(Cardinal Scale Mfg. Co., Webb City, MO).   Body composition was calculated based

on 7-site skinfold thickness measurements taken with a Lange® skinfold caliper

(Cambridge Scientific Industries, Columbia, MD).

<u>3.3 Pilot Tests</u>

Pilot data was collected to aid in the methodology of the current research study.

Pilot tests aided in the determination of which elliptical trainer brands to use.

Originally, two older models were in the Exercise Science Research Laboratory

(ESRL). The pilot tests allowed the researchers to recognize the potential inaccuracies

of using older models that had not recently been calibrated. Instead, two new models

from the activities center were used.

A portable metabolic measurement system, based on breath-to-breath gas

analysis and flow spirometry (Cosmed K4b2) was to be used for data collection during

the elliptical trainer testing sessions. It was deemed a valid and reliable product based

on the literature. Its use would eliminate the need to transport a metabolic cart to the

activities center for each elliptical trainer testing session. However, after countless

malfunctions and attempted repairs it was considered unstable. This led to the use of

one metabolic system for all testing procedures. Although it was a stationary system,

the researchers were able to wheel it to the activities center on a portable cart.

Third, the pilot tests aided in the determination of minimum fitness levels to be

met for inclusion in the study. It was estimated that subjects would have to attain a

VO_{2max} at or above the 60th percentile according to ACSM normative values to be

considered fit enough for the study.

Finally, the pilot tests assisted in the determination of the workloads that would be used for the study. The researchers attempted to use workloads that could be maintained for 30 minutes by both males and females who met the minimum fitness level for inclusion. Therefore, it was decided that the highest workload used in the study would be one at which most females could complete the 30-minute testing session.

3.4 Procedures

Most subjects reported to the lab and gym on three separate occasions. The first session lasted for approximately 1 hour. After completing the necessary forms, subjects performed a treadmill VO_{2max} test. Subjects jogged at a self-selected pace as the grade increased by 2% every two minutes. Subjects scheduled the first testing session within one week of the VO_{2max} test.

The second and third visits, which took place in the activities center, lasted for approximately one hour each. During these sessions subjects performed the exercise test on either the Precor or the TRUE elliptical trainer. Each subject was randomly assigned the elliptical trainer that would be used first. The exercise testing condition was counterbalanced with half the subjects beginning with the Precor and half with the TRUE.

Subjects that were unfamiliar with elliptical trainer exercise made three additional visits to the activities center before the first testing session. During the first practice session, subjects were instructed on how to operate each elliptical trainer and then given ample time to exercise and reach an adequate level of comfort at a fixed

workload. During the second and third practice sessions, subjects exercised at varying

workloads until attaining an adequate level of comfort.

3.5 Exercise Protocol

The exercise protocol consisted of six 5-minute stages for a total exercise time

of 30 minutes per session. Based on a Latin Square design, subjects were randomly

assigned one of four cadences to be maintained throughout each testing session (see

Table 3.1). The metabolic cart was calibrated before each session. Before each

exercise test, the subject's body weight was entered into the elliptical trainer. Age was

also programmed into the Precor brand elliptical trainer, but was not an option on the

TRUE brand. Subjects then exercised at six different workloads that were a

combination of the assigned cadence and each resistance in order to elicit a particular

watt level. Since the cadence was the same for both machines, equivalent workloads in

machine-given watts on the two machines were determined by changing the resistance

setting. The approximate resistance levels used for the Precor brand elliptical trainer

were 1, 3, 5, 7, 9, and 11, while the resistance levels used for the TRUE brand elliptical

trainer were 12, 13, 14, 15, 16, 17, 18, 19, and 20. The first and last stages were

intended to be the least and most difficult. The middle four stages were

counterbalanced to prevent an order effect from fatigue. An electronic metronome was

used to assist the subjects in the maintenance of the assigned cadence.

3.6 Data Analysis

Steady state oxygen consumption and heart rate measurements were obtained

during the last two minutes of each workload. Steady state oxygen consumption was

defined as a difference of less than 250 milliliters in the last two minutes of the stage.

Steady state heart rate was defined as a difference of less than 4 beats per minute in the

last two minutes. The number of calories burned during each 5-minute stage according

to the machine was recorded. The number actual calories burned were calculated based

on actual oxygen consumption values using the standard conversion of 5 kcal per liter

of oxygen (1). RPE for each elliptical testing session was obtained after subjects

completed both elliptical testing sessions. Subjects were asked to rate the entire 30-

minute session on a scale of 1 to 10, 1 being the least difficult and 10 being the most

difficult exercise they had ever experienced.

Table 3.1 Elliptical trainer testing session workloads

Cadence (spm)			
90	**104**	**120**	**134**
78			
87	87		
96	96	96	
107	107	107	107
118	118	118	118
131	131	131	131
	145	145	145
		161	161
			179

values expressed in Watts

3.7 Statistical Analysis

All statistical procedures were completed using SPSS statistical software

(Version 16.0 SPSS for Windows, SPSS Incorporated, Chicago, IL). Based on the data,

dependent t-tests were used to find differences between RPE, and machine-estimated

and actual calories burned per minute. A 2 x 3 repeated measures ANOVA was used to analyze differences between machines for oxygen consumption, heart rate, and caloric expenditure. The first factor (brand of machine) had two levels (TRUE, and Precor) while the second factor (workload) had three levels (107, 118, and 131 Watts). Because every subject exercised at the above three workloads, steady state data from these watt-levels were analyzed. Stepwise multiple nonlinear regression analyses were used to develop equations for estimating elliptical trainer steady state oxygen consumption. Cadence, resistance, and body weight were used as independent variables in the prediction of oxygen consumption. The R^2 value was used to determine the variance of the regression equation. The SEE was calculated to determine the accuracy of predicted oxygen consumption versus measured oxygen consumption. Oxygen consumption was estimated to be 3.5 ml/kg/min at a cadence and resistance of 0 for all participants.

A dependent t-test was performed to determine the significance of mean differences between predicted and measured oxygen consumption values. The probability of making a Type I error was set at $P < 0.05$ for all statistical analyses.

CHAPTER 4

RESULTS

One subject dropped out of the study after the VO_{2max} test. Another dropped out

after performing the VO_{2max} test and one of two elliptical testing sessions. This reduced

the number of subjects who completed the study to 23 (N=23). Descriptive

characteristics and baseline measures are located in Table 4.1. Both males and females

attained a VO_{2max} at or above the 90th percentile according to ACSM normative values.

Table 4.1 Descriptive characteristics and baseline physical measures

Baseline Physical Measures	Mean	SD
Age (yrs)	22.3	4.6
Height (cm)	172.0	8.2
Weight (kg)	67.5	9.3
Body Fat (%)	13.1	6.4
VO_{2max} (ml/kg/min)	64.1	11.8

4.1 Steady State Comparison

Mean values for oxygen consumption, and heart rate, are shown graphically in

Figures 4.1, 4.2, and 4.3. The TRUE elicited higher oxygen consumption, and heart

rate values than the Precor ($p<0.001$) at the same machine-given watt levels.

4.2 Rating of Perceived Exertion

Mean values for RPE are shown graphically in Figure 4.4. The TRUE elicited

higher RPE values than the Precor ($p<0.01$) at the same machine-given watt levels.
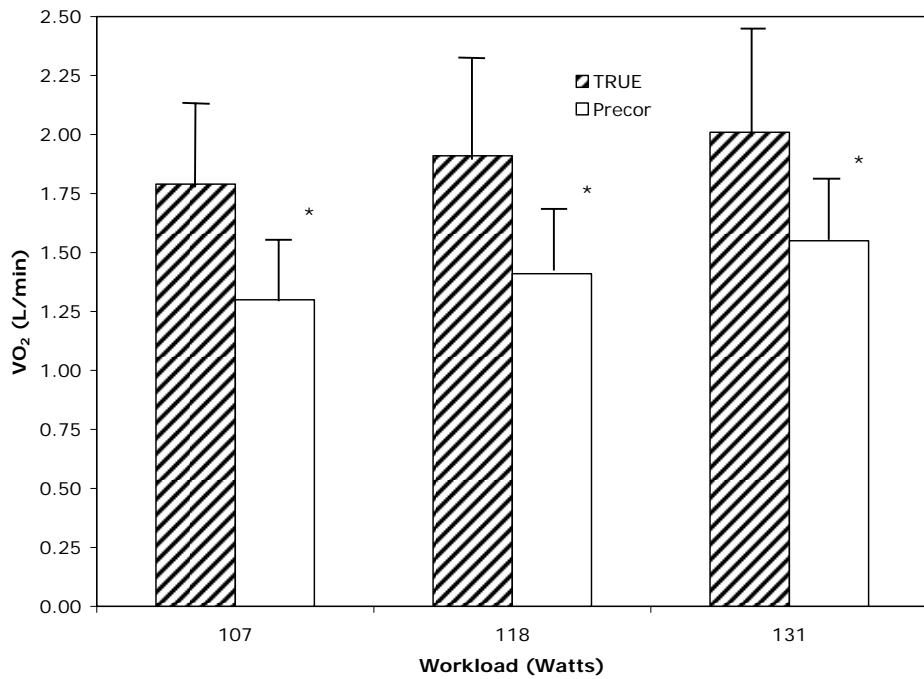
Figure 4.1 Absolute oxygen consumption by brand and workload. * Significantly different from TRUE, p<0.001.
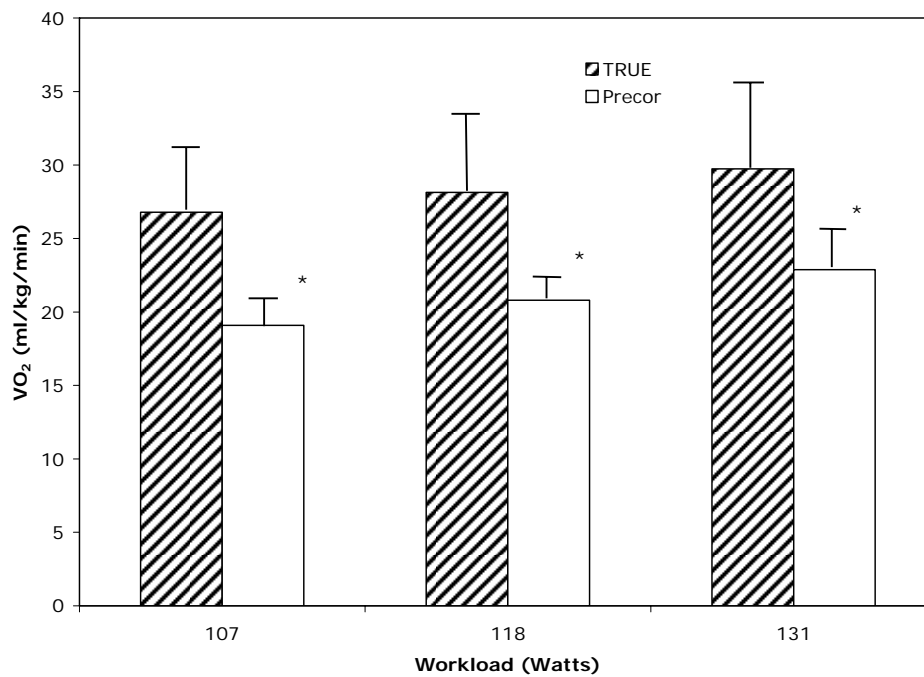
Figure 4.2 Relative oxygen consumption by brand and workload. * Significantly different from TRUE, p<0.001.

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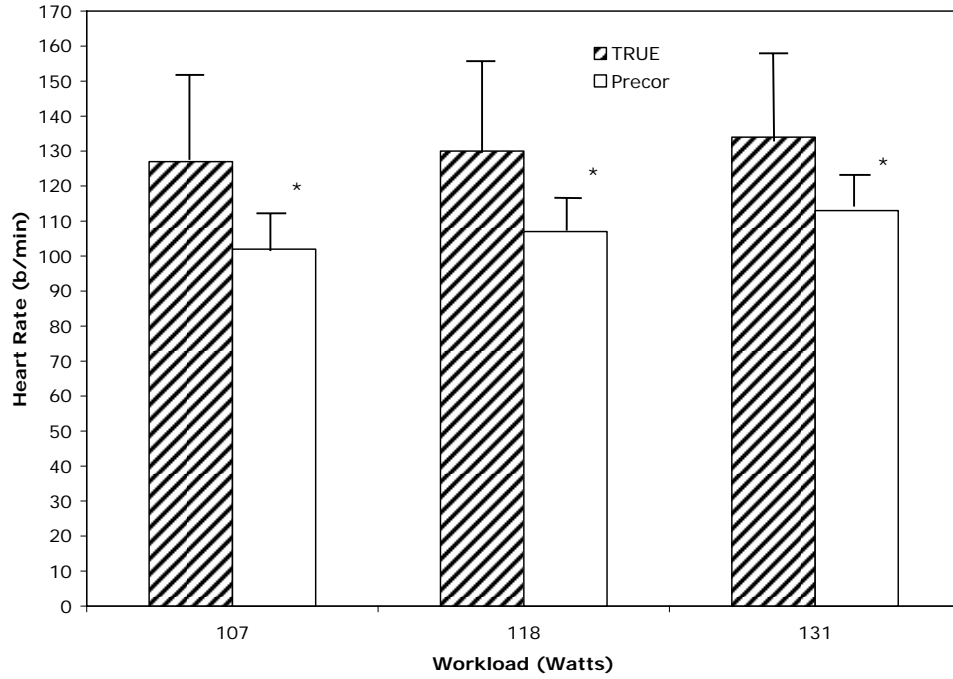
Figure 4.3 Heart rate by brand and workload. * Significantly different from TRUE, p<0.001.
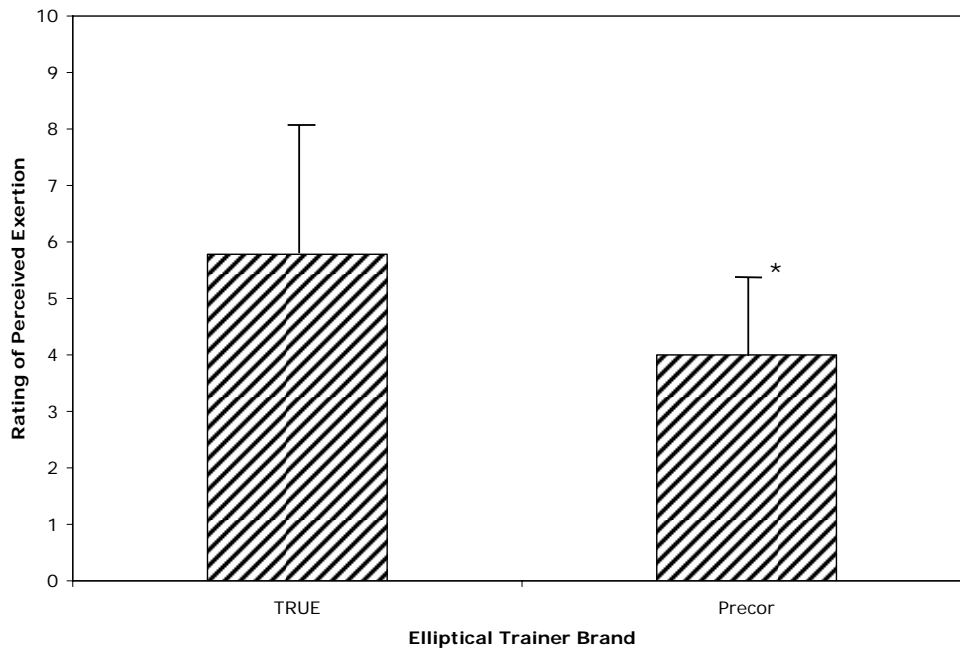
Figure 4.4 Rating of perceived exertion by brand. * Significantly different from TRUE, p<0.001.

4.3 Caloric Cost

Mean values for actual caloric cost are shown in Figure 4.5. The TRUE also elicited higher caloric cost than the Precor (p<0.001) at the same apparent watt levels.

Mean values for differences by brand are located in Table 4.2. Machine-estimated caloric cost was higher than actual caloric cost on both elliptical trainer brands (p<0.001). The TRUE overestimated caloric cost (113%) to a higher degree than the Precor (18.7%).
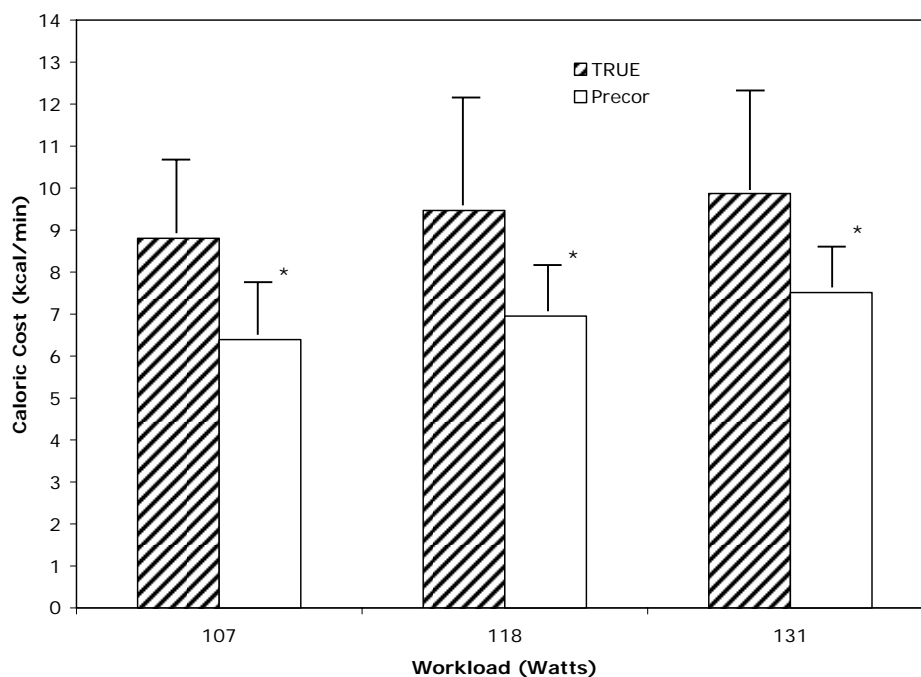
Figure 4.5 Caloric cost by brand and workload. * Significantly different from TRUE, p<0.001.

Table 4.2 Caloric differences by brand

Caloric Measures (kcal/min)	TRUE	Precor
Estimated Caloric Cost	$20.7 \pm 1.7+$	$8.6 \pm 1.8*+$
Actual Caloric Cost	9.7 ± 3.0	$7.3 \pm 2.0*$

Group mean $\pm$ SD for each dependent variable. * Significantly different from TRUE, $p<0.001$. + Significantly different from Actual Caloric Cost (cal/min), $p<0.001$.

<u>4.4 Prediction of Oxygen Consumption</u>

The metabolic prediction equations are located in Table 4.3, while the mean differences between measured and predicted oxygen consumption values are shown graphically in Figures 4.6 and 4.7. The relationship between measured and predicted oxygen consumption values are also shown graphically in Figures 4.8 and 4.9. Stepwise multiple nonlinear regression analyses were used to develop two separate metabolic prediction equations for submaximal elliptical trainer exercise, one for each elliptical trainer brand.

Mean differences between measured and predicted oxygen consumption resulted in underestimation across all nine workloads for the TRUE and ranged from -3.3 to -8.2 ml/kg/min for the TRUE. All mean differences were statistically significant, and the average mean difference across all workloads was 4.2 ml/kg/min. Mean differences for the Precor ranged from -1.6 to 1.3 ml/kg/min, with the only statistically significant difference at 131 watts. The average mean difference across all workloads was -0.2 ml/kg/min.

Table 4.3 Metabolic prediction equations

TRUE	VO_2 (ml/kg/min) = (0.001*cadence^2) + (0.002*resistance^3) + 3.8 ml/kg/min R^2 = 0.95, SEE = 2.6
Precor	VO_2 (ml/kg/min) = (0.134*cadence) + (0.009*resistance^3) + 3.2 ml/kg/min R^2 = 0.92, SEE = 2.4

where cadence = strides per minute, resistance = level, and kg = body weight
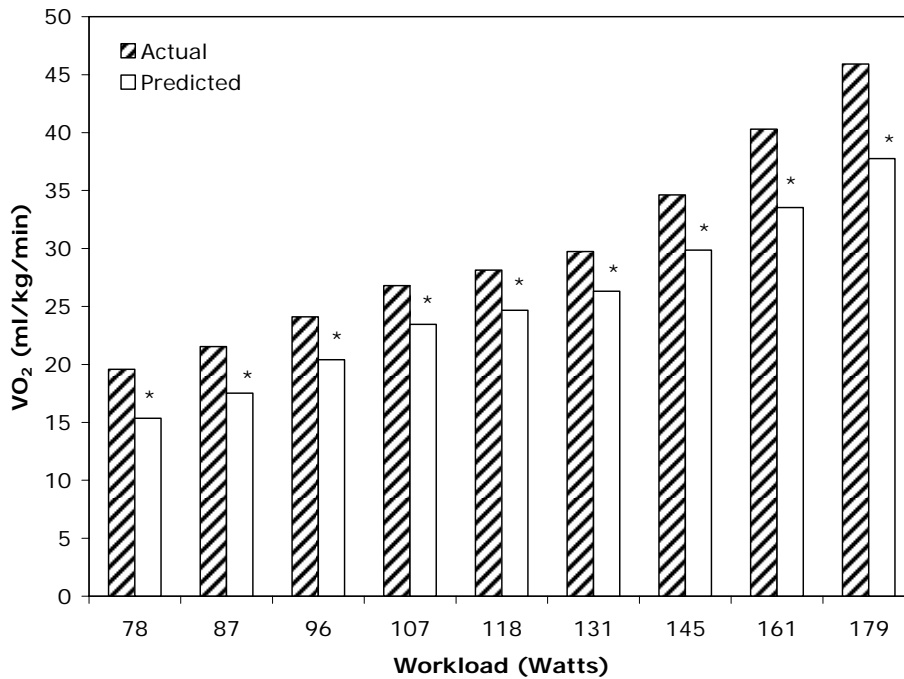
Figure 4.6 Mean differences between measured and predicted VO_2 values for the TRUE brand elliptical trainer at nine workloads. * Significantly different from Actual.
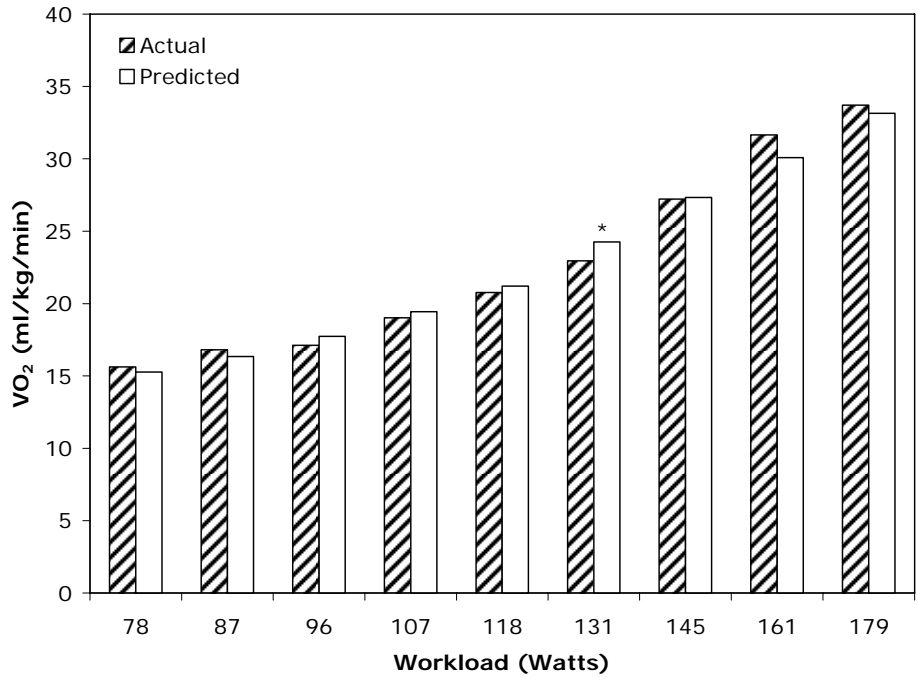
Figure 4.7 Mean differences between measured and predicted VO_2 values for the Precor brand elliptical trainer at nine workloads. * Significantly different from Actual.
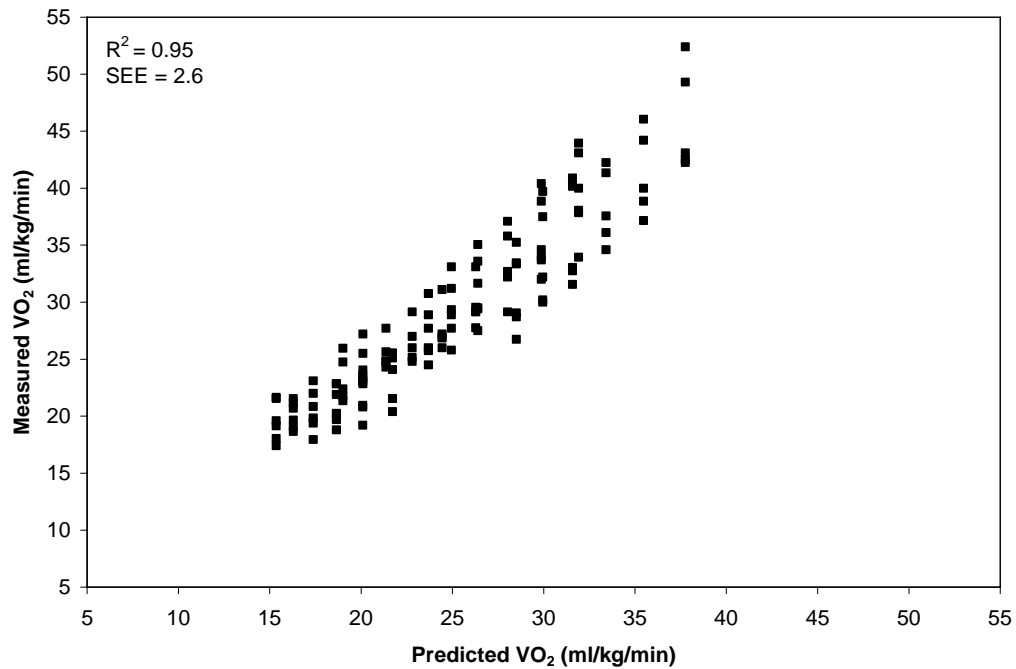
Figure 4.8 Relationship between measured and predicted VO_2 values for the TRUE brand elliptical trainer metabolic prediction equation developed in the present study.

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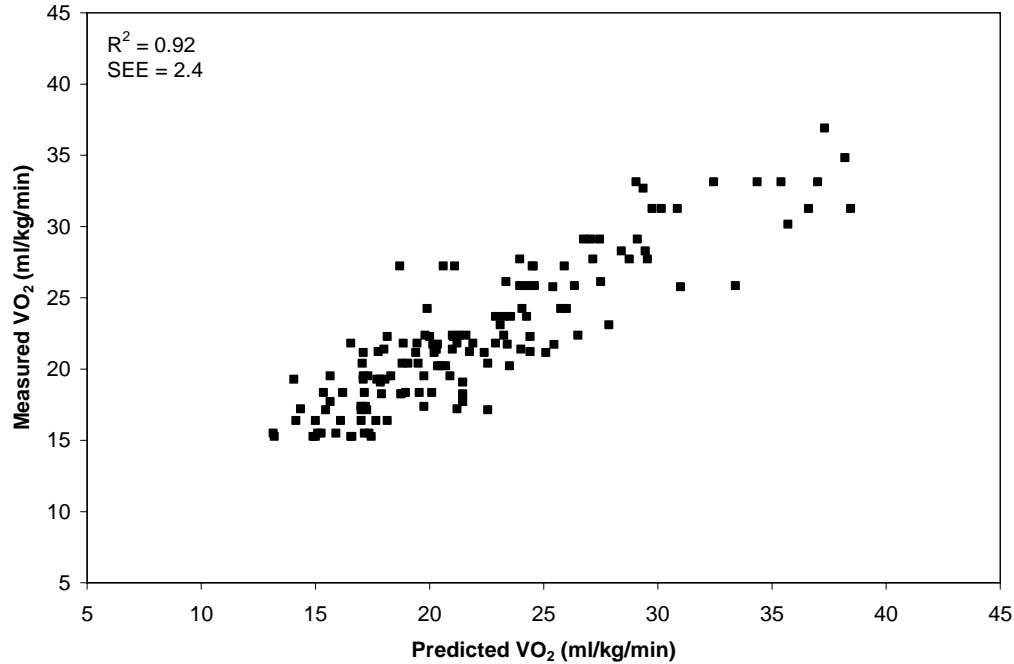
Figure 4.9 Relationship between measured and predicted VO$_2$ values for the Precor brand elliptical trainer metabolic prediction equation developed in the present study.

4.5 Gender Effects

Due to random assignment, only one female was assigned the highest cadence (134 spm). She was unable to complete either 30-minute elliptical trainer testing session. However, she completed five of the six stages on the Precor while only completing the first stage on the TRUE. In addition, she reported an RPE of 6 for the Precor and 10 for the TRUE elliptical trainer session. While this provides evidence of the difference between the machines, it also means that the prediction equations developed in this study are not accurate for females exercising at workloads of this magnitude.

CHAPTER 5

DISCUSSION

5.1 Physiological Differences Between Brands

The purpose of this study was to compare oxygen consumption, heart rate, caloric cost and rating of perceived exertion between elliptical trainer brands. This was the first study to make these comparisons and show differences. The TRUE was found to elicit higher oxygen consumption, heart rate and rating of perceived exertion than the Precor at the same apparent watt levels (Figures 4.1, 4.2, 4.3, and 4.4).

When examining reasons for these differences, the following must be considered. It was an assumption of the study that subjects were exercising at the watt levels expressed by each machine during the elliptical trainer testing sessions. It is well documented that calibration between different models may vary (12). Traditionally, watts are calculated with variables such as resistance, and cadence on most exercise machines (see Table 5.1). Possible workload variables for elliptical trainers include cadence, level of resistance, incline, and stride height and length. It is possible that each company used different variables to calculate watt levels. However, the calibration of workload parameters is proprietary information, so the assumption was made that workload parameters were accurate throughout all testing sessions. Fortunately, the aim of this study was not to elucidate *how* the machines produced the watt levels that appeared on the output screens. It was, rather, to show that *because*

each machine elicited different responses at the same apparent watt levels, metabolic prediction equations needed to be developed to match specific brands. However, as an independent query, both elliptical trainers were calibrated for cadence, stride height, and stride length on two separate occasions.

<u>5.2 Influential Variables</u>

A second major finding of the study was the need to develop two separate metabolic prediction equations, one for each elliptical trainer brand (Table 4.3). It was hypothesized that influential variables in the prediction equations would be cadence, level of resistance, and body weight. Neither of the regression equations developed in the present study included body weight as a variable. It should be noted that the TRUE displayed cadence in revolutions per minute (rpm) whereas the Precor displayed cadence in strides per minute (spm). While this does not change the results of the current study, those who use the equation should be aware that rpm should be converted to spm when using the metabolic prediction equation for the TRUE.

Body weight was not a powerful enough predictor to be included in the equations developed by Mier et al. (20), but was included in the equation developed by Dalleck et al. (6) (see Table 2.1). Interestingly, Dalleck et al. (6) used the enter method to produce their regression equation, essentially forcing body weight into the equation. The stepwise method was used in the production of the other four regression equations. Therefore, four of the five prediction equations do not include body weight as a variable. Elliptical trainer exercise is upright and seemingly a weight bearing exercise. However, the feet are in constant contact with the foot platforms and the range of

motion is fixed, possibly offsetting a portion of overall body weight. Therefore, it is difficult to know the role of body weight in the determination of oxygen consumption during exercise on an elliptical trainer. The subjects used in the present study had a mean weight of 67.5 ± 9.3 kg. Those who volunteered for participation in the studies of Mier et al. (20) and Dalleck et al. (6) had mean weights of 73.0 ± 15.2 and 72.3 ± 13.8 kg respectively, eliminating the possibility that body weight is a more powerful predictor in heavier individuals.

5.3 Standard Error of the Estimate

Standard Error of the Estimate for each metabolic prediction equation was calculated. The SEE values in the present study compare favorably with those of previous studies involving various modes of exercise (see Table 5.1). In general, the SEE for cycle ergometry and stair-stepping exercise ranges from 1.0 to 2.6 ml/kg/min (4, 14, 15, 16, 17, 18). Ruiz et al. (23) reported a higher SEE of 5.0 ml/kg/min for treadmill running. Mier et al. (20) reported SEE values for leg-only (1.9 ml/kg/min) and combined arm-leg elliptical trainer exercise (1.8 ml/kg/min). Dalleck et al. (6) reported an SEE value of 2.8 ml/kg/min for leg only elliptical trainer exercise. These values relate well to the equations developed for the in the present study (TRUE = 2.6 ml/kg/min, Precor = 2.4 ml/kg/min). From a practical standpoint, an error of less than 1 MET does not limit an equation's usefulness for exercise prescription by clinicians and health/fitness professionals. When professionals assess improvements in level of fitness based on predicted oxygen consumption, the intervention should elicit improvements of greater than 1 MET. Desirable SEE values (under 1 MET) ensure that improvements in

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fitness level can be credited to the intervention rather than variability in the error of the estimate.

The average oxygen consumption for TRUE elliptical trainer exercise across all workloads in the present study was 29.2 ml/kg/min. With an SEE of 2.6 ml/kg/min, this came out to an 8.3% error. The calculated percentage of error for the Precor in the present study was 10.5%, at an average oxygen consumption of 22.0 ml/kg/min and SEE of 2.4 ml/kg/min. This is a similar percentage of error reported by Stanforth et al. (24) during cycle ergometry (9-11%). The percentage of error calculated for Mier et al. (20), whose average oxygen consumption was 19.2 ml/kg/min, and SEE 1.8 ml/kg/min, was 9.4%. By comparison, the SEE values obtained in the present study are desirable.

5.4 Prediction of Oxygen Consumption

Mean differences between measured and predicted oxygen consumption resulted in underestimation across all nine workloads for the TRUE and ranged from -3.3 to -8.2 ml/kg/min for the TRUE. All mean differences were statistically significant, and the average mean difference across all workloads was 4.2 ml/kg/min. Mean differences for the Precor ranged from -1.6 to 1.3 ml/kg/min, with the only statistically significant difference at 131 watts. The average mean difference across all workloads was -0.2 ml/kg/min. The Precor results are quite accurate when compared to other modes of exercise (see Table 5.1). Stanforth et al. (24) reported mean differences of 1.1 ml/kg/min for a cycle ergometry equation. Ruiz et al. (23) reported mean differences of 4.7 ml/kg/min for treadmill running. These differences were large enough to assist in the authors' claim that the ACSM running equation overestimated oxygen consumption

and was not accurate. The average mean difference for the Precor in the present study

(-0.2 ml/kg/min) is slightly better than those reported by Dalleck et al. (6) for Precor

elliptical trainer exercise (-0.3 ml/kg/min). The TRUE results are similar to the mean

differences reported by Ruiz et al. (23), and could be due to the amount of variability in

oxygen consumption during elliptical trainer exercise on this brand. One possible

reason for this variability in oxygen consumption could be due to the amount of overall

work done by the arms (see section 5.8).

<div align="center">5.5 Difference Between Prediction Equations</div>

It was hypothesized that the metabolic prediction equations developed for each

brand of elliptical trainer would predict different energy costs for an individual despite

the use of similar workloads. This hypothesis is directly related to the anticipated

differences in oxygen consumption elicited by the two machines. The prediction

equations were formulated based on measured data. Since there was a difference in

measured oxygen consumption, it follows that there is a difference in prediction of

oxygen consumption by the two equations. Differences also exist between the various

elliptical trainer metabolic prediction equations and can be viewed side-by-side in Table

5.2.

Table 5.1 Summary of SEE values and mean differences among metabolic prediction equation studies

Reference	Mode	SEE (ml/kg/min)	Mean Differences Across Workloads (ml/kg/min)
Berry et al. (4)	Cycle ergometry	2.0	-
Lang et al. (13)	Cycle ergometry	1.3-2.6	-0.8 to 0.5
Latin et al. (15)	Cycle ergometry	1.3-2.6	-4.1 to 1.0
Latin et al. (16)	Cycle ergometry	1.0-2.0	-1.3 to 0.6
Londeree et al. (18)	Cycle ergometry	1.5	-
Stanforth et al. (21)	Cycle ergometry	1.9	1.1
Latin et al. (14)	Stair-stepping	1.7	-1.1 to -0.2
Ruiz et al. (23)	Treadmill running	5.0	4.7
Dalleck et al. (6)	Elliptical trainer	2.8	-0.3
Mier et al. (18)	Elliptical trainer	1.8, 1.9	-
Present study	Elliptical trainer	2.4, 2.6	-0.2, -4.2

Table 5.2 Comparison of elliptical trainer metabolic prediction equations

Mier et al.	Leg only (Precor)	VO_2 (ml/kg/min) = (0.097*stride rate) + (0.678*resistance) + 3.48 ml/kg/min R^2 = 0.90, SEE = 1.9 ml/kg/min
Mier et al.	Arm-leg (Precor)	VO_2 (ml/kg/min) = (0.101*stride rate) + (0.713*resistance) + 3.34 ml/kg/min R^2 = 0.95, SEE = 1.8 ml/kg/min
Dalleck et al.	Leg only (Precor)	VO_2 (ml/kg/min) = (1.5*cadence) + (1.22*resistance) – (0.11*weight) + 3.5 ml/kg/min R^2 = 0.78, SEE = 2.8 ml/kg/min
Present study	Arm-leg (Precor)	VO_2 (ml/kg/min) = (0.134*cadence) + (0.009*resistance^3) + 3.2 ml/kg/min R^2 = 0.92, SEE = 2.4 ml/kg/min
Present study	Arm-leg (TRUE)	VO_2 (ml/kg/min) = (0.001*cadence) + (0.002*resistance^3) + 3.8 ml/kg/min R^2 = 0.95, SEE = 2.6 ml/kg/min

where stride rate and cadence = strides per minute, resistance = level, and weight = kg.

5.6 Machine Calories

It was hypothesized that machine-estimated caloric cost of elliptical trainer
exercise would be significantly different from actual caloric cost. Based on the present
investigation, this hypothesis was upheld. It was expected that the makers would
overestimate caloric cost of the exercise. It is worth noting, however, that the TRUE
overestimated by 11.0 kcal/min compared to and overestimation of 1.4 kcal/min by the
Precor. The estimation of caloric cost is based on oxygen consumption. Therefore, the
makers use a built-in regression equation to estimate the oxygen consumption of the

exercise. It is possible that each company used different variables to estimate oxygen consumption. Traditionally, variables such as body weight and workload are used (see Table 2.1). However, the calculations used by the makers of the elliptical trainers are considered proprietary information. Interestingly, more variables were recorded into the Precor (age, weight, and workload) than the TRUE (weight and workload) before the onset of exercise. It is possible that this could play a role in the higher level of accuracy in estimating caloric cost of the exercise.

5.7 Location

The location of the data collection was one variable that the researchers were unable to account for. It was not possible to move the elliptical trainers into the lab, so the gas exchange equipment was moved to the elliptical trainers in the gym. Subjects were not allowed to listen to music or watch television during testing sessions. Subjects were instructed to focus on maintaining the assigned cadence. This resulted in accurate maintenance of the assigned cadence along with a non-confounding task on which to focus their attention.

5.8 Combined Arm-Leg Exercise

Elliptical trainer arm handles were used in the present study to minimize adverse effects on oxygen consumption. When holding on to fixed handles, subjects tend to lean forward and allow the arms to support their weight as the legs fatigue. Failure to control for arm support may result in reduced oxygen consumption and differences within individuals between tests at maximal levels (3, 13). In the present study, subjects may have recruited their arms to support or generate a higher percentage of the

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work rate throughout the testing sessions. This was more apparent during TRUE

elliptical testing sessions due to the way the machine is set up. The researchers were

unable to control for the percentage of work being done by the arms compared to the

legs. Bergh et al. (3) reported a decline in oxygen consumption during maximal

exercise when arm work accounted for greater than 40% of overall work rate. Since the

present study was a submaximal test, it is difficult to know the effect of varying

amounts of work done by the arms. Mier et. al. (20) measured submaximal oxygen

consumption during elliptical trainer leg only as well as arm-leg exercise. One equation

was developed for each type of exercise, with very little difference between the two

equations (see Table 5.2). Therefore, it was concluded that the involvement of arms

during submaximal elliptical trainer exercise produces a minimally higher oxygen

consumption than leg only exercise. However, the researchers did not control for body

fatness or fitness level. It has been shown that higher levels of body fatness and lower

levels of fitness have a negative effect on muscular efficiency (5). This reduction in

efficiency can result in greater reliance on the arms to perform work. Therefore, the

effect on oxygen consumption of adding arms to submaximal elliptical trainer exercise

is unknown.

<div align="center">5.9 Practical Implications</div>

From an exercise prescription standpoint, accurate metabolic prediction

equations for elliptical trainers are necessary. A difference among elliptical trainer

brands eliminates the convenience of using one universal equation for all elliptical

trainers. This difference, however, may lead to the acceptance of only one equation

<div align="center">40</div>

based on a particular brand. The Monark brand cycle ergometer, one of two brands for which a metabolic prediction equation has been published, is widely used in health care, sports medicine and research (1). Therefore it may be of importance to develop an equation based on the elliptical trainer of greatest validity in the same arenas. To date, Precor brand elliptical trainers are commonly used in research (6, 20), rehabilitation and fitness facilities.

The results of this study may have an affect on decisions of which brand of elliptical trainer to use. When exercising at machine-given workloads used in the present study, one will experience more intense bout of exercise on the TRUE. Unfortunately, the machine-estimated caloric cost of exercise on the TRUE overestimates by nearly 11 kcal/min. The Precor elicits lesser physiological responses, but more closely estimates caloric cost of exercise. If an individual wanted an accurate measure of how many calories he or she was burning, the Precor would likely be the choice, only overestimating caloric expenditure by 1.4 kcal/min.

<div align="center">5.10 Conclusions</div>

In conclusion, differences exist in physiological responses to submaximal elliptical trainer exercise at the same apparent watt levels. These differences may require the acceptance of a metabolic prediction equation based on a specific brand of elliptical trainer.
Future work should apply the newly developed metabolic prediction equations to a broader range of populations, including those who are sedentary, overweight, obese, or limited by a lower body disease or injury. More studies also need to be done across a

larger range of workloads so that the equation is applicable to a larger range of

individuals. It is also important to find the reliability of elliptical trainer exercise

measurements in order to determine day-to-day variability. Finally, the contribution of

arms to overall muscular work while performing elliptical trainer exercise has yet to be

elucidated.

APPENDIX A

STATEMENT OF INFORMED CONSENT

INFORMED CONSENT

PRINCIPAL INVESTIGATOR: Daniel Swier

TITLE OF PROJECT: Comparison of Oxygen Cost on Different Brands of Elliptical Trainers in the Development of a Metabolic Prediction Equation.

This Informed Consent will explain about being a research subject in an experiment. It is important that you read this material carefully and then decide if you wish to be a volunteer.

PURPOSE:

The purpose of this study is to determine if there is a difference in metabolic cost of steady state elliptical trainer exercise among brands. While prediction equations can be used to determine the metabolic cost on various modes of exercise, none have been validated for elliptical trainer exercise. However, before an equation can be developed, it is important to know if there is a difference among brands, which would eliminate the possibility of a universal equation for elliptical trainer exercise.

The purpose(s) of this research study is/are as follows:
        1. Is energy cost of elliptical trainer exercise different among brands?
        2. If so, how does this difference affect the development of a caloric prediction equations?

DURATION

You will be asked to make three visits to the Exercise Science Research Laboratories. The first visit will last for approximately 2 hours. The second and third visits will last approximately 1 hour each. Finally, if you have limited experience using an elliptical trainer, you will be required to make 3 additional visits to the laboratory to familiarize yourself with the equipment being used in this study. These three visits are intended to take place over the span of one week; after which time the first testing session can be scheduled. Approximately 40 people will be asked to participate in this study.

PROCEDURES

The procedures, which will involve you as a research subject, include:

The first visit to the laboratory will consist of completing the informed consent and a health history questionnaire. A prescreening interview will take place to ensure that you do not have enough health risks to keep you out of the study, and then you will be asked to complete a VO_{2max} test. During this test, you will jog at a self-selected pace

while the grade is increased by 2% every 2 minutes. You will be asked continue to jog until you feel like the exercise is the hardest that you ever remember completing. After 15 minutes of recovery and rest, you will be asked to practice on two different brands of elliptical trainers at various workloads for up to 10 minutes.

The second and third visits to the laboratory will last for approximately one hour each. During these sessions you will be asked to perform an exercise test on one of two elliptical trainers. The exercise protocol consists of six 5-minute stages for a total exercise time of 30 minutes per session. You will be assigned to exercise at one of four cadences (90, 104, 120, or 134 strides per minute), which will be maintained throughout the testing session. You will exercise at six different workloads that are a combination of the assigned cadence and each resistance (1, 3, 5, 7, 9, and 11).

If you are unfamiliar with elliptical trainer exercise, you will be asked to make three additional practice visits to the laboratory before the first testing session. During the first of these practice sessions, you will be instructed on how to operate each elliptical trainer and then given ample time to exercise and reach an adequate level of comfort at a fixed workload. During the second and third practice sessions, you will exercise at varying workloads until attaining an adequate level of comfort.

POSSIBLE RISKS/DISCOMFORTS

The possible risks and/or discomforts of your involvement include:

The possibility exists of adverse changes during the maximal exercise test. These changes could include abnormal blood pressure response, fainting, disorders of heart rhythm and very rare instances, heart attack. The risk of an event (heart attack, stroke) during maximal exercise testing is 0.06% and death 0.01%, (American College of Sports Medicine ®, Guidelines for Exercise Testing and prescription, 7th ed.). Every effort will be made to minimize these occurrences by a preliminary screening for heart disease risk factors and by precautions and observations taken during the test. For all maximal exercise tests, subjects will be prescreened, so that those having any exclusionary criteria will not be allowed to participate in the study. American Heart Association, Advanced Cardiac Life Support ® algorithms, if necessary. To this end, all necessary emergency equipment including defibrillator, airway supplies, and life-saving medication will be on site (emergency procedures attached). American College of Sports Medicine indications of stopping exercise tests will be used for all cases in order to minimize risks. In every case, two exercise technicians will perform these exercise tests. They will be exercise science students trained in basic cardiopulmonary resuscitation techniques (American Heart Association, BLS certified®). All staff members (faculty and students) involved in testing will regularly (1 monthly) rehearse emergency protocols and basic CPR skills as part of their professional duties in the Exercise Science and Research Laboratories.

POSSIBLE BENEFITS

The possible benefits of your participation are:
Aid in determining an ideal metabolic prediction equation for elliptical trainer exercise. Current prediction equations are utilized in health/fitness settings and allow individuals to estimate the energy expenditure of of their workouts. Potential benefits are also

related mainly to your personal motives for participating in this study, (i.e. understanding your sleep quality and how this relates to your daytime functioning, using the information from this test to evaluate your current health status, knowing your exercise capacity in relation to the general population, weight loss, understanding your fitness level for certain recreational activities, planning your physical conditioning program, or evaluating the effects of recent physical activity habits). Although your health and fitness might also be evaluated by alternative means, (e.g. a bench step test, an outdoor running test, or a physical exam), such tests do not provide as accurate a fitness assessment as the treadmill or bike test nor do those options allow equally effective monitoring of your responses.

ALTERNATIVE PROCEDURES / TREATMENTS

There are no alternative procedures or courses of treatment. However, you can elect not to participate in the study at any time with no negative consequences.

CONFIDENTIALITY

Every attempt will be made to see that your study results are kept confidential. A copy of the records from this study will be filed in Office #156 of the Activities Building in a locked file cabinet for at least three (3) years after the end of this research. Only principal and co-investigators and faculty sponsor will have access. The results of this study may be published and/or presented at meetings without naming you as a subject. Although your rights and privacy will be maintained, the Secretary of the Department of Health and Human Services, the UTA IRB, the FDA (if applicable), and personnel particular to this research (individual or department) have access to the study records. Your (e.g., student, medical) records will be kept completely confidential according to current legal requirements. They will not be revealed unless required by law, or as noted above.

COMPENSATION FOR MEDICAL TREATMENT:

The University of Texas at Arlington (UTA) will pay the cost of emergency first aid for any injury that occurs as a result of your participation in this study. UTA will not pay for any other medical treatment. Claims against UTA or any of its agents or employees may be submitted according to the Texas Tort Claims Act (TTCA). These claims may be settled to the extent allowable by state law as provided under the TTCA, (Tex. Civ. Prac. & Rem. Code, secs. 101.001, et seq.). For more information about claims, you may contact the Chairman of the Institutional Review Board of UTA at 817/272-1235.

FINANCIAL COSTS

The possible financial costs to you as a participant in this research study are:
1. There should be no financial costs to you as a participant unless you incur medical treatment outside the UTA covered costs.

CONTACT FOR QUESTIONS

If you have any questions, problems or research-related medical problems at any time, you may call Daniel Swier at 817/272-7017 or Dr. Jennifer Blevins at 817/272-5783. You may call the Chairman of the Institutional Review Board at 817/272-1235 for any questions you may have about your rights as a research subject.

VOLUNTARY PARTICIPATION

Participation in this research experiment is voluntary. You may refuse to participate or quit at any time. If you quit or refuse to participate, the benefits (or treatment) to which you are otherwise entitled will not be affected. You may quit by calling Daniel Swier, whose phone number is 817/272-7017 (swier@uta.edu). You will be told immediately if any of the results of the study should reasonably be expected to make you change your mind about staying in the study.

By signing below, you confirm that you have read or had this document read to you. You will be given a signed copy of this informed consent document. You have been and will continue to be given the chance to ask questions and to discuss your participation with the investigator.

You freely and voluntarily choose to be in this research project.

PRINCIPAL INVESTIGATOR: _____

_____ DATE

_____
SIGNATURE OF VOLUNTEER   DATE

_____
SIGNATURE OF PATIENT/LEGAL GUARDIAN (if applicable)   DATE

_____
SIGNATURE OF WITNESS (if applicable)

APPENDIX B

HEALTH HISTORY QUESTIONNAIRE

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO		
☐	☐	1.	Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	2.	Do you feel pain in your chest when you do physical activity?
☐	☐	3.	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?
☐	☐	6.	Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?
☐	☐	7.	Do you know of <u>any other reason</u> why you should not do physical activity?

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active — begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal — this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever — wait until you feel better; or
- if you are or may be pregnant — talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

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

NAME _____

SIGNATURE _____   DATE _____

SIGNATURE OF PARENT _____   WITNESS _____
or GUARDIAN (for participants under the age of majority)

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

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APPENDIX C

GRADED EXERCISE TESTING SHEET

Exercise Testing Sheet

Name:_____ ID: _____Age:_____
Date:_____ _____

Resting: Standing HR:_____   Resting Data (min.): _____

Exercise Test:

Time	Speed (mph)	Grade (%)	HR (bts•min^{-1})	RPE	Signs/Symptoms
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					
16					VO$_{2max}$:
17					R:

Total Test Time:_____

Reason for Termination:_____

Body Composition Assessment

Test Administrator: _____   Date: _____

Height: _____ (in)   Height:_____ (cm)

Weight: _____ (lbs)   Weight: _____ (kg)

Seven Site Skinfold

	#1	#2	#3	(mm)
Tricep	___	___	___	___
Chest	___	___	___	___
Subscap	___	___	___	___
Midaxillary	___	___	___	___
Abdomen	___	___	___	___
Suprailliac	___	___	___	___
Thigh	___	___	___	___

SUM ____

Machine Calories:

Brand/Cadence:_____   Date:_____

Resistance	Total Calories	Calories/Stage

Brand/Cadence:_____   Date:_____

Resistance	Total Calories	Calories/Stage

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BIOGRAPHICAL INFORMATION

Daniel P. Swier was born on April 21, 1984 in Edgerton, MN, and in May 2002, he graduated from Southwest Minnesota Christian High School in Edgerton. Daniel received a Bachelor of Arts degree in Exercise Science with a minor in Health and Career Concentration in Fitness Management from Northwestern College in Orange City, IA in May 2006. He accepted a graduate teaching assistantship in the Department of Kinesiology at the University of Texas at Arlington while attending as a full time graduate student from 2006-2008. He received his Master of Science degree in Physiology of Exercise in May 2008. He is also a Certified Strength and Conditioning Specialist through the National Strength and Conditioning Association.

Daniel has been accepted into the Ph.D. program in Exercise Science at the University of New Mexico in Albuquerque, NM. He has also been offered a graduate teaching assistantship, and plans to attend UNM beginning in the fall of 2008. His future career interests are to teach, conduct research, and coach soccer at the college or university level.