PHYSIOLOGICAL COMPARISON OF TRADITIONAL ELLIPTICAL EXERCISE AND NEWLY- DEVELOPED INDEPENDENT ELLIPSE

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RUNNING HEAD: Independent ellipse

ABSTRACT

The purpose of this study was to compare physiological responses(heart rate(HR) and oxygen consumption(VO2)) for traditional elliptical exercise and a newly-developed independent ellipse at equal work outputs as well as self-selected pace. Fifteen subjects(5 males, 10 females)(mean±SD:age: 20.8±1.2 yrs. Height: 171.9±7.6 cm., weight: 69.8±10.7 kg) volunteered to participate .Each subject performed the equal work output(60 RPM for 5 minutes) and the self-selected pace testing(10 minutes) on separate days within a 7-day period. Pairwise comparisons indicated significantly greater values at equal power outputs for both VO2(21.2±2.6 vs 19.1±2.7 ml/kg/min) and HR(128.3±16.1 vs 125.0±16.4 bpm) for the independent ellipse. At a self-selected pace, subjects also attained significantly higher VO2(24.2±2.7 vs 22.9±3.3 ml/kg/min) and higher HR(148.5±19.7 vs 143.6±19.0 bpm) on the independent compared to traditional ellipse. Results indicate that the independent ellipse provides a better cardiovascular workout than a traditional elliptical machine.

INTRODUCTION

Aerobic exercise is highly recommended for improving cardiovascular health, reducing risk for chronic disease, and decreasing morbidity and mortality(1). Exercise equipment that has been shown to improve cardiovascular health and provide an aerobic training effect include treadmills, cycle ergometers, rowing machines, steppers and elliptical machines. While all of the above have been shown to be of benefit, direct comparisons of these types of exercise equipment have generally found the treadmill to elicit greater physiological responses(8, 11,12). However, this has not always been the case, with the elliptical machine producing comparable, if not greater, heart rate and VO2 responses during maximal (2) and submaximal exercise(7,13) in some studies.

The only direct comparison of chronic effects of training utilizing the ellipse has shown that increases in VO2 max for the treadmill(5.7%), ellipse(6.8%), and stair stepper(4.4%) were similar and not significantly different($p>.05$)(4). The fact that vertical ground reaction forces for the ellipse were less than half that of treadmill running(11), this form of exercise may be preferred by overweight individuals, those with orthopedic or musculo-skeletal problems, or injured athletes.

The independent ellipse was created by placing two ellipse machines side to side and using the inside pedals of both machines, thus creating a machine in which each pedal is driven by a separate flywheel(see attached picture). In

addition to metabolic effects, the inventor has developed a 12-step training program designed to enhance the crossed extensor reflex, thereby increasing the speed of weight transfer and potentially reducing lower extremity injuries. For a more detailed discussion of the crossed extensor reflex, see Marieb(10). Briefly, the reflex is engaged when a weight-supported lower extremity encounters a force that may result in injury, such as stepping on a sharp object or encountering a forceful contact. The potentially injured extremity will immediately flex to reduce weight support while the contralateral limb extends to receive the body weight. The effectiveness of the training program in enhancing the crossed extensor reflex is currently under investigation.

The purpose of this study is to compare heart rate and metabolic responses of the independent ellipse to the traditional ellipse at both identical work outputs and self-selected intensities.

METHODS

Descriptive characteristics of the subjects are contained in Table I. Fifteen subjects(10 female, 5 male, age 20.8±1.2 yrs., height 171.9±7.6 cm., weight 69.8±10.7 kg) volunteered to participate. All subjects reported to be currently involved in some type of aerobic training program. The study had been previously approved by the University of St. Thomas Institutional Review Board.

Subjects reported to the University of St. Thomas Human Performance Lab on 2 separate occasions within a one-week period. Subjects were asked to refrain from any form of strenuous exercise prior to testing and eat lightly 2 hours prior to testing. Resting heart rate(Polar Accurex II, Polar Electro,Washington, NY) , standing height(centimeter) and weight(kilogram)(Seca 700, Hamburg, Germany) were measured prior to testing.

Subjects were given time to familiarize themselves with both machines, especially the independent ellipse, as this was a novel form of exercise for all subjects. This familiarization time also allowed for a warm-up. Each subject learned to use the independent ellipse in 5-10 minutes. Once the subject demonstrated ample skill in operating the independent ellipse, testing began. Subjects were instructed to maintain leg opposition for the independent ellipse just as they did for the traditional ellipse.

During the 5-minute period at equivalent power outputs, subjects maintained a metronome cadence of 60 RPM's for both machines. Cadence was checked periodically to insure accuracy. For the self-selected pace(10 minutes), subjects were instructed to exercise at an intensity that they would maintain for 30 minutes, thus simulating a typical aerobic workout. Research has indicated that perceptual regulation of exercise intensity during steady state exercise is valid, when compared to identical perceptual effort during a graded exercise test, and that the selected intensity is adequate to produce a cardiovascular training effect.(6). Cadence was measured every other minute for each machine and recorded. A 5-minute rest period was allowed between exercise bouts. Order of

testing(independent vs traditional ellipse) was randomized to reduce any possible residual effects of the previous exercise bout on the subsequent bout. Gas analysis was performed using the Medical Graphics VO2000 Metabolic Measurement System(Medical Graphics Corporation, St. Paul, Minnesota). The system has been previously validated(3). Calibration was performed prior to each test according to manufacturer instructions. Breath-by-breath measurements with 30-second averaging was used for all calculations. Statistical analyses were carried out using Minitab version 15 software program. Statistical significance was set at $p>.05$.

RESULTS

Equivalent Power Outputs

Regression analyses resulted in a non-significant slope($p>.05$) over the final 3 minutes of the 5-minute exercise bout for both oxygen consumption and heart rate, when measured on both elliptical machines. Mean values for these 3 minutes were used for all comparisons Table II and Graphs1 and 2 give heart rate and oxygen consumption values for equivalent power outputs. The 3.3 bpm difference in heart rate was small but significantly greater for the independent ellipse($t=2.49$, $p=.026$). Similarly, the 2.1 ml/kg/min difference in favor of the ellipse was small but significant($t=2.70$, $p=.017$).

Self-selected Pace

Regression analysis indicated a significant slope($p<.05$) from 3 minutes to 10 minutes for the independent ellipse for both heart rate and oxygen consumption. Regression using only the final 3 minutes indicated a slope not significantly different from 0($p>.05$). Mean values for the final 3 minutes were used in subsequent comparisons. For the traditional ellipse, the final 3 minutes indicated a non-significant slope($p>.05$) for both measurements and mean values were used here as well. Table III and Graphs 3 and 4 give heart rate and oxygen consumption values for the self-selected exercise bouts. The 4.9 bpm difference in heart rate($t=3.34$, $p=.005$) and 1.3 ml/kg/min difference in oxygen consumption($t=2.35$, $p=.034$) were significantly greater for the independent ellipse. However, at self-selected pace subjects chose a significantly higher cadence(74.6 ± 7.2 vs 71.9 ± 7.8 RPM, $t=3.42$, $p=.004$) on the traditional ellipse.

DISCUSSION

The major finding of this study was that the newly developed independent elliptical machine, when compared to the traditional elliptical machine, resulted in significantly higher heart rates and oxygen consumption at both equivalent power outputs and self-selected pace. Possible explanations for the higher metabolic requirement for the independent ellipse during equivalent power outputs may be

1) for the independent ellipse, each leg is driving a flywheel, while the traditional ellipse has both legs driving the same flywheel 2) all subjects were unfamiliar with the independent ellipse, possibly resulting in more inefficient exercise and a greater metabolic demand. However, the fact that significantly higher HR and VO2 values during self-selected exercise were obtained for the independent ellipse, in spite of significantly lower rpm's, was an interesting finding. One plausible explanation again is the inefficiency of the independent ellipse. However, we would speculate that the subject would perceive this inefficiency and extra metabolic requirement and select a lower cadence and exercise level. Further research is needed on the independent ellipse in which power output can be precisely measured and efficiency calculated.

Since maximal oxygen consumption(VO2 max) was not measured in this study, it is not possible to determine what percent of VO2 max subjects self-selected. However, the mean HR during self-selected exercise(143.6 and 148.5 for traditional and independent ellipses, respectively) are adequate to improve cardiovascular fitness, according to guidelines established by the American College of Sports Medicine(1).

Our finding that subjects self-selected an exercise intensity that elicited 74.6% and 72.2% of predicted maximal heart rate for the independent and traditional elliptical machines, respectively, was considerably lower than the 95% confidence interval of 88.2 to 93.8% reported by Batte(2) and the percent mean maximal heart rate of 87.2% reported by Porcari(11). However, in subjects of similar age and training as used in this study, Kravitz(9) obtained similar VO2

values(22.3 vs 22.9 and 24.2 for traditional and independent ellipses, respectively) The most likely explanation for the higher metabolic demands obtained by Batte and Porcari is the absence of arm work in this study, as subjects held a stationary bar as opposed to the arm work done by subjects in these 2 other studies. However, it has not always been shown that more muscle mass results in greater metabolic requirements(4,7,12). Other factors that may contribute to metabolic requirements during self-selected exercise besides total muscle mass are body position, weight-supported vs. weight-bearing- exercise, and specificity of training for subjects participating in the study.

The first limitation of this study that should be considered in evaluating results is that VO2 max and max HR were not measured. This resulted in the inability to determine the relative intensity for both equivalent power outputs and self-selected exercise. The VO2 max test was omitted due to the difficulty in recruiting subjects who would both perform the VO2 max test and visit the human performance lab on three different occasions.

A second limitation to be considered was the lack of arm work on the 2 elliptical machines. This does not allow for comparison of these results to other elliptical studies. The designer of the independent ellipse has reported that mechanical construction of an independent ellipse that would also include independent arm work would be extremely difficult and would take considerable time for subjects to familiarize themselves with this type of exercise.

CONCLUSION

From the results of this study, it is concluded that the newly devised independent ellipse produces significantly higher HR and VO2 for both equivalent power output and at self-selected pace when compared to the traditional ellipse. With regard to the latter, higher HR and VO2 were obtained in spite of a significantly lower power output for the independent ellipse. In addition to its greater metabolic requirements, the independent ellipse provides greater variety to training due to its many possible combinations of movements, since each leg operates independently of the other leg.

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Table I. Descriptive characteristics of subjects

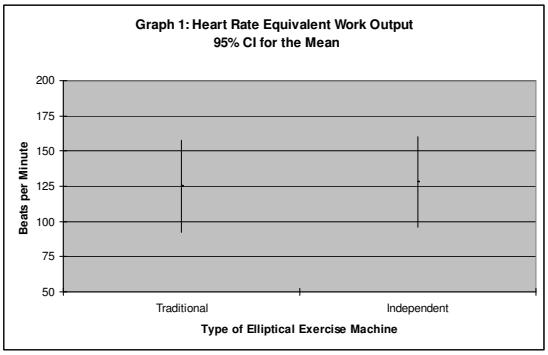
Age(yrs.)	Height(cm)	Weight(kg)
20.8Ñ1.2	171.9Ñ7.6	69.8Ñ10.7

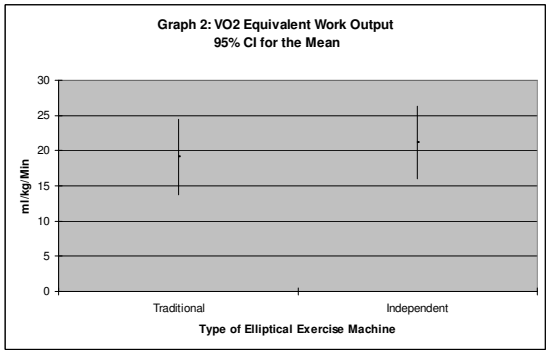
Table II.Heart Rate and Oxygen Consumption: Equivalent Work Output

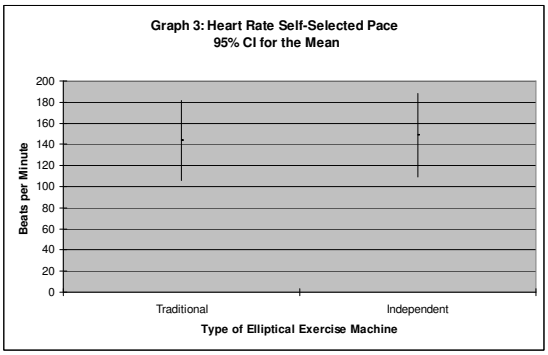
	Heart rate(bpm)	T-value	P-value	VO2(ml/kg/min)	T-value	P-value
Traditional Ellipse	125.0±16.4	2.49	.026	19.1±2.7	2.70	.017
Independent	128.3±16.1			21.2±2.6		

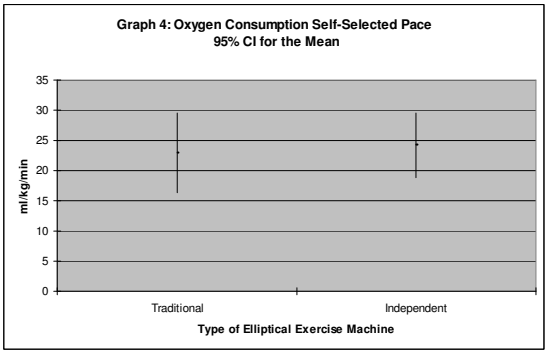
Table III. Heart rate and Oxygen Consumption: Self-selected Pace Ellipse

	Heart Rate (bpm)	T-value	P-value	Oxygen Consumption ml/kg/min)	T-value	P-value
Traditional Ellipse	143.6Ñ19.0	3.34	.005	22.9Ñ3.3	2.35	.034
Independent Ellipse	148.5Ñ19.7			24.2Ñ2.7		


Graph 1: Heart Rate Equivalent Work Output
95% CI for the Mean
Beats per Minute
200
175
150
125
100
75
50
Traditional
Independent
Type of Elliptical Exercise Machine


Graph 2: VO2 Equivalent Work Output
95% CI for the Mean
ml/kg/Min
30
25
20
15
10
5
0
Traditional
Independent
Type of Elliptical Exercise Machine


Graph 3: Heart Rate Self-Selected Pace
95% CI for the Mean
Beats per Minute
200
180
160
140
120
100
80
60
40
20
0
Traditional
Independent
Type of Elliptical Exercise Machine


Graph 4: Oxygen Consumption Self-Selected Pace
95% CI for the Mean
ml/kg/min
35
30
25
20
15
10
5
0
Traditional
Independent
Type of Elliptical Exercise Machine