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Accuracy of Calories Expended on 7 Commercially Available Exercise Machines: Validation for use a Cardio Alternatives for the Navy Physical Readiness Test

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Introduction:

The U. S. Navy uses commercially available cardiovascular exercise equipment as testing modality alternatives to the 1.5 mile physical readiness test (PRT) of cardiovascular fitness (1). Previous work by the Naval Health Research Center established scoring norms for both elliptical trainers and cycle ergometers, based on a regression analysis of maximum calories expended in 12 minutes on these devices and maximum effort 1.5 mile run times (2). These standards are published in the Chief of Naval Operations instruction 6110.1 series (1). In order to approve new cardiovascular exercise equipment for use during the PRT, the Navy tests the devices using human subjects by comparing calories indicated on the device to calories measured with a metabolic cart. The Navy uses the following criteria to determine the suitability of a device for use as a cardiovascular exercise mode alternative:

> "A stationary cycle [elliptical trainer] will be deemed suitably accurate if the 95% confidence interval for the slope of the regression of measured calories on device versus indicated calories includes the value 1."

In this case, the Navy would consider the slopes to be equivalent and would correct the indicated calories by employing an offset, which is the average difference between calories indicated and calories measured. This study reports the results of the testing of 7 devices: Precor EFX Elliptical, Precor UBK800 Bike, Octane 4700 Elliptical, Star Track E-UB Bike, Star Track E-TBT Elliptical, Precor AMT Elliptical, and the Octane 370 Elliptical.

Materials and Methods:

52 Research subjects were recruited to test the 7 devices. Table 1.0 details the subject population characteristics. After obtaining informed consent, subjects were briefed on the purpose of the study and the procedures. Subjects completed a PARQ prior to testing and any "yes" answers required medical clearance prior to participation. The 7 devices were tested in random order, with subjects performing at 3 different intensities on each device (see table 2.0) for a total duration of 12 minutes at each intensity. Subjects were given a device intensity level setting and cadence range to choose from for each device and were free to choose within those ranges (see table 2.0). Subjects were given the choice to test all 3 intensities during the same session, or 1-2 intensity levels per session. Subjects completed a maximum of one testing session per day, with time between testing sessions varying due to subject availability. Calorie expenditure was measured using a ParvoMedics 2400 True One metabolic cart. Prior to testing the metabolic cart was calibrated according to the manufacturer's specifications. The last 6 minutes of each testing intensity stage was used to compare calories expended on the device to calories measured on the metabolic cart. This was done to ensure that subjects had reached steady state VO2 and heart rate. Measured energy expenditure was calculated from VO2 data

using the equation: VO_2* [3.816 + (1.231*RER)] (3). The following analyses were conducted to investigate the accuracy of calorie counters on the seven devices as compared with calories measured via metabolic cart. A six minute indicated kilocalorie expenditure was used (minute 12 kcal – minute 6 kcal) and was converted to a minute energy expenditure rate (kcal * min^{-1}) to correspond with a previous Naval Health Research Center study (2). Linear regressions were run with calories counted via metabolic cart (kcal * min^{-1}) regressed on calories indicated by the equipment (kcal * min^{-1}) for each device.

Table 1.0 Subject Characteristics

			Standard
Females	N=15	**Mean**	**Deviation**
	Age	33.0	7.4
	Height	66.0	2.0
	Weight	155.2	18.4
Males	N=37		
	Age	39.0	7.4
	Height	70.1	2.4
	Weight	183.0	17.3

Table 2.0: Machine Measured Cadence and Intensity Settings For Work Bouts

Star Track E-UBK

		Low	Medium	High
Cadence		90-100	90-100	80-90
Work Level	♂	11-12	13-14	15-16
	♀	5-7	8-10	11-13

Precor UBK800

		Low	Medium	High
Cadence		90-100	90-100	80-90
Work Level	♂	2-3	6-8	12-14
	♀	1-2	5-7	9-11

Octane 4700 & 370

		Low	Medium	High
Cadence	♂	65-75	65-75	60-70
Work Level	♀	3-4	7-9	11-12

Precor 556I

		Low	Medium	High
Cadence	♂	130-150	130-150	130-140
Work Level	♀	4-6	9-10	12-14

Precor AMT

		Low	Medium	High
Cadence		110-125	100-115	95-110
Work Level	♂	3-4	8-9	13-14
	♀	1-2	5-7	10-11

Star Track E-TBT

		Low	Medium	High
Cadence		65-75	65-75	60-70
Work Level	♂	5-8	10-13	15-18
	♀	4-6	8-11	13-15

Results:

Two of the devices tested met the Navy's acceptance criteria for the slope, the Octane 370 Elliptical and the Octane 4700 Elliptical (see Table 3.0). The computed offset values for the approved devices were: 7.4 Kcal for the Octane 4700, and 21.4 Kcal for the Octane 370 (average difference from metabolic cart measured calories). These values would be added to the indicated machine calories to get a corrected value. Offset values were computed only for those devices that met the Navy slope approval criteria.

Table 3.0: Regression of Calories Indicated VS Calories Measured

Equipment	Intercept (95% CI)	Slope (95% CI)	R	SEE
Precor EFX Elliptical	-9.785 (-15.301, -4.270)	1.695 (1.212, 2.178)	.944	.647
Precor UBK800 Bike	3.217 (1.431, 5.003)	.576 (.401, .752)	.883	.606
Precor AMT Elliptical	-9.563 (-14.317, -4.808)	1.825 (1.431, 2.219)	.951	.808
*Ocatne 370 Elliptical	-1.086 (-4.236, 2.064)	1.286 (.978, 1.593)	.966	.595
*Octane 4700 Elliptical	2.201 (-.303, 4.705)	.862 (.636, 1.088)	.923	.813
Star Trac E-UB Bike	1.197 (-1.977, 4.370)	.588 (.370, .806)	.910	1.164
Star Trac E-TBT	2.750 (-.200, 5.700)	.659 (.416, .902)	.899	.970

Note: CI = confidence interval

Figure 2.0 shows the computed trend lines for each device, plotted against the line of identity (calories indicated = calories measured). The approved devices are depicted with red lines. The length of the lines indicates the data spread (highest and lowest value).

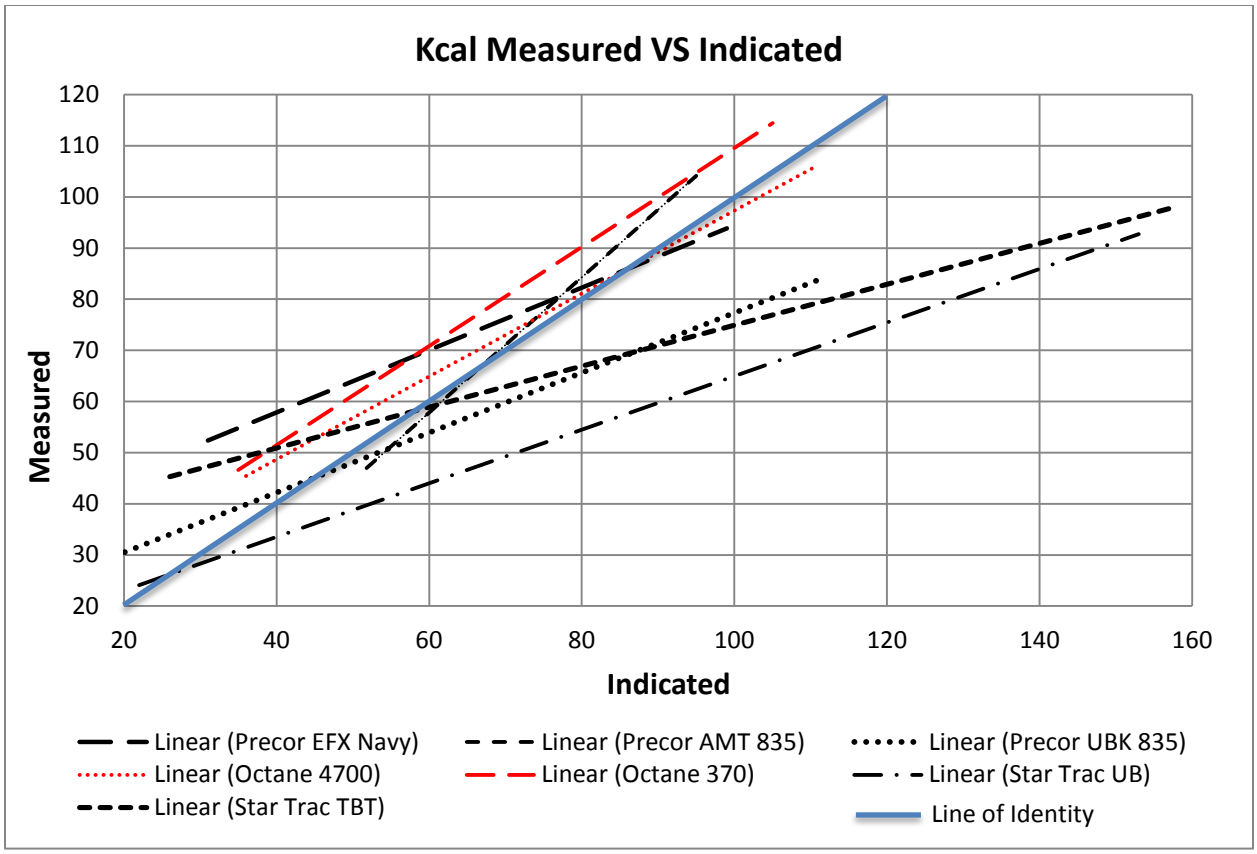

Figure 1: Calories Measured VS Indicated Compared to the Line of Identity

Table 4.0 shows the Borg rating of perceived exertion (4) for each device and stage, as well as the average heart rate for the last 6 minutes of each stage. The RPE and heart rate spread was similar for most devices except for the Precor AMT 835.

Table 4.0: Heart Rate and Borg Rating of Perceived Exertion

		RPE		Heart Rate		RPE	HR
		Mean	SD	Mean	SD	Spread	Spread
	High	13.0	0.8	146.2	16.6		
Precor EFX	Med	11.2	1.0	126.9	15.0	4.6	35.2
	Low	8.4	1.5	111.0	13.3		
	High	13.3	2.3	147.4	17.8		
Precor AMT 835	Med	11.9	1.8	144.8	18.7	**2.8**	**4.2**
	Low	10.6	1.8	143.2	20.0		
	High	14.1	2.1	149.8	18.4		
Precor UBK 800	Med	11.1	1.9	131.2	19.9	5.3	35.9
	Low	8.8	1.5	113.9	16.8		
	High	14.2	4.2	161.4	20.7		
Octane 4700	Med	11.0	3.3	132.8	19.3	5.4	32.8
	Low	8.9	1.9	128.5	24.9		
	High	14.6	2.4	158.6	11.7		
Octane 370	Med	11.5	1.6	145.2	17.2	6.3	31.7
	Low	8.3	1.8	126.9	21.3		
	High	14.0	2.2	143.5	18.7		
Star Trac UB	Med	10.3	2.4	122.7	23.5	5.9	37.7
	Low	8.1	1.3	105.8	16.6		
	High	13.5	2.4	159.8	24.5		
Star Trac TBT	Med	11.3	2.0	143.0	23.4	3.8	23.1
	Low	9.7	2.0	136.8	21.7		

Spread = highest value – lowest value

Discussion:

Although the Navy does not employ a slope correction, if the Navy chose to do so, two more devices might be considered good candidates for acceptance based on a high R^2 value ($\geq .9$) and low standard error of the estimate (≤ 1.0) : Precor AMT 835 Elliptical and the Precor EFX Elliptical. The device with the lowest data spread is the Precor AMT 835 Elliptical. Further analysis (see Table 4.0) that there was very little difference between the high, medium and low levels for the Precor AMT 835. The Precor AMT 835 was unique among the elliptical machines tested in that it had an additional degree of freedom in the stepping motion. The design is such that the stride length and height is variable and can be changed by a subject on the fly by simply applying more or less pressure in the X or Y axis. As a result, work performed is not simply determined by resistance level and cadence. It is also determined by stride length and height. Although not measured, the authors speculate that as the level (device resistance) was increased on the Precor AMT 835, subjects may have compensated by reducing motion in either the X, Y, or both planes. A reduction in range of motion would have reduced the amount of work performed. As a result, the current study may not have achieved 3 distinct work rates for the Precor AMT device.

References:

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