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## Measurement of Metabolic Responses on an Elliptical Cross-Trainer: Forward vs. Backward at Low and Moderate Intensities

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### ABSTRACT

**Jahn NL, Borgertpoepping MJ, Nordenskjold AJ, Dettmer JA.** Metabolic Response on an Elliptical Cross-Trainer: Forward vs. Backward. *Journal of Undergraduate Kinesiology Research*. 2007; 2(2):25-31. Elliptical cross-trainers are a fairly new exercise modality, and little research has been done to compare forward versus backward exercise movement. **Purpose:** The purpose of this study was to compare the metabolic response on an elliptical cross-trainer using a forward movement style versus a backward style. **Methods:** Fourteen active subjects (7 males, 7 females) with a mean age of  $21.1 \pm 1.2$  years, height of  $173.7 \pm 10.8$  cm, weight of  $76.1 \pm 18.2$  kg, and resting heart rate of  $70.1 \pm 9.0$  bpm were tested, exercising forward and backward at two different intensities and resistances.  $VO_2$ , kilocalories, RPE, and heart rate were measured during the 24-minute test duration. **Results:** The results of the study indicated that there was no significant difference ( $p > .05$ ) regarding  $VO_2$  or kilocalories in either direction at either resistance or intensity. Mean heart rate, however, was higher for both backward low intensity ( $126.8 \pm 15.6$  bpm) and backward moderate intensity ( $156 \pm 17.7$  bpm), although only backward moderate intensity was significant, at  $p = .04$ . The data gathered regarding the accuracy of the caloric expenditure reading on the elliptical cross-trainer in comparison to calculated values showed that the reading on the elliptical cross-trainer is accurate, at least on this make and model. **Conclusion:** It has been concluded that the elliptical cross-trainer is an effective mode of exercise to improve aerobic fitness and cardiovascular health.

**Key words:**  $VO_2$ , heart rate, kilocalories, RPE, modality, cadence, resistance, workload

### INTRODUCTION

Physical activity should be a very important part of our lives. It is crucial that the general public understands this in order to promote overall health and well-being. As little as 30 minutes per day, at a

moderate intensity, most days of the week is enough to achieve this goal, according to the American College of Sports Medicine (ACSM) (4). Being active greatly reduces chances of cardiac events, increases  $VO_2\max$ , decreases risk of obesity, diabetes, hypertension, and all-cause mortality.

To assist people with meeting these requirements, a new exercise modality has emerged over the past 5 years called an elliptical cross-trainer. Their growth in popularity stems from users seeing them as a good alternative to treadmills and stationary bikes, given the versatility of the machine. Unlike a treadmill or stationary bike, research shows it is possible to use forward and backward leg motion and still obtain an effective workout (3). Also, the elliptical cross-trainer is much more convenient than traditional cardiovascular exercise, such as running or walking outdoors. This is due to the ability of the user to select different resistances that are built into the machine, potentially giving the user an equally intense workout in a shorter amount of time, when compared to traditional forms of exercise. In addition, the elliptical cross-trainer is excellent for various populations, such as pregnant women or the elderly, due to the low impact nature of the machine (3).

In a study conducted by Mier, et al., it was found that increases in stride rate and resistance increased steady state oxygen uptake ( $VO_2$ ), minute ventilation (VE), heart rate (HR), and rating of perceived exertion (RPE) (1). In addition to this, it was noted that  $VO_2$  varied widely among individuals, possibly due to differences in experience using the elliptical cross-trainer, gender, and body composition (1). As for the specific topic of forward movement style versus backward, very little research has been conducted, and the results of these studies have been largely inconclusive. A study conducted by Kravitz, et al. found that when users went backwards, they burned 7% more kilocalories than when they went forward (2). The subjects were twenty male and female volunteers who completed five minute trials for each of five conditions (forward, backward, forward with increased speed, forward with resistance, and forward with increased slope) (2). However, a second study conducted by Bakken failed to find a difference in metabolic response between the two when subjects exercised forward and backward at identical speeds and resistances (3). In this study, twenty female subjects performed two ten minute sub-maximal tests consisting of forward and backward motion on the elliptical cross-trainer at equivalent work settings (3). Bakken determined that despite the lack of evidence for more effective training backward rather than forward, the elliptical cross-trainer is still an adequate stimulus to improve aerobic capacity (3). Although there has been some substantial research done regarding elliptical cross-training, an area that has conflicting findings involves physiologic expenditures while training on the elliptical cross-trainer, forward versus backward. Therefore, it seems that there is a need for more research on this topic.

The purpose of this study was to compare the metabolic response on an elliptical cross-trainer using a forward movement style versus a backward style. It is expected that going backward on the elliptical cross-trainer will yield greater physiological responses versus going forward.

## **METHODS**

### **Subjects**

For this study, 14 participants were used, with a mix of 7 males and 7 females, all with similar data. Refer to Table 1 for a complete description of subject characteristics. All subjects were considered active if they met the following criteria: exercising at least three times per week, at least 30 min of exercise per exercise session, and exercising at no less than a moderate intensity. Each subject gave informed consent, and both the study and consent were approved by the University Institutional Review Board for the Protection of Human Subjects. All subjects were familiar with elliptical cross-training, and were instructed on how the testing would be conducted.

**Table 1. Descriptive Statistics of Subjects**

Mean $\pm$ SD		
Variable	Male n=7	Female n=7
Age (yr)	21 $\pm$ 1.41	21.28 $\pm$ 1.11
Height (cm)	182.85 $\pm$ 3.43	164.57 $\pm$ 6.87
Weight (kg)	87.92 $\pm$ 16.18	64.25 $\pm$ 11.44
Resting HR (bpm)	67.14 $\pm$ 5.27	73.14 $\pm$ 11.3



### Instrumentation

The instruments that were used for this study were an elliptical cross-trainer, metabolic cart, scale, RPE charts, heart rate monitor, metronome, and tape measure. A Precor elliptical cross-trainer (Precor EFX 546i: Woodinville, WA) was used for all the aerobic testing. The Viasys metabolic cart (VMax Encore 229C: St. Paul, MN) was used to measure metabolic responses. A Polar heart rate monitor (Polar T31: Lachine, QC, Canada) was used to measure heart rate during the steady-state exercise trials. A metronome (Franz XB-700: New Haven, CT). Before testing, the subjects were asked to take a resting heart rate after sitting for 5 min.

Rating of Perceived Exertion (RPE) was measured on a scale of Zero to Ten. The RPE scale was explained to the subjects as if 1 was a resting state and 10 was explained as unable to continue (extremely exhausted).

### Procedures

Subjects were instructed not to participate in strenuous exercise for 24 h before testing, and also not to eat a large meal within 2 h of being tested. The subjects' height and weight were recorded along with the subjects' resting heart rate prior to testing. The resting heart rate was measured after the subject was seated for no less than 5 min. A heart rate monitor was placed around the subjects' chest. The heart rate data was read from the elliptical cross-trainer heart rate screen. The metabolic cart was calibrated properly and the subject was properly connected to the metabolic cart.

Testing consisted of four, six-minute bouts of forward and backward motions at low and moderate intensities. The incline on the elliptical cross-trainer was set at 4 for the entire study. The resistance was

4 for the low intensity and 8 for the moderate intensity. The reason the set levels for incline and intensity were chosen was because the incline and resistance on the elliptical cross-trainer range from 1 to 20, 1 being low and 20 being high. Therefore, 4 was chosen as low intensity and incline throughout the study, for both variables. Also, 8 was chosen as moderate intensity based on the fact that it is near the middle of the continuum for intensity. The metronome was set at 100 bpm for the low intensity and 144 bpm for the moderate intensity. If a subject was observed off cadence, they were immediately instructed to return to the designated cadence for that exercise bout. The order of the direction and intensity was randomized to prevent an order effect. At every five minute interval the calorie reading on the elliptical cross-trainer was recorded for one minute. At six min, the calorie reading was recorded once again along with the subjects' heart rate. The recording of the calories and heart rate were recorded every 5 and 6 minute interval for 24 min. Refer to Table 2.

**Table 2. Elliptical Cross-trainer Workloads in the Present Investigation**

Randomized				
Parameter Workload	Forward		Backward	
	Cadence	100	144	100
Resistance	4	8	4	8
Incline	4	4	4	4

**Statistical Analysis**

MINITAB 14.0 and SPSS 14.0 were used for all statistical analyses. Paired *t*-tests were used to compare mean physiological responses to forward vs. backward elliptical cross-training for both low and moderate intensities, as well as to measure the accuracy of the caloric expenditure monitor on the cross-trainer. Level at statistical significance was referenced at  $p \leq .05$ .

The metabolic difference between going forward and backward at low and moderate intensities on an elliptical cross-trainer and the accuracy of the calorie readings on the elliptical cross-trainer was calculated. The independent variables are intensity (low and moderate) and movement (forward and backward) on the elliptical cross-trainer. The dependent variables are heart rate, VO<sub>2</sub>, kilocalories, and RPE.

**RESULTS**

Table 3 shows the metabolic variables that were measured at the different intensities. The formula used to calculate %HRR is as follows: Actual HR = (%HRR)(HRR) + Resting HR. Mean heart rates were used for both actual HR as well as resting HR (refer to Tables 1,3). Table 4 shows the *p*- and *t*-values, degree of freedom, mean difference, and standard error difference that were associated with determining the significance between the dependent variables at the designated intensities. Table 5 shows the comparison between the caloric expenditure reading obtained from the elliptical cross-trainer and the values calculated from VO<sub>2</sub> results.

**Table 3. Comparison of Metabolic Variables Measured at Low and Moderate Intensities Backward and Forward**

Parameter	Mean ± SD			
	FM	BM	FL	BL
VO <sub>2</sub> (ml/kg/min)	30.3 ± 4.3	30.8 ± 3.6	19.2 ± 1.6	19.4 ± 2.4
HR (bpm)	151.5 ± 20.3	156 ± 17.7	121.9 ± 18.1	126.8 ± 15.6
Kcals/min (estimated)	11.5 ± 0.7	11.8 ± 0.9	7.3 ± 0.5	7.4 ± 0.6
Kcals/min (measured)	11.2 ± 1.4	11.5 ± 1.6	7.2 ± 1.5	7.3 ± 1.4
RPE	3 ± 1.1	3.4 ± 1.5	1.6 ± 1.1	1.9 ± 1.2
%HRR	64%	67%	40%	44%

-Forward Moderate (FM), Forward Low (FL), Backward Moderate (BM), and Backward Low (BL)

**Table 4. Paired t-test variables for HR, VO<sub>2</sub>, kcals, RPE comparison**

Parameter	p-value	t-value	Degree of Freedom	Mean difference	Std. Error Difference
HR (FM vs BM)	.04	2.82	13	4.5	1.97
HR (FL vs BL)	.16	1.48	13	4.93	3.33
VO <sub>2</sub> (FM vs BM)	.30	1.07	13	.57	1.99
VO <sub>2</sub> (FL vs BL)	.63	.27	13	.27	.54
Kcals (FM vs BM)	.18	1.41	13	.27	.19
Kcals (FL vs BL)	.76	.31	13	.06	.2
RPE (FM vs BM)	.21	1.33	13	.36	.27
RPE (FL vs BL)	.37	.94	13	.29	.3

-Forward Moderate (FM), Forward Low (FL), Backward Moderate (BM), and Backward Low (BL)

**Table 5. Paired t-test variables for kcals/min elliptical cross-trainer readings vs VO<sub>2</sub> measured kcal expenditure**

Parameter	FM	BM	FL	BL
p-value (kcals/min)	.359	.651	.853	.720
t-value (kcals/min)	.951	.463	.188	.366
df (kcals/min)	13	13	13	13
Mean difference	.355	.295	.093	.146
Std. Error Difference	.373	.637	.496	.4

-Forward Moderate (FM), Forward Low (FL), Backward Moderate (BM), and Backward Low (BL)

## DISCUSSION

The purpose of this study was to compare the metabolic response on an elliptical cross-trainer using a forward movement style versus a backward style. Based on the results of this research study, the initial hypothesis stating that exercising backward on the elliptical cross-trainer will yield greater physiological responses compared to exercising forward is rejected. The data has shown that, regardless of whether a forward or backward movement style is used, the same physiological responses are elicited. The only exception to this was the significant difference found in heart rate when exercising at the moderate intensity, where exercising backward resulted in a higher heart rate than did exercising forward. The results found when comparing the caloric expenditure reading from the elliptical cross-trainer with our calculated results were inconclusive, due to the fact that two of the variables were not significant, and two were significant.

The results of this study regarding physiological response correlate with the results of the study done by Bakken (3), which concluded that there was no physiological response when comparing forward versus backward movement. In the study done by Bakken, it was found that as the intensity increased, physiological variables significantly increased. This was also shown in the current study, in that the physiological effects showed a significant difference from low to moderate intensity. The results of this study refute the results of the study done by Kravitz, et. al (2), which concluded that there was a 7% difference in caloric expenditure forward versus backward, with the backward motion having a greater caloric yield.

When looking at the ACSM guidelines for exercise prescription, the results of the current study demonstrate that each exercise bout (FM, BM, FL, BL) fulfills the ACSM guidelines for physical activity. The protocol of the current study met the recommended duration for daily exercise of 20-60 minutes, energy expenditure goals (150-400 kcals/day), and exercise intensity (40-85% HRR). In terms of energy expenditure, if each of these bouts were individually extended over 24 minutes, all 4 would meet the minimum 150 kcal/day requirement, as follows: (FM 268.8 kcals, BM 276 kcals, FL 172.8 kcals, BL 175.2 kcals).

In theory, the backward movement on the elliptical cross-trainer would result in greater muscle activation of the quadriceps. This would in turn result in an increase in oxygen consumption due to the large muscle mass of the quadriceps opposed to the smaller muscle mass of the hamstrings used in forward motion. However, the results from this study were unable to substantiate this theory.

This study had several possible limitations. All of the subjects were tested in all four areas in the same day, in concurrent intervals, meaning fatigue could have had a role in the results. In addition, all of the subjects were active individuals, so this data can only be generalized toward active individuals, with possible different results for an inactive population. Future research is needed in the area of elliptical cross-trainers and the physiological differences between forward and backward motion when exercising. Future studies could look at higher intensities with increased incline and resistance, increased stride rate, and observation of muscle activation on the elliptical cross-trainer as opposed to running on a traditional surface.

## CONCLUSION

Based on our findings, there is no significant difference between exercising forward versus backward on an elliptical cross-trainer at 4% incline and resistances set at 4 and 8, respectively, as specified by Precor EFX 546i. In addition, the comparison of caloric expenditure between the elliptical cross-trainer and measured calculations was not significant, meaning that the caloric expenditure reading on the elliptical cross-trainer, at least for this make and model, is accurate.

This study has shown that, according to the data gathered, exercising on the elliptical cross-trainer

is very beneficial to overall health and well-being. Populations such as the obese or those recovering from lower extremity injuries can benefit from exercise on this modality, due to the low impact nature of the elliptical cross-trainer. It has been concluded that the elliptical cross-trainer is an effective mode of exercise to improve aerobic fitness and cardiovascular health.

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