UNIVERSITY OF WISCONSIN- LA CROSSE

Graduate Studies

EVALUATION OF ENERGY EXPENDITURE ON THE WOODWAY® CURVE TREADMILL

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science, Clinical Exercise Physiology

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EVALUATION OF ENERGY EXPENDITURE ON THE WOODWAY® CURVE TREADMILL

By Lance T. Maerz

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science, Clinical Exercise Physiology.

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ABSTRACT

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This study was designed to 1) compare the caloric expenditure values displayed on the Curve's console to directly measured values, and 2) if there was a significant difference between displayed and measured values, to develop a regression equation to more accurately predict energy expenditure on the Curve. Fifty-five volunteers (27 male and 28 female) walked or ran on the Curve treadmill at four different speeds (between 2-8 mph) for five minutes at each speed. The caloric expenditure values displayed on the Curve's console were recorded and compared to measured calories using a Jaeger Oxycon portable metabolic analyzer. Across the speeds tested, the Curve console systematically overestimated measured caloric expenditure by 67-117%. Based on these findings, the following regression equation was developed on the data from 40 of the subjects using stepwise multiple regression:

Predicted Kcals = -9.217 + (2.574 * speed) + (.051 * weight)

The new equation's R = .96, R^2 = .92, SEE = 1.06 kcal, and CV = 10.6%. The new equation was cross-validated using 15 additional subjects with a R of .97 and CV of 11%. Based on these findings, this new equation should provide a more accurate estimation of caloric expenditure when exercising on the Curve.

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INTRODUCTION

The Woodway® Curve treadmill (Woodway® USA Inc; Waukesha, WI) is a relatively new piece of aerobic exercise equipment. Developed in 2009, the non-motorized Curve has a distinct curved-shape track which is purported to recruit more of the user's posterior leg muscles, lower rear foot-strike pressures, and perhaps most interestingly, allows users to expend about 30% more calories than exercising on a standard motorized treadmill (Snyder, Myatt, Weiland, Bednarek, Reynolds 2010a, b, Snyder, Edlbeck, Myatt, Reynolds, 2011). Most pieces of exercise equipment have computerized displays that help guide the user's exercise program by displaying calories burned, time exercised, distance, and other data unique to the workout or equipment. Computerized displays are beneficial, in that they have been shown to promote better exercise adherence and lower dropout rates (Annesi, 2008). Additionally, Shakudo et al. (2011) found that subjects who received computerized feedback during an exercise program worked 26.5% harder during their exercise program.

The Curve has a computerized display that provides information on speed, distance, heart rate, time, and calories expended. For most people, exercise pulse rate and calories are important facts that guide their program. Pulse is measured using a wireless Polar heart rate monitor (Polar Electro, Kempele, Finland) and energy expenditure is derived using a pre-programmed energy expenditure prediction equation. The Curve uses the American College of Sports Medicine's (ACSM, 2010) running formula for predicting energy expenditure. That equation is

$$VO_2 = 3.5 + (0.2 \text{ x speed}) + (0.9 \text{ x speed x grade})$$

Speed is detected from the treadmill belt and the equation assumes a grade of 6%. The ACSM equation predicts oxygen consumption, which is converted to caloric expenditure assuming a constant body weight of 180lbs (81kg).

Users that are working toward a weight loss goal depend on displayed values of energy expenditure to know how many calories they have expended during their workout. To our knowledge, the accuracy of the Curve's console for energy expenditure (kcal) has not been evaluated. Anecdotal evidence from our exercise program participants suggests that the caloric expenditure values displayed on the Curve's console are overestimated. Additionally, previous research also suggests that the ACSM equation overpredicts energy expenditure (Brody, Darby, Browder, Palmer, and McDougle, 2002) (Ruiz, Sherman, 1999).

The purposes of the this study were to 1) compare the caloric expenditure values displayed on the Curve's console to directly measured values, and 2) if there was a significant difference between displayed and measured values, to develop a regression equation to more accurately predict energy expenditure on the Curve.

METHODS AND PROCEDURES

Subjects

Fifty-five volunteers between the ages of 18-28 years were subjects for this study. Every effort was made to recruit subjects of various ages, weights, and fitness levels in order to improve the generalizability of the results. The protocol was approved by the Institutional Review Board for the Protection of Human Subjects prior to data collection. Each subject completed the Physical Activity Readiness Questionnaire (PAR-Q) and provided written informed consent prior to being admitted into the study.

Testing Protocol

Subjects practiced on the Curve treadmill for at least two sessions for a minimum of 30 minutes prior to being tested. Based on each subject's fitness level, each was assigned four different speeds to walk or run. These speeds were between 2-8 miles per hour (mph). Each stage lasted five minutes. Subjects were not allowed to use handrail support as this could alter oxygen consumption (Berling, Foster, Gibson, Doberstein, Porcari, 2006). Speeds for each individual were chosen so that they did not exercise beyond 15 on the 6-20 Borg Scale of Rating of Perceived Exertion (RPE) (Borg, 1973). Throughout the testing, heart rate (HR) was monitored each minute with a Polar HR monitor. Oxygen consumption and caloric expenditure were measured continuously with a Jaeger Oxycon portable metabolic analyzer (CareFusion Corporation, San Diego, California). The caloric expenditure values displayed on the Curve's console were recorded and compared to measured calories using the Oxycon portable metabolic analyzer.

Statistical Analysis

A regression equation to predict caloric expenditure was developed based on the data from 40 subjects using IBM Statistical Package for the Social Science (SPSS) Version 20.0 software package (IBM, Armonk, New York). Age, height, weight, gender, and speed were used as independent variables to develop the equation. Once the prediction equation was developed, it was cross-validated by inputting data from the remaining 15 subjects. Predicted and directly measured caloric values were compared using paired t-tests and regression analysis.

RESULTS

Descriptive characteristics of the 40 subjects in the initial portion of the study are presented in Table 1.

Table 1. Descriptive characteristics of subjects in the validation group (N=40)

	Male (n= 19)	Female (n= 21)
Age (years)	21.5±1.93	21.4±2.04
Height (in)	71.3±2.61	65.3±3.08
Weight (lbs)	176.0±20.88	133.1±15.03

Values represent mean ± standard deviation.

The first thing that was done was to compare the caloric expenditure (kcal/min) from the metabolic cart to the Kcal values obtained from the Curve console. Those results are presented in Table 2. Across the speeds tested, the Curve console systematically overestimated measured Kcals by 67-117%. This relationship is graphically presented in Figure 1.

Table 2. Comparison of caloric expenditure measured using the metabolic analyzer compared to Kcal values obtained from the Curve console

Speed (mph)	Subjects (n)	Console Kcals	Measured Kcals	Difference
2.2±.03	2	10.2±.04	6.1±1.58*	67%
2.6±.07	4	11.9±.51	5.8±2.21*	105%
3.1±.12	20	13.9±.55	6.4±1.46*	117%
3.6±.10	27	16.2±.43	7.5±1.56*	116%
4.0±.11	25	18.3±.54	8.6±1.65*	113%
4.5±.13	21	20.2±.60	9.6±1.80*	110%
4.9±.14	20	22.2±.71	11.6±1.76 *	91%
5.5±.11	11	24.8±.51	12.5±1.60*	98%
5.9±.15	16	26.5±1.26	14.7±2.28*	80%
6.5±.20	6	28.8±1.80	15.6±2.98*	85%
6.9±.08	2	31.1±.42	18.0±.23*	73%
7.4±.12	3	33.5±.70	17.4±1.33*	93%
7.9±0.00	1	35.6±0.00	17.9±0.00*	99%

Values represent mean ± standard deviation.
*Significantly different than Console Kcals ($p<.05$)

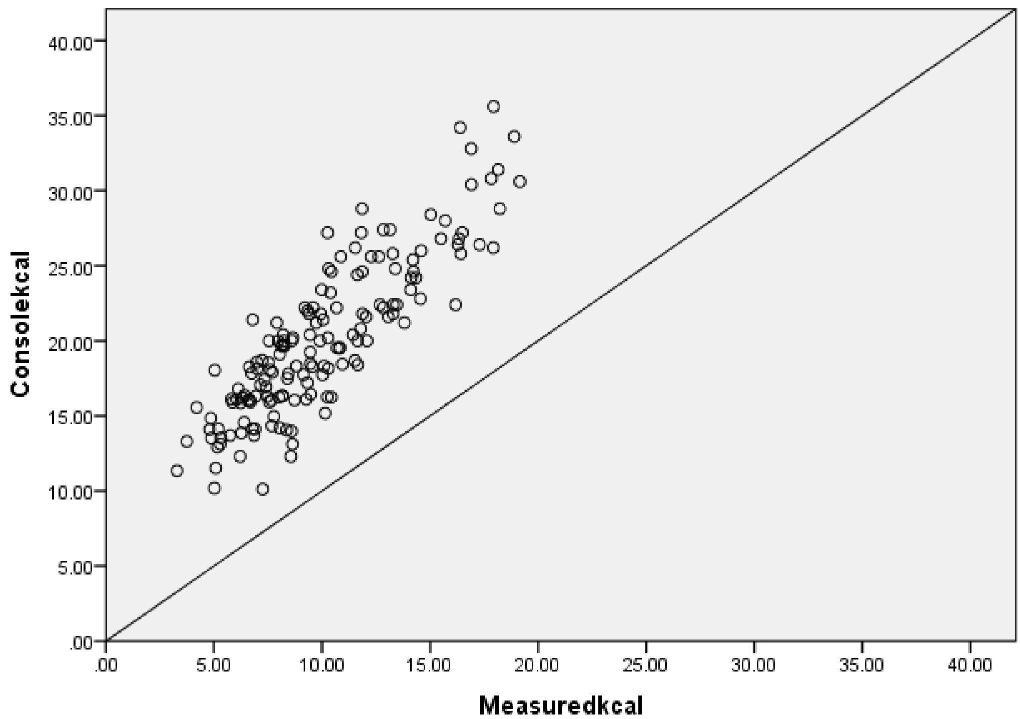

Figure 1. Comparison of measured caloric expenditure (kcal/min) versus values from the Curve console

As a result of the data presented in Table 2 and Figure 1, it was decided that a new equation needed to be developed to predict Kcals on the Curve. Because the relationship between speed and kcal was linear (Figure 2), a linear regression equation could be developed.

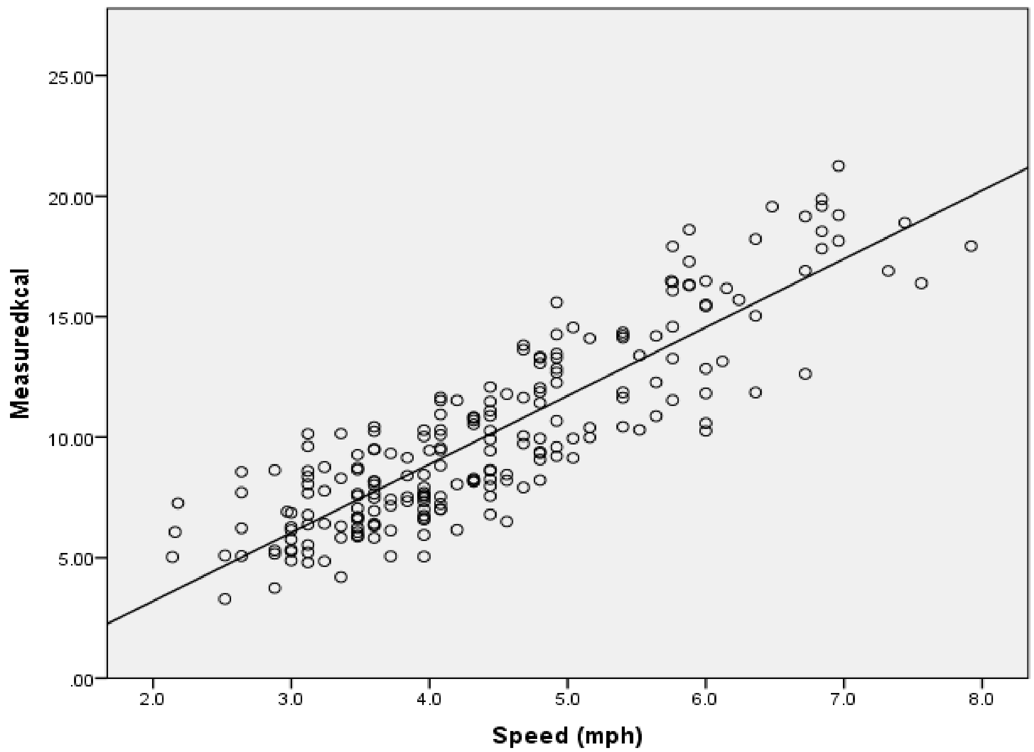

Figure 2.Relationship of measured caloric expenditure (kcal/min) and speed (mph)

Regression analysis was calculated using stepwise regression. Independent variables entered into the regression model to predict caloric expenditure (kcals/min) were speed (mph), age (yrs), height (in), weight (lbs), and gender (0=female, 1=male). The first equation developed used speed in the equation. That equation was:

Predicted Kcals = -2.484 + (2.840 * speed)

R=.87, R^2=.76, SEE=1.92 kcal, CV= 19.2%

The next step added weight into the equation, and was:

Predicted Kcals = -9.217 + (2.574 * speed) + (.051 * weight)

R=.96, R^2=.92, SEE=1.06 kcal, CV= 10.6%

The third and final step added gender information into the equation. That equation was:

Predicted Kcals = -7.326 + (2.5484 * speed) + (0.33 * weight) + (1.671 * gender)

R=.97, R^2=.94, SEE=.98 kcal, CV= 9.8%

Because the third step of the equation only explained an additional 2% of the variance (R^2 changed from .92 to .94 from step 2 to step 3) and SEE only improved by .08 kcal (SEE changed from 1.06 to .98 from step 2 to step 3). It was decided to use the equation from step 2.

The relationship between measured Kcals and predicted Kcals using the equation developed from step 2 is presented in Figure 3.

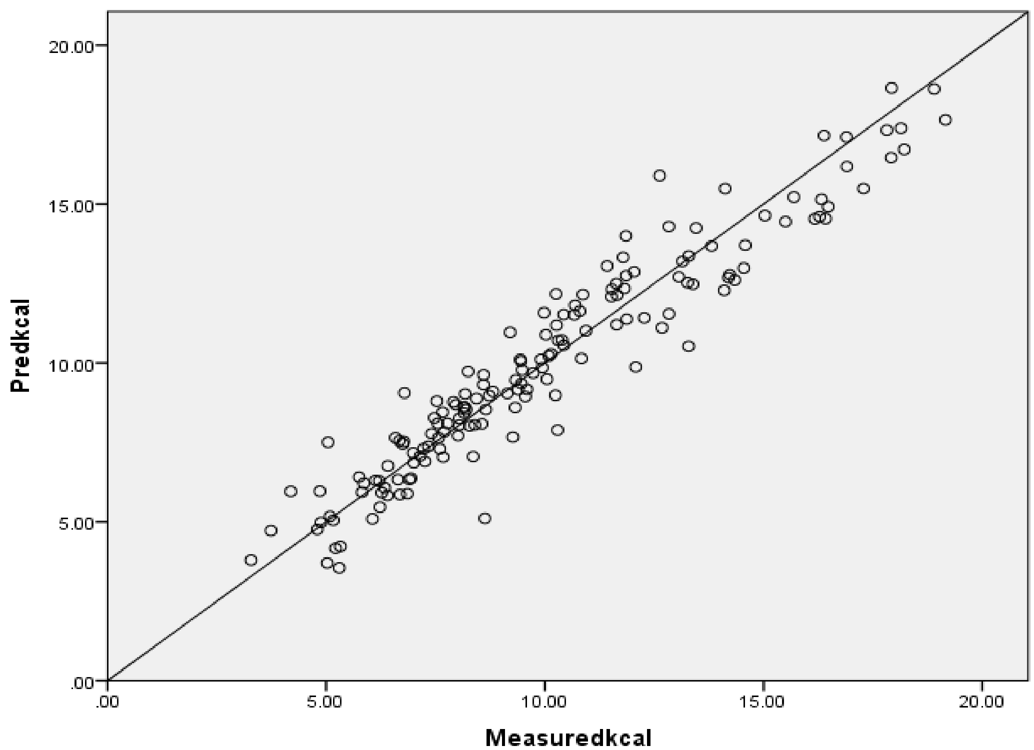

Figure 3. The relationship of measured caloric expenditure (kcal/min) and predicted kcals using the developed equation

One way to look at the accuracy of a new equation is to look at the difference between the measured values and predicted values for each subject (residuals). Residuals should be clustered uniformly around 0 for a good equation. These values are presented in Figure 4. Another way to determine the accuracy of a prediction equation is to calculate standardized residuals. This is done by taking each residual value and turning it into a positive number. By taking the mean of standardized residuals, it can be determined, on average, how accurate the equation is for an individual. These values are presented in Table 3. It can be seen that on average, predicted values were within .81 kcal/min, or +/- 8% of the measured value (range of 2-14%).

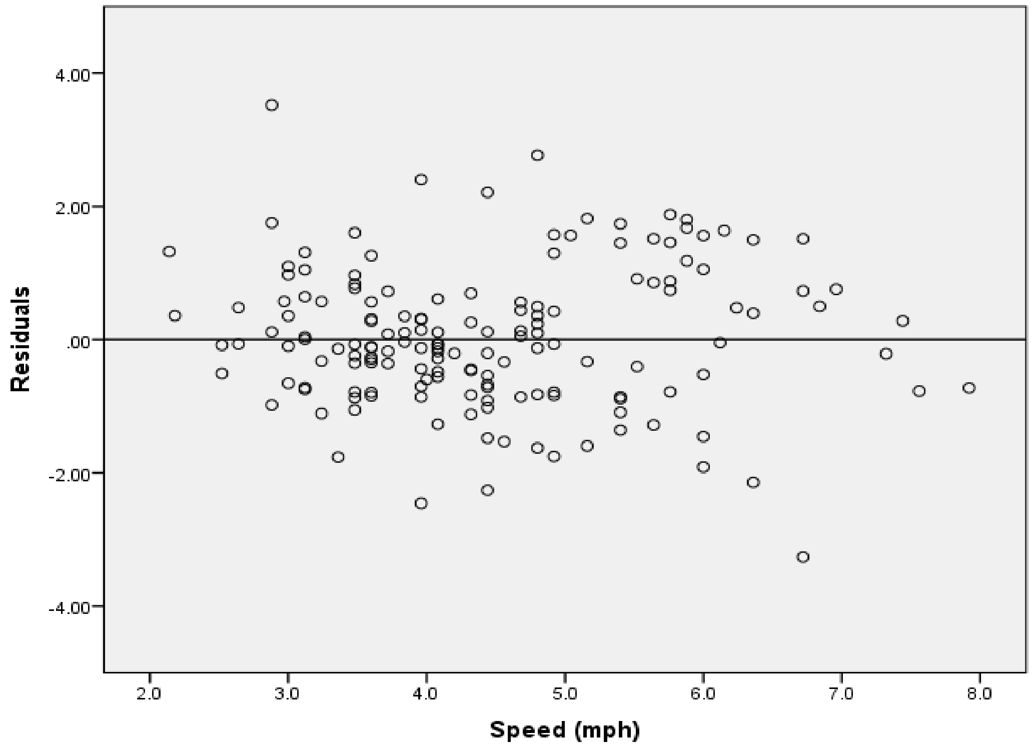

Figure 4. Plot of the residuals (the difference between the measured caloric expenditure values (kcal/min) and the predicted kcal values from the developed equation)

Table 3. Standardized residual values represented as a percentage of the measured Kcal value at each stage

Speed (mph)	Subjects (n)	Measured Kcals	Standardized Residuals	% of Mean
2.2±.03	2	6.1±1.58	.84	14%
2.6±.07	4	5.8±2.21	.29	5%
3.1±.12	20	6.4±1.46	.83	13%
3.6±.10	27	7.5±1.56	.59	8%
4.0±.11	25	8.6±1.65	.53	6%
4.5±.13	21	9.6±1.80	.80	8%
4.9±.14	20	11.6±1.76	.96	8%
5.5±.11	11	12.5±1.60	1.12	9%
5.9±.15	16	14.7±2.28	1.19	8%
6.5±.20	6	15.6±2.98	1.59	10%
6.9±.08	2	18.0±.23	.63	4%
7.4±.12	3	17.4±1.33	.42	2%
7.9±0.00	1	17.9±0.00	.72	4%

Values represent mean ± standard deviation.

Cross-validation

In order to cross-validate the equation developed to predict Kcals, 15 individuals with similar demographic characteristics to the original sample were tested and their data were inserted into the developed regression equation. Descriptive characteristics of the cross-validation group are presented in Table 4.

Table 4. Descriptive characteristics of subjects in the cross-validation group (N=15)

	Male (n= 8)	Female (n= 7)
Age (years)	21.6±0.92	21.6±1.27
Height (in)	70.7±3.05	66.1±2.14
Weight (lbs)	188.5±21.14	138.5±15.46

Values represent mean ± standard deviation.

A plot of the measured Kcal values versus the predicted Kcal values in the cross-validation sample is presented in Figure 5. The relationship between measured and predicted Kcals was R=.97, R^2= .94, SEE of 1.15 kcals, and CV=11%. The standardized residuals for measured Kcals at each stage are presented in Table 5. On average, predicted values were within 1.11kcal/min, or +/- 10% of the measured value (range of 6-15%).

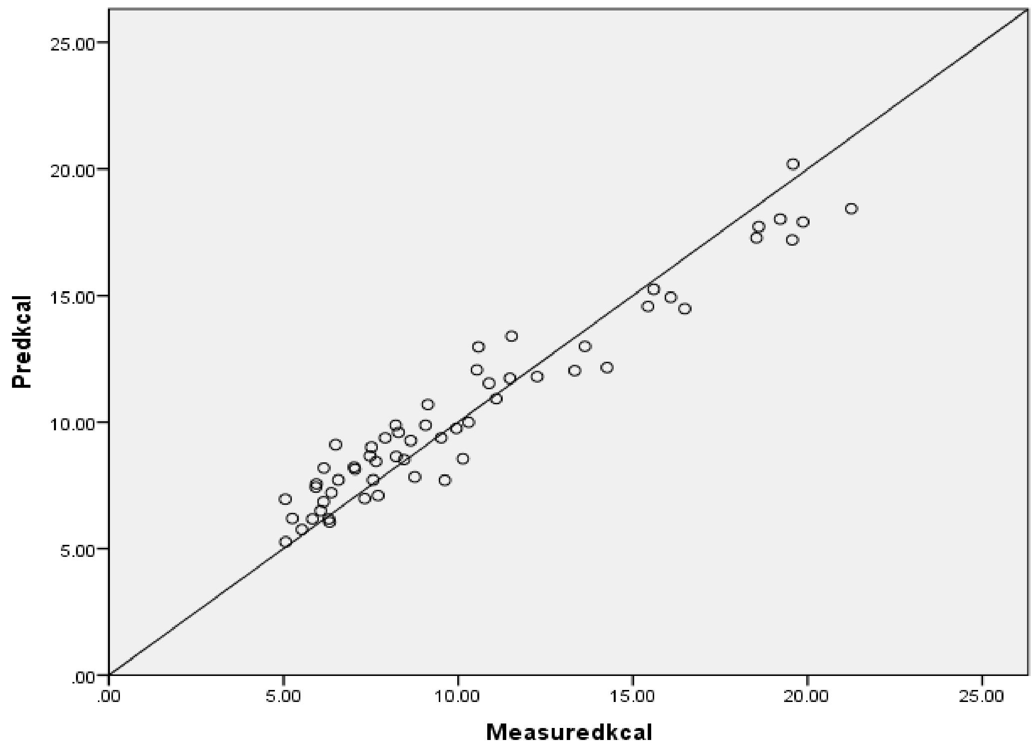

Figure 5. The relationship between measured caloric expenditure (kcal/min) and predicted kcal in the cross-validation group

Table 5. Standardized residual values represented as a percentage of the measured Kcal value at each stage

Speed (mph)	Subjects (n)	Measured Kcals	Standardized Residuals	% of Mean
2.2±0.00	1	6.1±0.00	.44	7%
2.6±0.00	2	6.4±1.87	.41	6%
3.1±.08	7	7.4±2.04	1.02	14%
3.5±.12	10	7.1±1.43	.81	11%
4.0±.11	11	7.8±1.70	1.16	15%
4.5±.12	8	10.1±2.25	.79	8%
4.9±.10	8	11.5±2.75	1.06	9%
5.9±.12	5	15.4±2.96	1.46	10%
6.5±0.00	1	19.7±0.00	2.36	12%
6.9±.07	5	19.7±1.00	1.57	8%

Values represent mean ± standard deviation.

DISCUSSION

The purpose of this study was to compare the caloric expenditure values displayed on the Curve's console to directly measured values and if there was a difference, to develop a regression equation to more accurately predict energy expenditure on the Curve. Analysis of the measured energy cost and the predicted energy cost (obtained from the Curve console) determined that the console values significantly overpredicted measured values by 67-117%.

The Curve's console uses the American College of Sports Medicine's running formula for predicting energy expenditure. To solve the equation, speed is detected from the treadmill belt and grade is assumed to be 6%. The ACSM equation actually predicts oxygen consumption, which is converted to caloric expenditure assuming a constant body weight of 180lbs (81kg). Though a discrepancy between measured and console-displayed values was expected, as not all users are 180lbs, there appeared to be no relationship between body weight and the difference of measured versus displayed caloric expenditure (Figure 6).

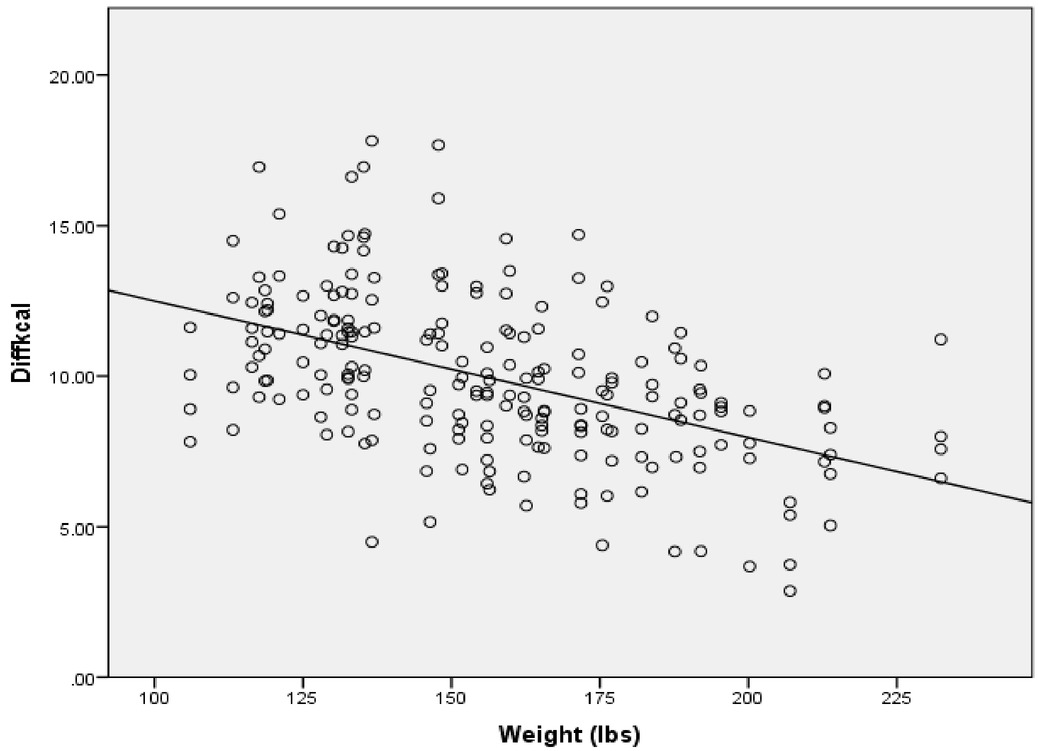

Figure 6. Relationship between speed and the difference between measured and console-displayed caloric expenditure

However, as the relationship between speed and caloric expenditure was linear, a linear equation could be developed to more accurately predict energy expenditure on the Curve. It was decided to use the equation that only used speed and weight, as the addition of gender into the equation only explained an additional 2% of the variance (R^2 changed from .92 to .94) and SEE only improved by .08 kcal (SEE changed from 1.06 to .98). This means that when a user exercises on the Curve, he or she will only need to input their weight into the software. This is also beneficial to Woodway® as it requires one less component to be incorporated into their console's software.

Analysis of the equation developed to predict caloric expenditure (kcal/min) found an excellent correlation between measured and predicted caloric expenditure values (R= .96), with a standard error of the estimate that averaged 10.6% of the mean.

The SEE helps to describe the predictive accuracy of a prediction equation in that 95% of predicted values will fall between +/-2 SEE of the mean. However, this value does not give a good representation of how accurate predicted values are for an individual, thus standardized residuals were developed. The average standardized residual value was .81 kcal/min, or +/- 8% of actual values. This means that if an individual were to exercise on the Curve, the value for caloric expenditure displayed on the console can be expected to be within .81kcal/min, or +/- 8% of the actual values. For instance, if someone was expending 6 kcal/min on the Curve, the value displayed on the console would be expected to be within .81 kcals of the “real” value. This relationship was constant across all of the workloads tested.

Cross-validation of the equation in 15 other subjects indicated that the prediction equation worked very well. Correlation between measured and predicted values were R=.97 and CV values averaged 11% of the mean.

These findings are particularly useful for users that are exercising as part of a weight management program. Many individuals guide their exercise program by monitoring caloric expenditure which they obtain from the console of exercise equipment. Individuals that exercise on the curve actually expend less than half of the calories displayed on the console. For instance, a 150lb person walking on the Curve at a speed of 4.0 mph for 30 minutes would expend about 319 kcals (-9.217 + (2.574 * 4.0) + (0.51 * 150)). However, the console would display that this same user had expended 550 calories, an overprediction of 231 kcals. Additionally, if this user guided their workout by monitoring caloric expenditure and wished to expend 500 kcals, using the console’s monitor, this user’s 4 mph workout would need to last roughly 27 minutes; however, the user would actually have to walk for 47 minutes (20 minutes longer) according to the findings of this study. This has tremendous implications for those individuals who are working toward a weight loss goal or simply toward maintaining their current weight.

SUMMARY

The current console on the Curve treadmill significantly over-predicts caloric expenditure during exercise. The equation that was developed to predict caloric expenditure has excellent predictive accuracy based upon all of the statistical analyses conducted. While the absolute difference between measured and predicted caloric expenditure values varies slightly across the speeds tested (typical speeds used by subjects similar to those used in current study), the accuracy of the prediction equation can be expected to average +/- 8% of the actual value.

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Snyder, A. C., Myatt, C., Weiland, N., Bednarek, J., & Reynolds, K. (2010) B. *Energy expenditure while running on a non-motorized treadmill*. Informally published manuscript, Human Movement

Woodway® Curve Treadmill.W229 N591 Foster Court, Waukesha, Wisconsin 53186.

APPENDIX A

PAR-Q

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

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 and 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 any other reason 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.

APPENDIX B

INFORMED CONSENT

INFORMED CONSENT

EVALUATION, DEVELOMENT, AND CROSS VALIDATION OF A REGRESSION EQUATION TO PREDICT ENERGY EXPENDITURE ON WOODWAY® CURVE TREADMILL

I, ____, volunteer to participate in a research study being conducted at the University of Wisconsin-La Crosse.

Purpose and Procedures

- The purposes of this study are to 1) compare the caloric expenditure values displayed on the Curve's console to directly measured values and 2) develop a regression equation to more accurately predict energy expenditure on the Curve.
- My participation will involve four, 5-minute exercise bouts of walking or running at varying speeds on the Curve treadmill. The testing will be terminated when I achieve a subjective effort of 15 on the 6-20 Borg Scale. This corresponds to exercise which is subjectively defined as "hard," but not maximal.
- During the testing, I will have my heart rate measured with a heart rate monitor, which consists of a chest strap and wrist watch type receiver. I will also breathe into a scuba-type mouth piece so that my expired air can be collected and analyzed.
- My participation in this study will consist of one session lasting approximately 45 minutes.
- Testing will take place in the Recreational Eagle Center on the University of Wisconsin-La Crosse campus.
- Research assistants will be conducting the research under the direction of Dr. John P. Porcari, a Professor in the Department of Exercise and Sport Science.

Potential Risks

- Fatigue, leg tiredness, and shortness of breath, similar to participating in any sort of submaximal exercise are possible as a result of this study.
- Dangerous irregularities in heart rhythm, heart attack, and stroke are always a possibility with exercise. However, the risk of serious or life-threatening complication is very low (<1/10,000 tests) in subjects who are appropriately screened and who are accustomed to regular exercise.
- The test will be stopped immediately upon the development of any complications.
- Individuals conducting the tests are trained in CPR and Advanced Cardiac Life Support.

Benefits of Participation

- By volunteering for this study I will benefit myself by understanding more about my physical fitness and responses to exercise.
- Based on the results of this study, we will be able to determine if the calorie tracker on the Curve's display is accurate and if it is not, we will develop an equation to be used that is more accurate. This will be of benefit to users of the Curve treadmill to help guide their exercise program.

Rights and Confidentiality

- My participation is voluntary.
- I may choose to discontinue my involvement in the study at any time without penalty.
- The results of this study have the potential of being published or presented at scientific meetings, but my personal information will be kept confidential.

I have read the information provided on this consent form. I have been informed of the purpose of this test, the procedures, and expectations of myself as well as the testers, and of the potential risks and benefits that may be associated with volunteering for this study. I have asked any and all questions that concerned me and received clear answers so as to fully understand all aspects of this study.

If I have any other questions that arise I may feel free to contact Lance Maerz, the principal investigator, at (608) 628-2526 or the study advisor, Dr. John Porcari, a Professor in the Department of Exercise and Sport Science, UW-L (608) 785- 8684. Questions in regards to the protection of human subjects may be addressed to the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects at (608) 785-8124.

Subject ________________________________ Date_____________________________

Investigator_____________________________ Date_____________________________

APPENDIX C

RATING OF PERCEIVED EXERTION

6	**No exertion at all**
7	**Extremely light**
8	
9	**Very light**
10	
11	**Light**
12	
13	**Somewhat hard**
14	
15	**Hard (heavy)**
16	
17	**Very hard**
18	
19	**Extremely hard**
20	**Maximal exertion**

APPENDIX D

REVIEW OF LITERATURE

Review of the Literature

Introduction

The Woodway® Curve Treadmill is a relatively new piece of aerobic exercise equipment that has a distinct curved-shape track. The treadmill is non-motorized, so there are no external electrical costs to operate the machine. The total-manual operation provides a dynamic training tool that allows an athlete to instantly adjust speed with a few accelerated steps. Additionally, users are not subject to speed up time as they control speed. This treadmill also has an advantage over other treadmills by offering no top speed, so the opportunities on this treadmill are limitless.

Previous Research on The Curve Treadmill

The University of Wisconsin- Milwaukee has completed several studies on the Curve to evaluate and develop claims associated with this treadmill. The first two studies (2010_A, 2010_B) on the Curve were in regards to energy expenditure while walking and running on the non-motorized Curve Treadmill compared to a motorized treadmill (Snyder, Myatt, Weiland, Bednarek, Reynolds, 2010).

In the study that compared walking on the non-motorized Curve to a motorized treadmill, twelve moderately-active college-aged participants (7 males aged 22.7 $\pm$ 2.4, 5 females aged 22.4 $\pm$ 1.7) walked for three stages for six minutes each at speeds of 1.5, 2.5 and 3.5 miles per hour on each of the treadmills with the order being randomized. Oxygen uptake was measured using a mobile gas analyzer system (MetaMax 3B, Cortex Biophysiks GmbH, Germany) and heart rate was monitored using a Polar heart rate strap (Polar Electro, Finland). It was found that oxygen uptake variables and heart rate were all significantly greater for the Curve Treadmill than for the motorized treadmill(Snyder, Myatt, Weiland, Bednarek, Reynolds, 2010).

The next study that the University of Wisconsin- Milwaukee (Snyder, Myatt, Weiland, Bednarek, Reynolds, 2010) completed was comparing running on the non-motorized Curve to a motorized treadmill. Nine college-aged experienced runners participated in this study. Participants performed an incremental exercise test on a motorized treadmill to determine lactate threshold and maximal values. The subjects then performed four randomized exercise bouts of six minutes at 50%LT, 65%LT, 80%LT and LT running speeds on both the non-motorized Curve treadmill and the motorized treadmill. Heart rate was monitored using a Polar heart rate strap (Polar Electro, Finland) along with blood lactate, oxygen consumption, Rating of Perceived Exertion (RPE) and muscle oxygen saturation levels. It was found that all oxygen uptake variables, heart rate, blood lactate and RPE values were significantly greater for the Curve Treadmill than for the motorized treadmill.

The last study that the University of Wisconsin- Milwaukee (Snyder, Edlbeck, Myatt, Reynolds, 2011) completed on the Curve was on the foot pressures of walking, jogging and running on the non-motorized Curve compared to a motorized treadmill. Eleven moderately-active college-aged participants (6 males aged 23.2 $\pm$ 1.5, 5 females aged 25.2$\pm$ 2.6) walked at 1.34m/s, jogged at 2.23m/s and ran at 3.13m/s on three different randomized treadmills: two motorized, a belt driven and a slatted, and the non-motorized Curve Treadmill. Foot pressures were measured using Tekscan shoe inserts (Tekscan, South Boston, MA) and were recorded for 10 seconds after performing the speed for approximately one minute at the prescribed speed. It was found that fore-foot pressures were not different between the three treadmills for the three speeds assessed, however rear foot pressures were significantly less on the Curve Treadmill than for the two motorized treadmills at all three speeds.

Factors Affecting Prediction Equations

Several factors influence the accuracy of regression equations. Age, fitness level, gender, weight, familiarity with equipment, and health conditions of the participants that help create the equation are a few of the dozens of factors that can influence the accuracy of these equations. Because of these factors, a regression equation will be most accurate for a target population when the equation is developed using participants of that target population. Rateike (2000) used fifty male and female volunteers (mean age = 63.6 $\pm$ 9.61 years) with known cardiac disease or significant risk factors for CAD for his study on the evaluation of MET values on the NuStep 4000 recumbent stepper. He used this population as the NuStep is predominantly used by this age group. Additionally, Rateike used this population as one of his purposes of his study was to develop a more accurate MET prediction equation so that cardiac rehabilitation professionals could rely on the displayed MET levels when prescribing exercise. After finding that the NuStep overpredicted the measured MET values by 44-73%, Rateike developed a regression equation that more accurately predicted MET values (R =.92, R^2 = .84, SEE = .62 METS). In order to be more accurate, a good correlation (Pearson's r) and low standard error of estimate (SEE) are needed. Once Rateike had created his regression equation to predict MET values on the NuStep 4000, Paschke (2000) cross validated the regression equation by using 18 patients with either cardiac or pulmonary disease (mean age = 69.1

years). Paschke used a similarly aged population as Rateike to validate accuracy as it is generally accepted that cardiac patients have lower MET values at any given workload compared to healthy adults. Thus, it would not have been appropriate for Paschke to cross validate Rateike's regression equation on college-aged experienced runners as the values would not have been congruent.

Since the population that uses the Curve treadmill varies in age, gender, race, and fitness level, volunteers for this study will have to be fitting of these categories- of varying age, gender, race, fitness level, etc.- so that the prediction equation can be generalizable. The larger population will also increase generalizability of the equation to accurately predict energy expenditure on the Curve Treadmill.

Prediction Equations

Prediction equations, by nature, are supposed to be as accurate as possible, but it is impossible to create a prediction equation that is 100% accurate for every person that uses them, as there are person-to-person differences from fitness level and efficiency to age, gender and weight. The Curve Treadmill uses the American College of Sports Medicine's (ACSM, 2010) running formula for predicting energy expenditure: VO_2 = 3.5 + (0.2 x speed) + (0.9 x speed x grade) with 180lbs (81.6kg) and 6% incline inputted for weight and grade respectively. In 2002, Brody, Darby, Browder, Palmer, and McDougle examined whether oxygen consumption (VO_2) estimated from the ACSM metabolic equations was comparable to measured VO_2 achieved by cardiac rehabilitation patients during three exercises- treadmill walking, leg cycling and arm cycling. 20 participants (aged 54 $\pm$ 10 years) were randomly assigned to five minutes of exercise on three modes of exercise- arm ergometer, cycle ergometer, and treadmill. Metabolic data was collected using a portable gas analyzer (TEEM 100) from the last 2 min of exercise on each mode. In conclusion, the ACSM's metabolic prediction calculations for treadmill, arm ergometer, and cycle ergometer overestimated oxygen consumption by 13%, 34%, and 19% respectively.

Benefits of Computerized Display

It is relatively easy work to create prediction equations, but the question remains whether they are beneficial to the user or not. Annesi (1998) studied the effects of computer feedback on adherence to exercise. He took 164 participants (control group n = 71; M age = 37.4 $\pm$ 10.1, treatment group n = 93; M age = 40.4 $\pm$ 10.7) and provided personalized exercise prescriptions. The treatment group received feedback on form, repetitions, work completed and goal setting via a computerized display. Participants in the treatment group had 38% increased attendance, 45% higher adherence, and 46% less dropout as compared to the control group which did not receive feedback of any kind. Similarly, Shakudo et al. (2011) studied whether providing participants in an exercise program with regular feedback on their exercise progress affected their adherence to the program regimen. A total of 105 participants aged 25-68 years with borderline hypertension and a body mass index $\geq$ 25.0 participated in the study by being randomized to complete 12 weeks of regular aerobic exercise in one of three interventions. The Group A (n = 37) was provided with both feedback information on their exercise progress and a health letter, while the Group B (n = 37) was provided with the health letter only and the Group C (n = 31) was the control group, which was not provided anything. When measuring exercise performance, in the form of percent achievement of target exercise level during the 12-week period, Group A had 26.5%, Group B had 22.9%, and Group C had 17.4%. This data suggests that subjects who received regular feedback during the exercise program tended to have higher exercise performance. This research combined with the $1.15 billion treadmill market (U.S. Department of Labor, 2008) and 4.6 million Americans above the age of 16 (Sporting Goods Manufacturer's Association, 2012) that use treadmills, stresses the magnitude of people that depend on the accuracy of these displays as their form of feedback on their workouts.

Accuracy of Oxycon Metabolic Analyzer

Reliable ways to measure gas exchange are vital for human performance studies such as this. The classical Douglas bag method (Douglas, 1911) has been well tested and is considered outstanding in accuracy (Astrand and Rodahl, 1986). However, the bags restrict freedom of movement which has placed a demand upon the development of portable metabolic measurement systems. Rosdahl, Gullstrand, Salier-Eriksson, Johnsson, and Schantz (2010) compared the Oxycon Mobile metabolic analyzer (Carefusion Germany, 234 GmbH, Hoechberg, Germany) to the Douglas bag method by having 58 subjects perform numerous sub-maximals and maximal exercise sessions on a cycle ergometer. VO_2 was measured without any statistical significance between the Douglas bag method and the Oxycon Mobile within a wide measurement range (1-5.5 L/min^{-1}) while VCO_2 was overestimated by 3-7%. V_E was also accurate at submaximal work rates but underestimated maximal V_E by 4-8%. As the present study will use only sub-maximal work rates, the Oxycon Mobile will be an accurate for measuring oxygen consumption.

Summary

Minimal research has been done on the Curve Treadmill's prediction equation's accuracy of predicting energy expenditure. Anecdotal evidence suggests that oxygen consumption displayed on the Curve's console in the caloric form is fallaciously high.

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