ABSTRACT

RATEIKE, C. J. Evaluation of MET values on the NuStep 4000 Recumbent Stepper. MS in Adult Fitness/Cardiac Rehabilitation, December 2000, 33pp. (J. Porcari)

The purposes of this study were to determine the accuracy of the MET values on the NuStep Recumbent Stepper console compared to measured values, and if they were different, develop a regression equation to more accurately predict MET values on the NuStep across a wide range of workloads. Fifty male and female volunteers (mean age = 63.6 $\pm$ 9.61 years) with known cardiac disease or significant risk factors for CAD served as Ss. All Ss completed 1 submaximal test on the NuStep beginning at either 25 or 50 watts and increasing by 25-50 watts per stage. Each stage was 5 min in duration and VO_2 (METS) and HR were recorded each minute. It was found that MET levels on the NuStep overpredicted the measured MET values by 44-73%. Based on these findings, the following regression equation was developed using a stepwise multiple regression technique.

Predicted METS = {4.927 + 6.47 (weight in kg) + .03245 ($watts^2$)}/(weight in kg * 3.5)

The new equation had a $R = .92$, $R^2 = .84$, SEE = .62 METS. Thus, this new equation should provide more accurate estimation of MET values on the NuStep, especially for an older cardiac population.

EVALUATION OF MET VALUES ON THE NUSTEP 4000 RECUMBENT STEPPER

A MANUSCRIPT STYLE THESIS PRESENTED

TO

THE GRADUATE FACULTY

UNIVERSITY OF WISCONSIN-LACROSSE

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THESIS FINAL ORAL DEFENSE FORM

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The candidate has successfully completed the thesis final oral defense.

Thesis Committee Chairperson Signature — Date: 5/24/00

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

Associate Dean, College of Health, Physical Education, and Recreation — Date: 6-9-00

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INTRODUCTION

The NuStep 4000 Recumbent Stepper is a relatively new piece of aerobic equipment to the field of exercise physiology (1). It is a modality that incorporates a full body movement pattern (upper and lower extremities) performed in a seated position (see Appendix A). The movement pattern for the lower body is an asynchronous pushing motion with a maximal stepping depth of 10 in. The upper body pattern is an asynchronous motion using a push and pull method that coincides with the movement of the lower body (as in walking). Stepping cadence and resistance can be altered to achieve a wide range of exercise workloads.

One of the key measurements in workload assessment is the MET, which represents the rate of oxygen uptake in an average resting individual (2). During oxygen consumption assessment, it is important to use steady-state values to represent the average of oxygen consumption during activity (1). One MET is nominally equivalent to 3.5 ml O_2/kg/min and as a person exercises, oxygen consumption increases. An easy way to express this increase in oxygen uptake is in multiples of the assumed average resting metabolic rate. Because of its convenience, MET values are very important for exercise prescription. Given knowledge of the fitness level of the individual, one can assign appropriately intense workloads on the basis of achieving a certain level of METS.

On many contemporary pieces of equipment, a computerized console indicates the workload and MET level at which an individual is exercising. These numbers are generated by a regression equation built into the computer software of the machine. Anecdotal evidence suggests that MET values at any given workload (watts) on the NuStep are erroneously high . A previous study at the University of Toledo verified this (3) (see Appendix B). However, the Toledo study incorporated only college-aged individuals as subjects. Since the NuStep is intended primarily for an older clinical population, it needs to be tested in these individuals because factors such as age, fitness level, and health status could possibly affect achieved MET values (1).

The purposes of the study were: to compare MET values on the console of the NuStep to measured values, and if the values are significantly different, to develop a regression equation to accurately predict METS.

METHODS AND PROCEDURES

Subjects

The subjects for this study were 50 volunteers between the ages of 43-85 years. All subjects were affiliated with the La Crosse Exercise and Health Program at the University of Wisconsin-La Crosse (UW-L) and had either documented cardiovascular disease or pulmonary disease, or had multiple risk factors for cardiovascular disease.

The protocol was approved by the Institutional Review Board prior to conducting data collection. All laboratory testing took place in the Human Performance Laboratory at UW-L. Each subject completed an informed consent prior to testing (see Appendix C).

<u>Validity Testing</u>

Measurements were taken to validate the Aerosport KB1C analyzer using the QMC metabolic cart (see Appendix D). These measurements were taken in order to determine the level of accuracy of the Aerosport KB1C. The data suggested minimal variation between the two testing apparatuses.

<u>Testing Protocol</u>

Preliminary pilot testing investigated the effects of various combinations of step depth, resistance, and cadence on oxygen consumption (METS). It was found that, with minor variation, METS were similar at any given power output (watts) regardless of how the workload was achieved. Therefore, it was determined that at each testing workload (watts), subjects would be allowed to self-select any combination of the above variables to attain the desired power output. We felt that this would more accurately represent the real world, where subjects vary in how they choose to exercise (e.g., some people choose to use a faster cadence, while others choose a higher resistance).

Subjects began exercising at a power output of either 25 or 50 watts, depending upon their fitness level, and increased their workloads by 25 or 50 watts per stage. Each stage was 5 min in duration with 1 min of rest in between stages. Subjects completed as many stages as possible, and testing was stopped when subjects achieved the top of their current target heart rate range or a perceived exertion of 15 on the 6-20 Borg scale (4) (see Appendix E). It was felt that this was the highest level at which they could maintain a steady state and produce consistent data.

Oxygen consumption was measured continuously with an Aerosport KB1-C portable analyzer and heart rate was measured by radiotelemetry. The oxygen consumption values from min 4 to 5 were averaged and used to represent steady state oxygen consumption at each stage.

Statistics

Standard descriptive statistics were used to characterize the subject population and to summarize the data collected at each stage. Comparisons of measured MET values to the console values at each stage were made using paired t-tests. Because there was a significant difference between measured and console MET values, a stepwise multiple regression analysis was used to develop a regression equation to predict METS across the range of workloads used in the study. All data were analyzed using the SPSS statistical software package.

RESULTS

The physical characteristics of the subjects are presented in Table 1. Table 2 presents the data comparing the actual measured MET values versus the console values on the NuStep. It can be seen that the NuStep overpredicted actual MET values by 44-73%. This relationship is illustrated graphically in Figure 1. Based on these findings, a regression equation was developed to more accurately predict MET values on the NuStep.

Table 1. Descriptive characteristics of the subjects (N = 50).

Variable	Total N = 50	Females n = 16	Males n = 34
Age (yrs) (range)	*63.6 ± 9.61* (43-85)	*60.4 ± 8.28* (44-73)	*65.1 ± 9.93* (43-85)
Height (cm) (range)	173.3 ± 9.26 (155-193)	164.3 ± 5.23 (155-174)	177.6 ± 7.50 (165-193)
Weight (kg) (range)	82.6 ±16.04 (54-116)	68.3 ± 8.73 (54-90)	89.4 ±14.14 (60-116)

Table 2. Comparison of the measured versus NuStep metabolic equivalents.

N	Watts	Resistance (range)	Steps/min (range)	Measured METS	NuStep METS	% Diff (NuStep-Actual)
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%
14	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 ($p < .05$)

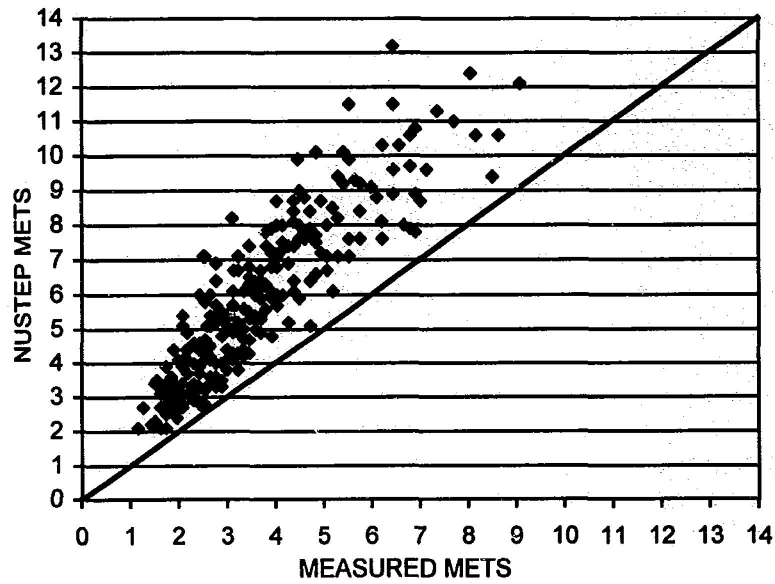

Figure 1. Plot of MET from the NuStep console vs measured METS

Development of the Regression Equation

Analysis revealed that the data were distributed in a curvilinear pattern with increasing workloads. This trend is indicated in Figures 2 (VO_2 versus WATTS) and 3 (Measured METS versus WATTS) and held true regardless of whether the data were represented in absolute (ml/min) or relative terms (METS). The implications of this finding are that the equation to be developed could not be a simple linear regression equation, but had to include some sort of quadratic (squared) component.

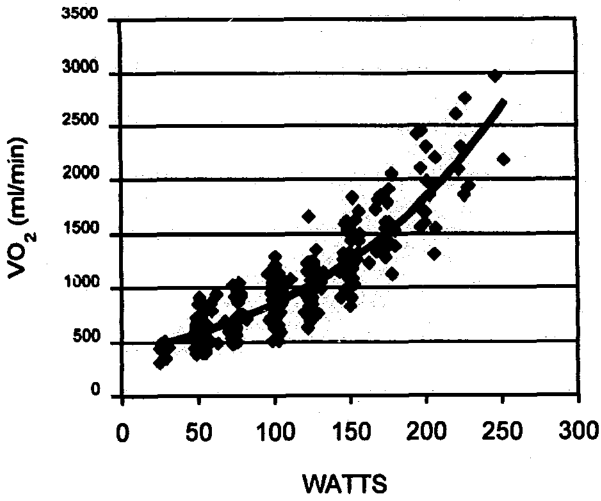

Figure 2. Plot of VO_2 (ml/min) vs watts on the NuStep.

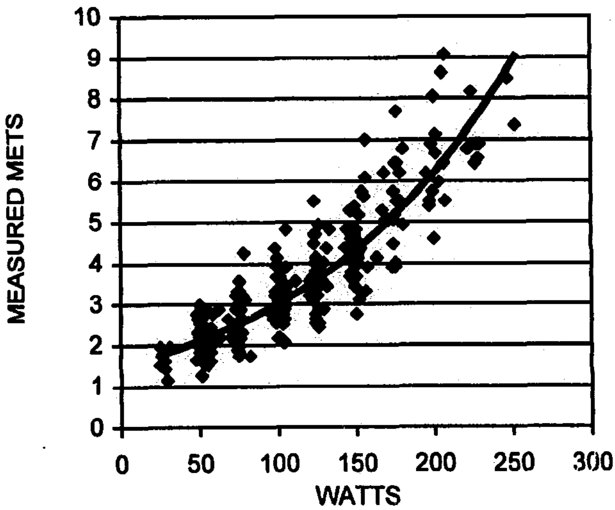

Figure 3. Plot of measured METS vs watts on the NuStep.

Correlational analysis revealed that the strongest correlations with oxygen consumption (ml/min) were with watts squared (watts x watts) and body weight (in kg).

Stepwise multiple regression analysis confirmed this relationship and those two variables were entered into the equation to predict VO_2, which was subsequently converted to METS. The resultant curvilinear equation was: Predicted METS = 4.927 + {(6.47 * body weight kg) + (.03245 * watts^2)}/(body weight in kg * 3.5)

$R = .92$, $R^2 = .84$, SEE = .62 METS, CV = 18%

The predicted METS were also plotted against measured MET values (Figure 4), and it can be seen that the values were equally distributed around the line of identity using the new equation.

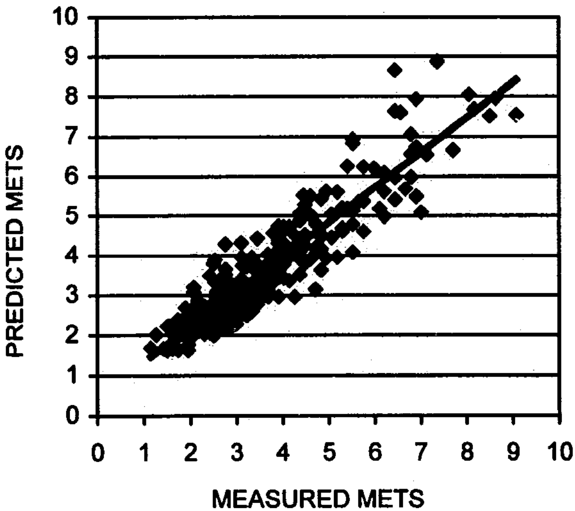

Figure 4. Plot of predicted METS vs measured METS.

Another way to determine the accuracy of data is to look at the standardized residual, which is the average difference between actual and predicted values for each person. The average standardized residuals are presented in Table 3. It can be seen that values are relatively low and increase as workload increases. The average standardized residual was .45 METS.

Table 3. Workload (WATTS) and the average standardized residual values at various workloads (WATTS) on the NuStep.

N	Workload (WATTS)	Standardized Residual (METS)
7	25	.22
50	50	.33
29	75	.30
49	100	.46
37	125	.51
41	150	.56
19	175	.61
14	200	.65

DISCUSSION

The resultant equation to predict VO_2, thus MET equivalents on the NuStep, has an excellent correlation and an acceptable standard error of the estimate. The coefficient of variation (SEE/mean) is 18%, which is also within the range of most other prediction equations reported in the literature for other modalities (1,2).

Coefficient of variation for prediction equations is typically in the range of 10-25% (2). Quite obviously, the lower the CV the better, but because this study used subjects with a wide range of ages, fitness levels, and pathology, it was not unexpected that there would be quite a bit of variability in the data.

The mean values for METs at each workload were somewhat lower than the data collected at the University of Toledo (see Appendix B). Possible reasons for these differences could be related to several factors. It is generally accepted that cardiac patients have lower MET values at any given workload compared to healthy adults, primarily due to impaired oxygen uptake kinetics (see Appendix F). The higher body weights of the subjects in the current study (77.2 kg versus 82.6 kg) also reduced the apparent MET values at any given stage. Finally, it is possible that the mechanism within the NuStep may have loosened up over the course of the testing or during shipping. If the NuStep was not calibrated properly, then the watt readout may be inaccurate. As a result, if the watt values are not correct, MET values will be invalid. In addition, the resistance is controlled by a magnetic flywheel that appears to apply a much greater resistance at higher workloads. Therefore, NuStep watt values may underrepresent the true watt values. All of these factors could have influenced the measured MET values.

The resultant equation should give acceptable MET estimates that can be used in a cardiac or pulmonary rehabilitation setting. A pilot study, conducted on 54 patients in the La Crosse area found that they work out, on average, at approximately 75 watts, and utilize 70-80 steps per min. Table 2 confirms that at this workload most subjects are exercising at a workload corresponding to 2-3 METS. This is comparable to the range of MET values that individuals work at on other modalities (e.g., treadmill, Airdyne, etc.) If one looks at the standardized residual values (Table 3), the predicted MET values should be within about .3 METS, or within 10-15% accuracy for most subjects. This degree of accuracy would be considered excellent for exercise prescription purposes.

CLINICAL APPLICATIONS

The results of this study were used to develop a regression equation in order to accurately predict MET values on the NuStep total body recumbent stepper. The accuracy of METS is important for exercise prescription purposes, especially for those with cardiovascular and/or pulmonary disease. Typically, exercise prescription involves calculating a target heart rate for each patient. Workloads on various modalities are then chosen to get people within that heart rate range. While most people are comfortable with modalities such as the treadmill or a cycle ergometer, they have less experience prescribing workloads on a new piece of equipment such as the NuStep. The results of this study should allow professionals to prescribe workloads on the NuStep with a greater degree of accuracy of confidence.

Because the MET values on the console were much higher than measured values, persons exercising on the NuStep were not working as hard as they thought. By developing a new equation, one can be more confident that the numbers on the console directly reflects the actual workout they are doing.

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APPENDIX A

NUSTEP 4000 RECUMBENT STEPPER PHOTO

NuStep 4000 Recumbent Stepper Testing in UW-L Laboratory

APPENDIX B

UNIVERSITY OF TOLEDO STUDY

University of Toledo NuStep Recumbent Stepper Study Report

Level	METS NuStep	METS Jaeger	* METS (% diff) NuStep - Jaeger	WATTS	RPE	n
1	4.63	4.17	.46 (11)	83.2	8.5	10
2	5.25	4.05	1.2 (30)	99.5	9.3	10
3	6.81	4.74	2.07 (30)	134.6	10	10
4	7.85	5.37	2.48 (32)	158.3	11.9	10
5	9.45	6.68	2.77 (29)	198.2	12.7	10
6	10.15	7.69	2.46 (24)	214.4	14.9	10
7	12.16	9.18	2.98 (25)	252.7	15.7	9
8	12.53	9.26	3.27 ([illegible]6)	267.8	16	6
9	15.01	11.84	3.17 (21)	322.2	17.5	6
10	16.3	12.71	3.59 (22)	325.3	18.5	5

Subjects

Variables	Total n = 20	Females n = 10	Males n = 10
Height	67.6 ± 3.241	65.77 ± 1.825	70.19 ± 2.947
Weight	170.81 ± 35.186	156.96 ± 32.649	187.7 ± 1.394
Age	22.8 ± 4.162	22.82 ± 5.036	22.78 ± 3.030

* Arnos, J. A pilot study to evaluate MET values on the NuStep (Unpublished Master's Thesis, Toledo University). University of Toledo, 1999.

APPENDIX C

INFORMED CONSENT

Informed Consent

Title of Investigation: Evaluation of MET 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 exercise equipment (NuStep 4000). I have been informed that I will perform a number of exercise bouts starting out 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 collected and analyzed. The total testing time will last approximately 60 minutes. Testing will stop when I achieve the top level of my current exercise training heart rate and/or a RPE of 15. A resting period of one minute will be given in between each stage. Testing will take place in 221 Mitchell Hall.

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 that are involved. These include angina pectoris (chest pain), shortness of breath, increased heart rate, ECG 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 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, during the testing, exercise physiologists trained in Advanced Cardiac Life Support will be present.

I understand that there are no "disguised" procedures and that the investigator, Chad J. Rateike explained all procedures accurately and honestly. I also understand that if I have any questions about my participation in the study I can ask at any time. If any questions should arise, call Chad J. Rateike at (608) 788-2516 or his supervisor John Porcari, Ph.D. at (608) 785-8684. I consent to participate given that the results may be eligible for publishing and I cannot be identified individually. All results will be held 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 that would preclude my participation in the tests described above. I have been informed that I am able to withdraw from the study at any time without penalty. Any questions regarding the protection of human subjects may be addressed to Dr. Garth Tymeson, Chair of UW-LaCrosse IRB for the Protection of Human Subjects, phone # (608) 785-8155.

Subject's Signature	Date
Witness Signature	Date

APPENDIX D

VALIDITY TESTING OF AEROSPORT KB1C ANALYZER

Validity Testing of Aerosport KB1C Analyzer

Watts	QMC Metabolic Cart	Aerosport KB1C
50	5.2 ml O_2.kg.min	2.7 ml O_2.kg.min
100	9.4 ml O_2.kg.min	9.2 ml O_2.kg.min
150	13.1 ml O_2.kg.min	12.8 ml O_2.kg.min

APPENDIX E

RATING OF PERCEIVED EXERTION

Borg's Rating of Perceived Exertion 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 5:90-93, 1973.*

APPENDIX F

BRUCE TREADMILL PROTOCOL

Bruce Treadmill Protocol

Stage	MPH	Grade	Min	Healthy	Cardiac
			1	3.2	3.6
I	1.7	10 %	2	4.0	4.3
			3	4.9	4.9
			4	5.7	5.6
II	2.5	12%	5	6.6	6.2
			6	7.4	7.0
			7	8.3	7.6
III	3.4	14%	8	9.1	8.3
			9	10.0	9.0
			10	10.7	9.7
IV	4.2	16%	11	11.6	10.4
			12	12.5	11.0
			13	13.3	11.7
V	5.0	18%	14	14.1	12.3
			15	15.0	13.0

* American College of Sports Medicine: Guidelines for Exercise Testing and Prescription, 6th Ed. Philadelphia, PA. Williams and Wilkins, 2000, p. 102.

APPENDIX G

REVIEW OF RELATED LITERATURE

REVIEW OF RELATED LITERATURE

Introduction

The NuStep recumbent stepper is a piece of exercise equipment involving a full body asynchronous movement that is performed in a seated position. It has adjustable workloads that control how much tension is on the machine and thus will control the difficulty of the exercise. The cadence (speed) and the stepping depth are also controlled by the operator (full stepping depth is 10 in). As a person exercises, a certain watt measurement is displayed according to the intensity placed upon the machine. The lower the resistance, the higher the cadence has to be in order to maintain a prescribed watt level, and conversely, the higher the resistance, the slower the cadence has to be in order to exercise at the same assigned workload.

Previous Study on the NuStep

A study was done at the University of Toledo (see appendix B) to evaluate the metabolic equivalents associated with exercise on the NuStep. The subjects were healthy college-aged subjects (22.8 $\pm$ 5.036) who exercised at 100 steps/min and performed four 5-min intervals. Each subject was assigned to one of two protocols: (1) exercising at levels 1, 3, 5, 7, 9, and (2) exercising at levels 2, 4, 6, 8, 10. It was found that the NuStep console MET values overpredicted measured oxygen consumption values by 11–32 %.

Factors Affecting Prediction Equations

There are a number of factors that affect the accuracy of regression equations, one being the age and fitness level of subjects in the study. This study incorporated an older population (age 43-85) that either had cardiac/pulmonary disease or were at risk for developing coronary artery disease. The subjects were selected based on the population that uses the NuStep, therefore increasing the accuracy of the developed equation. Persons that have cardiac/pulmonary disease typically have lower oxygen kinetics (which affects the measurement of oxygen consumption). Another factor which affects accuracy is the efficiency of the subjects. Depending on the activity and fitness level of the subjects, they can vary in their muscular efficiency (4). Other factors such as fat mass (body fat %) and fat-free mass (muscle) can also affect prediction equations (5). Those that have less body fat and more muscle have a lower energy requirement to do the same amount of work (4). Finally, displayed workloads on exercise equipment may differ because of frequency of use. Over time, machines tend to "loosen up" and become less accurate.

Regression Analysis for Predicting Workloads

Most pieces of exercise equipment have regression equations built into their software to predict such things as MET levels, fitness, and caloric expenditure. Regression equations are also commonly used to predict aerobic capacity ($VO_{2\,max}$), usually from some sort of submaximal test. In order to be accurate, a good correlation (Pearson's r) and low standard error of estimate (SEE) are needed. Many times SEE is represented as the coefficient of variation (CV). The higher the correlation, and the lower the SEE and CV, the better the prediction.

There have been a number of classic studies that have developed widely used equations from submaximal exercise tests. Some examples are the Rockport 1mile walk test, the Astrand bicycle ergometer test, the Harvard step test, the Cooper 12 minute run/walk test, and the Queens College step test (1). These tests all have excellent correlations and reliability and low SEE values. The Rockport One-Mile Track Walk Test predicts a person's $VO_{2\,max}$ by having them perform at least two walking trials on the track and compares the results to a maximal treadmill test (1). There was a strong correlation between actual and predicted maximum values ($r = .93$) and a low SEE (.325 $l.min^{-1}$). The Harvard step test, consists of using bench stepping to predict $VO_{2\,max}$ (2). Subjects are assigned to step up and down continuously for 60 secs using a 16.25 in step and the results were compared to a maximal treadmill test (3). The correlation was $r = .76$, but no SEE was given. In 1968, Cooper studied 150 U.S. Air Force male officers and airmen in order to predict maximal oxygen consumption (4). Each subject was assigned to perform a maximal treadmill test and a 12-minute field test. Cooper found a strong correlation ($r = .90$) between predicted and measured values. Lastly, the Queen's College Step test was developed in 1972 to evaluate the reliability and interrelationships between maximal oxygen intake, physical work capacity, and step-test scores in college women (1). The equation which was developed had a correlation of $r = .75$ and a SEE = 2.9 ml/kg^{-1}.

The Role of Exercise Prescription

Exercise prescription plays an important role for anyone starting or involved in an exercise program. Exercise prescription involves assigning workloads typically using values such as watts, mph, rpms, METs, etc., in order to maintain a certain heart rate. One common way to prescribe exercise is to assign METs. A MET is defined as the amount of oxygen consumed relative to body weight and time (O_2/kg/min) (5). This is especially important for cardiac/pulmonary patients because they typically work at specific heart rates. Heart rate is sensitive to changes in MET levels; therefore, METs need to be accurate on the console of the exercise equipment. Exercise professionals are able to comfortably assign MET levels so that patients know what intensities to select on the machine. It is important that patients work within their assigned MET levels/heart rates to achieve the maximal benefit of each rehabilitation session toward recovery.

Summary

There has been minimal research done on the NuStep 4000 Recumbent Stepper. The previous research at the University of Toledo incorporated healthy individuals and has shown that the NuStep overpredicts MET values by 11-32%. By using older (cardiac) subjects, the results found should be more accurate because the NuStep is used primarily by older individuals. The results of this study show an overprediction of MET values by 44-73%. In addition, a larger sample size (N =50) was used in this study as compared to Toledo (N = 20).

The results of this study compare favorably to other prediction equation studies that have been done. There is a low standard error of estimate, a good correlation, and appropriate coefficient of variation. The prediction equation developed should adequately predict MET values for an older cardiac population. Therefore, increasing the accuracy of an exercise prescription for these individuals.

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