

ABSTRACT

Paschke, W. Cross validation of two regression equations developed to predict MET levels on the Nustep 4000 Recumbent Stepper. MS in Adult Fitness/ Cardiac Rehabilitation, December 2000, 28pp. (J. Porcari)

In a companion study, Rateike (2000) developed two regression equations to predict metabolic equivalents (METS) above and below 115 watts on the NuStep 4000 Recumbent Stepper. The purpose of this study was to cross-validate these predictions in a separate sample. Eighteen patients with either cardiac or pulmonary disease (mean age = 69.1 yrs) were used as subjects. Each subject started at either 25 or 50 watts and increased by 25 or 50 watts per stage until an RPE of 15 was reached. Each stage was 5 minutes in duration and VO_2 was measured continuously. A 1 minute rest period separated each stage of exercise. There was no significant difference ($p < 0.05$) between measured and predicted MET values at any of the stages or overall (predicted = 3.05 METS, measured = 2.95 METS). The correlation between actual and predicted values was $r = 0.91$, standard error of the estimate (SEE) was 0.38 METS, and total error (TE) was 0.41 METS. These results indicate that the newly developed prediction equations provide excellent estimates of metabolic overload and should allow cardiopulmonary rehabilitation professionals to prescribe workloads on the Nustep with greater accuracy and confidence.

The two regression equations developed by Rateike (2000) were as follows:

$$\leq 115 \text{ watts} = -150 + (5.77 * \text{wt (kg)}) + (5.87 * \text{watts}) / \text{wt (kg)} / 3.5 \text{ ml O}_2/\text{kg}/\text{min}$$

$$\geq 115 \text{ watts} = (-7.6 + (6.76 * \text{wt (kg)}) + (.03347 * \text{watts}^2) / \text{wt (kg)}) / 3.5 \text{ ml O}_2/\text{kg}/\text{min}$$

CROSS VALIDATION OF TWO REGRESSION EQUATIONS DEVELOPED
TO PREDICT MET LEVELS ON THE NUSTEP
4000 RECUMBENT STEPPER

A MANUSCRIPT STYLE THESIS PRESENTED
TO
THE GRADUATE FACULTY
UNIVERSITY OF WISCONSIN-LA CROSSE

IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE
MASTER OF SCIENCE DEGREE

BY
WILLIAM PASCHKE
DECEMBER 2000

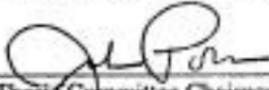
COLLEGE OF HEALTH, PHYSICAL EDUCATION, AND RECREATION
UNIVERSITY OF WISCONSIN-LA CROSSE
THESIS FINAL ORAL DEFENSE FORM

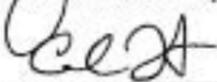
Candidate: William Paschke

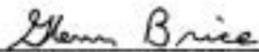
We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

Master of Science in Adult Fitness/Cardiac Rehabilitation

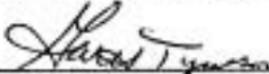
The candidate has successfully completed the thesis final oral defense.

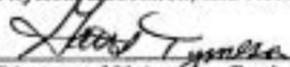

Thesis Committee Chairperson Signature 6/21/00
Date


Thesis Committee Member Signature 6/21/00
Date


Thesis Committee Member Signature 6-21-00
Date

This thesis is approved by the College of Health, Physical Education, and Recreation.


Associate Dean, College of Health,
Physical Education, and Recreation 6/29/00
Date


Director of University Graduate Studies 6/29/00
Date

ACKNOWLEDGEMENTS

Sincere thanks go out to my family for their continual support and guidance in my life.

I would like to thank Community Memorial Hospital in Menomonee Falls, WI, Barb Fagan, and Chad Rateike for their cooperation and assistance in selecting and testing subjects. Likewise, thanks to all the subjects who participated in my study.

Special thanks go out Dr. John Porcari for his tremendous involvement in all phases of my thesis. Additional thanks go out to Dr. Glenn Brice and Dr. Carl Foster for their contributions with the revisions of my thesis.

Lastly, I would like to extend love and gratitude to the 1999 – 2000 Adult Fitness/Cardiac Rehabilitation class and faculty. Thanks for the year full of great memories. Best wishes to all of you in your future endeavors.

TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS.....	iii
LIST OF TABLES.....	v
LIST OF FIGURES.....	vi
LIST OF APPENDICES.....	vii
INTRODUCTION.....	1
METHODS.....	2
Subjects.....	2
Testing Protocol.....	3
Equipment and Physiologic Responses Monitored.....	3
Analysis Techniques.....	3
RESULTS.....	4
Descriptive Characteristics.....	4
Test Results.....	5
DISCUSSION.....	7
REFERENCES.....	10
APPENDICES.....	11

LIST OF TABLES

TABLE	PAGE
1. Descriptive Statistics of the Subjects.....	4
2. Mean Data Collected at Different Watt Outputs.....	5

LIST OF FIGURES

FIGURE	PAGE
1. Comparison of NuStep METS and Measured METS.....	6
2. Comparison of Predicted METS and Measured METS.....	7

LIST OF APPENDICES

APPENDIX	PAGE
A. Data from the study by Arnos (1999).....	11
B. Data from the study by Rateike (2000).....	13
C. Informed Consent.....	15
D. Borg's Rating of Perceived Exertion Scale.....	18
E. Review of Related Literature.....	20

INTRODUCTION

The NuStep 4000 recumbent stepper (NuStep INC; Ann Arbor, MI) is a rather new and unique piece of exercise equipment used primarily in the field of cardiac and pulmonary rehabilitation. It is best described as a recumbent stair stepper with arm movements utilized in a repetitive push then pull alternating sequence. The upper and lower body movements are performed simultaneously, but in an asynchronous, opposite fashion. Maximum step depth is 10 inches and step tension and speed are adjustable and can accommodate a wide range of exercise workloads.

The determination of exercise workload often involves the use of metabolic (MET) equivalents. One MET represents 3.5 ml O₂/kg/min or the amount of oxygen the average person utilizes at rest. As exercise intensity increases, the resulting oxygen demand increases, causing an increase in ventilation and oxygen utilization. Therefore, there is a linear relationship between exercise intensity and both oxygen consumption and MET levels. In the cardiac and pulmonary rehabilitation setting, this information is extremely important when assigning appropriate exercise workloads for individual patients.

The NuStep, like many other pieces of exercise equipment, has a computerized console which calculates work output and MET levels. These numbers are determined by a regression equation within the computer software package. There has been growing speculation that the MET values indicated on the NuStep console at each workload (watt output) were grossly inaccurate. A pilot study at the University of Toledo by Arnos using

students as subjects found that the numbers displayed on the NuStep console ranged from 11 – 32% higher compared to measured values at various workloads (see Appendix A).¹ A study in our laboratory also found the MET values displayed on the NuStep console overpredicted measured METS. Rateike found that measured values were 44 – 73% lower than the NuStep console values at workloads between 25 – 250 watts (see Appendix B).² Based on his results, Rateike developed the following two equations to predict METS at workloads below and above 115 watts, respectively:

$$\leq 115 \text{ watts: } -150 + (5.77 * \text{wt (kg)}) + (5.87 * \text{watts})/\text{wt (kg)} / 3.5 \text{ ml O}_2/\text{kg}/\text{min}$$

$$> 115 \text{ watts: } (-7.6 + (6.76 * \text{wt (kg)}) + (.03347 * \text{watts}^2)/\text{wt (kg)}) / 3.5 \text{ ml O}_2/\text{kg}/\text{min}$$

However, when developing any equation, that equation needs to be cross-validated in a separate sample to establish its validity. The purpose of this study was to cross validate these two new equations for predicting MET values on the NuStep at various workloads.

METHODS

Subjects

This study involved testing 20 individuals between the ages of 40 – 80 years old who had documented heart or lung disease and were currently involved in a cardiac and/or pulmonary rehabilitation program. To eliminate any possible subject selection bias, subjects were recruited from and tested at Menomonee Falls Community Memorial Hospital in Menomonee Falls, WI. Male and female patients with differing body sizes and fitness levels who were clinically stable were eligible to participate in this study. The University of Wisconsin-La Crosse Institutional Review Board (IRB) before any data were collected, approved the testing protocol used in this study. Informed consent (see

Appendix C) was obtained from each volunteer following an informational session where the details of the test were thoroughly explained.

Testing Protocol

The testing portion of this study involved the same protocol as used by Rateike.² Data were collected across a wide range of commonly used workload intensities (25 – 150 watts) and each subject completed as many 5 minute stages as tolerable. The beginning intensity of 25 or 50 watts was incrementally increased by 25 or 50 watts per stage. A 1 minute rest period separated each stage. Testing ceased once the subject reached their upper limit of their current exercise target heart rate range or reached a rating of perceived exertion (RPE) of 15 on the Borg RPE scale (see Appendix D).³ By selecting patients of various abilities, the data collected covered the desired workload range.

Equipment and Physiologic Responses Monitored

Precautionary efforts included the constant monitoring of heart rate, EKG, and periodic assessment of blood pressure by auscultation. Oxygen consumption was collected and analyzed by open circuit spirometry using the Aerosport KB1 - C portable gas analyzer. The KBI-C was calibrated before each test using gasses with a known gas fractions and volume. Borg's 6 – 20 version of the RPE scale was used to rate each participant's subjective effort.

Analysis Techniques

Statistical analysis involved the comparison of predicted and measured MET values across the various stages using repeated measures ANOVA. Tukey's post-hoc

tests were used to make pairwise comparisons. Alpha was set at 0.05 to achieve statistical significance. The validity of the equations were also assessed using Pearson product moment correlations (r), constant error ($CE = \text{predicted mean} - \text{measured mean}$), standard error of the estimate ($SEE = SD\sqrt{1-r^2}$), and total error

$$(TE = \sqrt{\frac{\text{sum}(\text{measured} - \text{predicted})^2}{\text{number}}}).$$

RESULTS

Descriptive Characteristics

Twenty subjects (14 males and 6 females) participated in the current study. However, only 18 subjects (13 males and 5 females) were included in the statistical analysis. Two subjects were excluded due to their inability to accommodate the Aerosport KBI-C mouthpiece throughout the entire test, rendering their data inaccurate. Descriptive characteristics for the 18 subjects who successfully completed testing are presented in Table 1.

Table 1. Descriptive Statistics of the Subjects.

(n)	Age (yrs)	Height (cm)	Weight (kg)
Males (13)	69.7 ± 8.6	176.1 ± 5	82.8 ± 14.6
Females (5)	67.4 ± 5.7	151.7 ± 7	68.8 ± 11.1
Total (18)	69.1 ± 7.8	169.4 ± 14	78.9 ± 14.9

Test Results

The data collected during the study include the number of subjects who exercised at each workload, average NuStep watts attained, resistance, steps per minute (SPM), measured METS, predicted METS, and METS from the NuStep console (see Table 2).

Table 2. Mean Data Collected at Different Watt Outputs.

(n)	NuStep Watts	Resistance (range)	SPM (range)	Measured METS	Predicted METS	NuStep METS
8	27.6 ± 1.5	1 (1)	60.8 (43-79)	1.82 ± .51	1.83 ± .04	2.35 ± .24*
18	52.2 ± 3.4	1.11 (1-3)	76.2 (63-105)	2.53 ± .40	2.40 ± .13	3.35 ± .45*
12	72.5 ± 4.6	2 (2)	79.6 (69-97)	2.59 ± .49	2.87 ± .23	4.22 ± .62*
11	102.5 ± 3.6	3 (3)	84.7 (74-110)	3.58 ± .51	3.60 ± .34	5.69 ± .79*
8	124.5 ± 4.9	3.78 (3-4)	83.0 (73-93)	3.65 ± .49	3.96 ± .43	6.04 ± 1.25*
5	150.6 ± 7.4	4.5 (4-5)	92.2 (80-116)	4.59 ± .91	5.05 ± .83	7.52 ± 1.60*

* Significantly different than measured METS ($p < 0.05$)

No significant difference ($p > 0.05$) was found between measured METS and predicted METS using the new equations at any of the work stages. There were significant differences ($p < 0.05$) between measured METS and METS from the NuStep console at each stage. The NuStep overpredictions ranged from 38 – 77% across the various stages. The disparity in measured METS and NuStep METS is graphically represented in Figure 1.

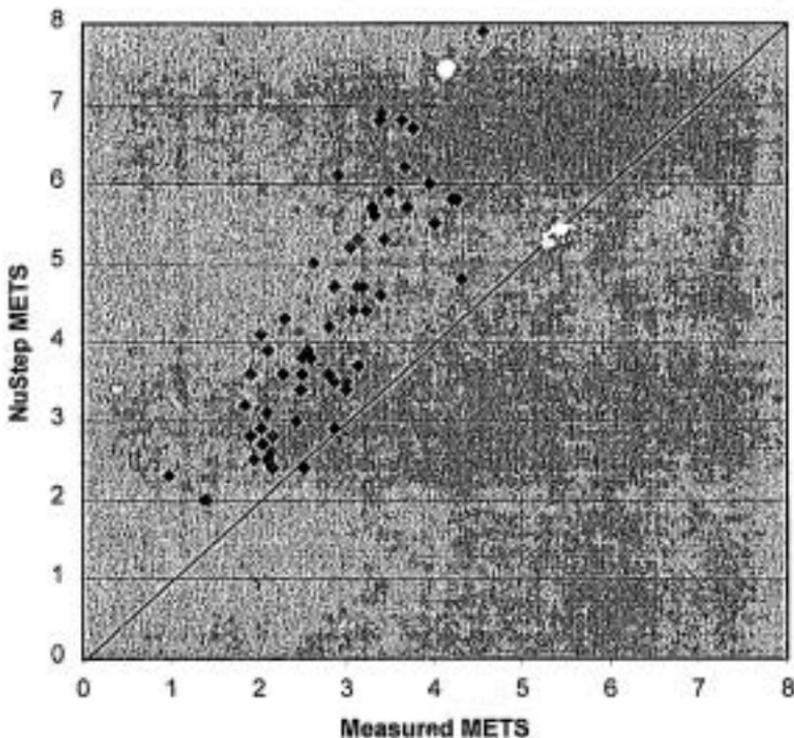


Figure 1. Comparison of NuStep METS and Measured METS

The goal of any prediction equation is to produce: no significant difference between measured and predicted means (CE), a high correlation (r) between measured and predicted values, a low standard error of the estimate (SEE), and a low total error (TE). This means the equation will predict accurately with a small range of variability. In the current study, the overall CE was 0.1 METS, the correlation (r) between measured

and predicted values was 0.91, the overall SEE was 0.38 METS, and overall TE was 0.41 METS. The relationship between measured and predicted values is presented in Figure 2.

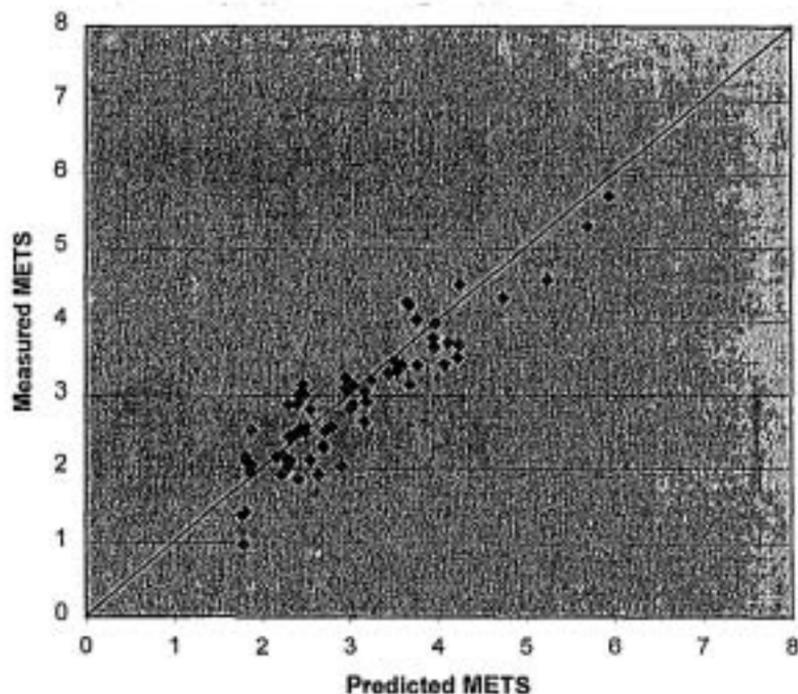


Figure 2. Comparison of Predicted METS and Measured METS

DISCUSSION

The current and previous research performed on the NuStep confirms that the current NuStep console overpredicts MET levels at various workloads. The NuStep

overpredicted measured METS by 38 – 77% in the current study. In the studies by Amos and Rateike, measured METS were overpredicted by 11 – 32% and 44 – 73%, respectively.^{1,2} Therefore, exercise prescription developed using the current NuStep console values will not be accurate, as patients would be assigned workloads lower than desired.

The resampling technique utilized in the current study has been shown to be an effective method of cross validation. Observing consistent patterns in repeated independent samples is the only means for establishing and increasing the degree of validity about any research finding.⁴ In a study evaluating the accuracy of a cycle ergometry $\text{VO}_{2\text{max}}$ prediction equation using a 15 watt/min protocol the correlation was $r = 0.94$ for males and $r = 0.93$ for females and the SEE values were 212 ml/min and 147 ml/min, respectively.⁵ In cross validation analysis the correlations ranged from 0.92 - 0.95 for both genders.⁵ The Rockport 1 mile walk test was found to have a correlation of $r = 0.93$ and a SEE of 0.325 L/min between predicted and measured values in a large population sample.⁶ The cross validation of the Rockport one mile walk test produced a correlation of $r = 0.92$ and a SEE of 0.355 L/min.⁶ These data indicate an accurate equation.

In the current study, there was no significant difference between predicted and measured means at any of the stages or overall (CE = 0.1 METS) and the correlation between measured and predicted values was $r = 0.91$. The SEE was 0.38 METS and TE was 0.41 METS. This indicates the new equations more accurately predict MET levels with a smaller range of variability than the current equation utilized in the NuStep

console. Once these equations have been incorporated into the computerized NuStep console, cardiopulmonary professionals can prescribe exercise using this piece of exercise equipment with much more confidence and accuracy.

REFERENCES

1. Arnos, J: Metabolic equivalents (METs) associated with exercise on the NuStep stepper. Unpublished pilot study, University of Toledo, Toledo, OH 1999.
2. Rateike, C: Evaluation of MET values on the NuStep 4000. Unpublished master's thesis, University of Wisconsin-La Crosse, La Crosse, WI 2000.
3. Borg, G: Perceived exertion: A note on history and methods. Med Sci Sports Exerc 1973;5:90 – 93.
4. Jensen, R. L., and Kline, G. M: The resampling cross-validation technique in exercise science: modeling rowing power. Med Sci Sports Exerc 1994;26:929 – 933.
5. Storer, T. W., Davis, J. A., and Caiozzo, V. J: Accurate prediction of VO_{2max} in cycle ergometry. Med Sci Sports Exerc 1990;22:704 – 712.
6. Kline, G. M., Porcari, J. P., Hintermeister, R., Freedson, P. S., Ward, A., McCarron, R. F., Ross, J., and Rippe, J. M: Estimation of VO_{2max} from a one mile track walk, gender, age, and body weight. Med Sci Sports Exerc 1987;19:253 – 259.

APPENDIX A

DATA FROM THE STUDY BY ARNOS (1999)

Data from the study by Arnos (1999)

Level	METS NuStep	METS Jeager	*METS (% Dif) NuStep - Jeager	Watts	Heart Rate (bpm)	RPE (6 - 20)	n
1	4.63 (.205)	4.17 (.269)	.46 (11)	83.2	109	8.5	10
2	5.25 (.308)	4.05 (.377)	1.20 (30)	99.5	115	9.3	10
3	6.81 (.354)	4.74 (.347)	2.07 (30)	134.6	121	10.0	10
4	7.85 (.403)	5.37 (.491)	2.48 (32)	158.3	135	11.9	10
5	9.45 (.414)	6.68 (.429)	2.77 (29)	198.2	142	12.7	10
6	10.15 (.509)	7.69 (.740)	2.46 (24)	214.4	158	14.9	10
7	12.16 (.615)	9.18 (.618)	2.98 (25)	252.7	167	15.7	9
8	12.53 (.957)	9.26 (1.305)	3.27 (26)	267.8	172	16.0	6
9	15.01 (.792)	11.84(1.011)	3.17 (21)	322.2	175	17.5	6
10	16.3 (1.651)	12.71 (1.359)	3.59 (22)	325.3	187	18.5	5

* Significantly different than measured METS at all levels ($p < 0.05$)

Arnos, J: Metabolic equivalents (METS) associated with exercise on the NuStep stepper.

Unpublished pilot study, University of Toledo, Toledo, OH 1999.

APPENDIX B

DATA FROM THE STUDY BY RATEIKE (2000)

Data from the study by Ratajke (2000)

N	Watts	Resistance (range)	SPM (range)	Measured METS	NuStep METS	% Dif NuStep-Measured
7	27.4 ± 2.2	1.30 (1-2)	43.9 (36-63)	1.6 ± .3	*2.3 ± .2	44
50	52.8 ± 3.3	1.46 (1-3)	66.1 (46-81)	2.2 ± .5	*3.3 ± .5	50
29	75.0 ± 2.7	2.10 (1-5)	78.0 (66-99)	2.7 ± .6	*4.3 ± .6	59
49	102.2 ± 7.3	2.90 (2-5)	83.2 (60-111)	3.1 ± .6	*5.3 ± .8	71
37	125.5 ± 4.8	3.60 (2-6)	87.9 (64-120)	3.7 ± .7	*6.5 ± 1.1	73
41	150.9 ± 4.5	4.30 (3-6)	91.4 (76-125)	4.4 ± .9	*7.5 ± 1.3	68
19	174.7 ± 3.3	5.10 (4-7)	91.4 (68-106)	5.4 ± 1.1	*8.4 ± 1.6	56
4	202.6 ± 7.8	6.40 (4-8)	93.3 (76-115)	6.6 ± 1.3	*9.6 ± 1.9	46

* Significantly different than Measured METS ($p < 0.05$)

Ratajke, C: Evaluation of MET values on the NuStep 4000. Unpublished master's thesis, University of Wisconsin-La Crosse, La Crosse, WI 2000.

APPENDIX C
INFORMED CONSENT

Informed Consent

Title of Investigation: Cross Validation of Metabolic Values on the NuStep 4000

I, _____ (print name) consent to participate as a volunteer in a study involving submaximal exercise testing on a new piece of equipment (NuStep 4000).

I have been informed that I will perform a number of exercise bouts starting at a low level and progressing to a fairly hard level of exertion. During the exercise testing, blood pressure, electrocardiograph (ECG), heart rate, and rating of perceived exertion (RPE) will be continually monitored. In addition, I will be required to breathe through a scuba type mouthpiece so that my expired air can be analyzed. The total testing time will be approximately 60 minutes. Testing will stop when I reach the top level of my current exercise training heart rate and/or RPE of 15. A resting period of one minute will be given in between each stage. Testing will take place in the cardiac rehab gym or EKG lab.

I have been informed that I may quit exercising at any time if I wish. During physical activity of any type, there are always risks and discomforts involved. These include ANGINA (CHEST PAIN), SHORTNESS OF BREATH, INCREASED HEART RATE, EKG CHANGES, ISCHEMIA, HEART ATTACK, STROKE, AND IN RARE INSTANCES, DEATH. The complication rate for maximal diagnostic exercise testing in patients with known or suspected heart disease is about 6/10,000 for all complications and about 1/10,000 for serious complications. During submaximal exercise similar to therapeutic exercise training (as in this study), the complication rate is about .1/10,000 tests. Also, the mouthpiece may cause the jaw to become tired from holding it in the mouth. If I experience any of these symptoms I will notify certified personnel immediately. As a precaution, exercise physiologists trained in Advanced Cardiac Life Support will be present.

I understand there are no "disguised" procedures and that the investigator, Will Paschke, explained all procedures accurately and honestly. I also understand that if I have any questions about my participation in this study I can ask at any time. If any questions should arise, call Barb Fagan (262) 532-3287, call Will Paschke at (608) 785-3346 or the supervisor of the study John Porenri, Ph.D. at (608) 785-8684. I consent to participate given the results may be eligible for publishing and I cannot be identified individually. All results will be held strictly confidential.

I consider myself to be in stable cardiovascular health and to my knowledge I am not infected with a contagious disease or have any limitations to preclude my participation in the test described above. I have been informed that I am able to withdraw from this study at any point without penalty. Any questions regarding the protection of human subjects may be addressed to Dr. Garth Tyneson, Chair of UW-LaCrosse IRB for the protection of Human Subjects, phone # (608) 785-8155.

Compensation For Injuries: I agree to take the risks listed above. In the event that physical injury occurs as a result of this research, my physician will help me find treatment. Medical services for such an injury will be my financial responsibility. I understand that such physical injury does not mean negligence has occurred. I also understand that I may contact the Chairman of the Investigational Review Board of Community Memorial Hospital at (262) 532-3009 for further information in the event that physical injury occurs as a result of this research.

I have read all of the above, asked questions, received answers concerning areas I did not understand, and willingly give my consent to participate in this program. Upon signing this form I will receive a copy.

Subject's Signature

Date

Witness Signature

Date

I have defined and fully explained the study as described herein to the subject.

(Name of Principal Investigator or Authorized Representative)

(Position Title)

Signature

Date

APPENDIX D

BORG'S RATING OF PERCEIVED EXERTION SCALE

Borg's Rating of Perceived Exertion (RPE) Scale

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

Borg, G: Perceived exertion: A note on history and methods. Med Sci Sports Exer: 1973;5:90 - 93.

APPENDIX E

REVIEW OF RELATED LITERATURE

REVIEW OF RELATED LITERATURE

Introduction

The primary use of the NuStep 4000 recumbent stepper lies within the fields of cardiac and pulmonary rehabilitation. Patients in these fields with low functional capacities or who have orthopedic or ambulatory limitations have found the NuStep to be a comfortable and tolerable mode of exercise. It is quickly and easily adjustable to accommodate each patient's physical dimensions (seat depth and arm handle lengths) and exercise workload (resistance). These characteristics make the NuStep a favorite choice of exercise for both patients and rehabilitation personnel.

Essential components of individualized exercise prescription include the appropriate exercise mode, intensity, duration, frequency, and progression with special consideration made to each patient's health status, risk factors, responses to exercise (HR, BP, ECG), and personal goals and preferences.¹ Effectiveness of individualized exercise prescription decreases as accuracy in implementing these component decreases.

Oxygen consumption (VO_2) measurements indicate the capacity of the body to transport and utilize oxygen while also providing a measure of energy cost and cardiorespiratory fitness.¹ The direct measurement of VO_2 is rarely used in diagnostic or functional tests in large populations due to the constraints of time, skill, money, and equipment. However, research has shown that during aerobic exercise, VO_2 has a direct linear relationship with increasing workloads.^{2,3} This linear relationship between VO_2 and workload has allowed the development of numerous regression equations to predict VO_2 during the more common exercise modalities such as walking, running, and leg

ergometry. Very little research has been performed on the NuStep. This review of literature will discuss factors affecting prediction equations, popular equations currently in use, and research performed on the NuStep.

Factors Affecting Prediction Equations

There are a number of prediction equations in the literature to predict VO_2 . Some incorporate total test time (treadmill protocols, the Rockport walk test, 1.5 mile run), total distance covered (Cooper 12 min run/walk test), maximal workloads attained (cycle ergometry protocols), or heart rate response to set workloads (Sjostrand and Astrand tests⁴).

There have also been numerous attempts to incorporate demographic characteristics to improve the accuracy of prediction equations. Common variables such as age,^{5,6} weight,^{7,8} and gender^{9,7} have been included as predictor variables. Other variables more difficult to classify such as activity level,^{5,6,10,11} and clinical status^{10,12} have also been utilized. Prediction equations are usually population specific, meaning they are most accurate when used with subjects that are similar to the population sample used to develop the equation.¹⁰ This fact explains the variance in certain prediction equations when used with a different population. Therefore, to obtain the most accurate results, careful consideration in the selection of prediction equations should be made based on the population sample used in the development of the prediction equation, subject characteristics, and the equipment available for testing.

Prediction Equations

Bruce and Balke Treadmill Protocols

Clinical application of prediction equations most often utilize either the Bruce or Balke treadmill protocols. The Bruce treadmill protocol incorporates changes in speed and grade every three minutes. The Balke treadmill protocol uses a constant speed of 3.3 mph with grade increasing 1% every minute. Clinical exercise testing using any protocol ceases when diagnostic changes occur signifying disease or when the subject reaches maximum fatigue, and VO_{2max} is determined from maximal test time. In a study which evaluated the Bruce and Balke protocols to predict VO_{2max} , the correlation (r) between measured and predicted values were 0.87 and 0.80, and the SEE values were 4.71 ml/kg/min and 3.95 ml/kg/min, respectively.¹³ These predicted estimates of VO_{2max} were considered to be relatively good.

Cooper 12 Min Run/Walk Test

The Cooper 12 min run/walk test uses total distance covered in 12 minutes as the only variable for predicting VO_{2max} . Large numbers of subjects can be tested with minimal requirements (measured distance and stopwatch). Among nine teenage boys that were 14 and 15 years old, the correlation (r) value between predicted and measured was 0.90, but the SEE was unavailable.¹⁴ In a study involving younger adolescent boys aged 11 to 14 years, the correlation between predicted and measured VO_{2max} was 0.65.¹⁵ Once again the SEE was unavailable in this study but the test-retest reliability was $r = 0.94$.¹⁵ The differing correlations may be due to small sample sizes, or differences in growth and motivation level of the subjects.¹⁴ While this test can make reliable general

classifications concerning cardiorespiratory fitness, accuracy in assessing VO_{2max} may be highly affected by the characteristics of the population being tested.

Rockport Walk Test

The Rockport walk test utilizes total time to cover a one mile distance, age, gender, weight, and immediate posttest heart rate to predict VO_{2max} . Similar to the Cooper 12 minute run/walk test, the Rockport walk test can accommodate large numbers of people and only requires a measured distance, stopwatch, and the ability to accurately measure heart rate. In the original study, the correlation between measured and predicted values was 0.93 and the SEE was 0.325 L/min in a sample of 343 subjects between the ages of 30 and 69 years old.⁷ Because the test was developed over a wide age and fitness range, and utilized a large sample size, the Rockport walking test can be used over a broad range of subject populations.⁷

Sjostrand and Astrand Tests

Participation in maximal exercise tests in certain individuals may be deleterious to their health. In these situations, submaximal exercise tests are appropriate for evaluating functional capacity and prescribing safe and effective exercise. Two possible alternatives to maximal exercise tests include the Sjostrand and Astrand submaximal bicycle tests.⁴ The Sjostrand test incorporates three stages of continuous work intervals, each lasting 6 minutes in duration. Heart rates (HR) are recorded during the fifth and sixth minute of each stage and are averaged to determine steady state values. The slope of the three submaximal steady state HRs is extrapolated to a maximum steady state HR of 170 beats per minute.

The Astrand test requires only one steady state HR value. Thus, it only requires a single 6 minute stage of exercise. Once again, HR is recorded during the fifth and sixth minute of exercise and then averaged to obtain a steady state value. This HR and work rate value is then compared to table values to predict VO_{2max} . In a study involving 83 apparently healthy 30 - 70 year old males, the correlations between measured and predicted VO_{2max} for the Sjostrand and Astrand tests were 0.58 and 0.55, respectively.¹⁶ The SEE values were unavailable but the constant error for the Sjostrand and the Astrand tests were 4.7 ml/kg/min and 6.2 ml/kg/min, respectively.¹⁶ The low correlation values and large differences between predicted and measured mean VO_{2max} indicate that the prediction accuracy of these equations was quite poor in the group of subjects tested.

NuStep Research

In a clinical setting, accurate predictions of exercise intensity are needed to prescribe safe and effective exercise. Recent research has shown that the computerized console on the NuStep overpredicts MET values by 11 - 32 % (see Appendix A) in apparently healthy college students.¹⁷ A study at the University of Wisconsin-La Crosse found the NuStep console overpredicted measured values by 44 - 73% (see Appendix B) in a clinical population.¹⁸ Based on his data, Rateike developed two regression equations to more accurately predict METS on the NuStep. Because the relationship between energy cost and workload on the NuStep was curvilinear above 115 watts, two equations were developed for exercise above and below 115 watts, respectively. In addition, the new equations by Rateike had a correlation of $r = .92$, and SEE was .62 METS, establishing a level of validity for the equations.¹⁸

Summary

The NuStep is a piece of aerobic exercise equipment that is comfortable and can be easily adjusted to persons of all sizes and physical abilities. It is especially popular in a cardiopulmonary rehabilitation setting. However, previous research has shown the NuStep console to inaccurately predict METS at all workloads. Since accurate exercise prescription is essential in a clinical population, Rateike developed two regression equations to better predict MET levels on the NuStep. Because the equations were developed on a clinical population, they should allow cardiopulmonary rehabilitation professionals to design exercise prescriptions with much more accuracy and confidence on the NuStep.

REFERENCES

1. American College of Sports Medicine: ACSM's Guidelines For Exercise Testing and Prescription, 6th ed. Philadelphia, PA: Williams and Wilkins, 2000.
2. Dill, D. B: Oxygen used in horizontal and grade walking and running on the treadmill. J Appl Physiol 1965;20:19 – 22.
3. Margaria, R., Cerretelli, P., Aghemo, P., and Sassi, G: Energy cost of running. J Appl Physiol 1963;18:367 – 370.
4. Astrand, P., and Rodahl, K: Textbook of Work Physiology, 3rd ed. New York City, NY: McGraw-Hill Book Co, 1986;354 – 387.
5. Hermison, R. T., and Faulkner, J. A: Prediction of maximal oxygen uptake by a stepwise regression technique. J Appl Physiol 1971;30:833 – 837.
6. Bruce, R., Kusumi, F., and Hosmer, D: Maximal oxygen intake and nomographic assessment of functional aerobic impairment in cardiovascular disease. Am Heart J 1973;85:546 – 562.
7. Kline, G. M., Porcari, J. P., Hintermeister, R., Freedson, P. S., Ward, A., McCarron, R. F., Ross, J., and Rippe, J. M: Estimation of VO_{2max} from a one mile track walk, gender, age, and body weight. Med Sci Sports Exerc 1987;19:253 – 259.
8. Storer, T. W., Davis, J. A., and Calozzo, V. J: Accurate prediction of VO_{2max} in cycle ergometry. Med Sci Sports Exerc 1990;22:704 – 712.
9. Latin, R. W., and Berg, K. E: The accuracy of the ACSM and a new cycle ergometry equation for young women. Med Sci Sports Exerc 1994;26:642 – 646.
10. Foster, C., Jackson, A., Pollock, M., Taylor, M., Hare, J., Sennett, S., Rod, J., Sarwar, M., and Schmidt, D: Generalized equations for predicting functional capacity from treadmill performance. Am Heart J 1984;107:1229 – 1234.
11. Morrow, J., Van Handel, P., Bradley, P., and Kearney, J: The validity of the ACSM energy requirement equation with well trained athletes at altitude. Med Sci Sports Exerc 1988;20:S1.

12. Sullivan, M. and McKirnan, D: Errors in predicting functional capacity for postmyocardial infarction patients using a modified Bruce protocol. Am Heart J 1984;107:486 – 492.
13. Froelicher, V., Thompson, A., Davis, G., and Triebwasser, J: Prediction of maximal oxygen consumption. Chest 1975;68:331 – 336.
14. Doolittle, T. L., and Bigbee, R: The twelve minute run - walk: A test of cardiorespiratory fitness in adolescent boys. Res Quarterly 1968;39:491 – 495.
15. Maksud, M. G., and Coutts, K. D: Application of the Cooper twelve minute run - walk test to young males. Res Quarterly 1971;42:54 – 59.
16. Kasch, F. W: The validity of the Astrand and Sjostrand submaximal tests. Physician Sports Med 1984;12:47 – 52.
17. Amos, J: Metabolic equivalents (METs) associated with exercise on the NuStep stepper. Unpublished pilot study, University of Toledo, Toledo, OH 1999.
18. Rateike, C: Evaluation of MET values on the NuStep 4000. Unpublished master's thesis, University of Wisconsin-La Crosse, La Crosse, WI 2000.