THE EFFECTIVENESS OF THE ELLIPTIGO AS AN EXERCISE MODALITY IN HEALTHY ADULTS

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

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December, 2015
THE EFFECTIVENESS OF THE ELLIPTIGO AS AN EXERCISE MODALITY IN
HEALTHY ADULTS

By: Nicole Rendier

We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Master of Science in Clinical Exercise Physiology. The candidate has completed the oral defense of the thesis.

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ABSTRACT

Rendler, N.M. The effectiveness of the ElliptiGO as an exercise modality in healthy adults. MS in Clinical Exercise Physiology, December 2015, 38pp. (J. Porcari)

The ElliptiGO is a hybrid between a bicycle and an elliptical cross-trainer and is meant to be used outdoors. The purposes of this study were to 1) to determine the relative exercise intensity of exercise on the ElliptiGO, and 2) to determine if this intensity fell within ACSM guidelines for improving respiratory fitness. Subjects included 7 male (23.6 ± 3.8 years old) and 9 female (23.2 ± 1.0) active adults. All subjects completed two exercise tests. Tests included a 30-minute self-selected exercise bout on the ElliptiGO, and a graded maximal exercise test on the treadmill. It was found that heart rate averaged 84% of % maximal HR and VO₂ averaged 75% of VO₂max during the ElliptiGO workout. Males burned significantly more kcal/min than females (14.5kcal/min vs 11.5kcal/min). Based on these results, exercising at a self-selected intensity on an ElliptiGO provides a moderate intensity workout that meets the current ACSM guidelines for improving aerobic fitness and body composition.
ACKNOWLEDGEMENTS

I would first like to thank the University of Wisconsin-La Crosse for allowing me to use the 400 meter outdoor track in Roger Harring stadium to conduct my ElliptiGO research. Without the university’s flexibility, this study would not have gone as smoothly as it did.

I would also like to extend my gratitude towards Dr. John Porcari, Dr. Jeff Steffen, and Scott Doberstein. Their guidance and support made this entire process very worthwhile, and they pushed me to be the best researcher that I can be. I also owe much of my gratitude to Chris Dodge due to his uncanny ability to fix any problem I had with my equipment, and his wonderful demeanor when I needed his assistance during testing.

I would like to thank my wonderful classmates and volunteer participants for helping me with my study, whether it was participating in it or assisting with some of the testing. Their willingness to commit and be flexible for something that was not their main priority means a lot to me and certainly made my study much more enjoyable.

Last but not least, I would like to thank my wonderful parents and family. The sacrifices they have made for me to be here and accomplish something like this is truly amazing and I cannot thank them enough for being there every step of the way.
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INTRODUCTION

Engaging in habitual aerobic exercise has been shown to have many health and wellness benefits. These benefits include a decreased risk of developing coronary artery disease (CAD), an increase in maximal oxygen uptake (VO₂max), decreased resting heart rate (HR) and blood pressure, improvement in body composition, improved glucose tolerance, and a better sense of overall well-being (ACSM, 2010).

The American College of Sports Medicine (ACSM) has set forth guidelines recommending that adults engage in a minimum of 150 minutes of aerobic activity per week (ACSM, 2010). The exercise should be conducted at 64-94% of maximal HR or 40-85% of VO₂max. This can be divided up into 30-minute bouts of moderate intensity activity five days per week or 20-minute bouts of vigorous activity on three days of the week (ACSM, 2010). According to a self-reported study from the Center for Disease Control and Prevention (CDC), only one in five adults (20%) are meeting these recommendations for aerobic fitness ("How Much Physical Activity Do Adults Need?"

Centers for Disease Control and Prevention).

That statistic seems odd given the fact that there are many different avenues for people to engage in physical activity, especially aerobic exercise. There are traditional activities such as running, walking, cycling, swimming, as well as relatively newer modes of exercise. For well over a decade, elliptical cross-trainers have increased in popularity. The most common reason for this is, that unlike running and walking, an elliptical cross-trainer produces less stress to the lower extremities since it provides more stability for the
ankle, knee and hips as compared to walking or running (Burnfield, Shu, Buster & Taylor 2010). Brown, Cook, Krueger and Heelan (2010) found that there were no mode-related differences with regard to VO₂max, maximal HR, or energy expenditure between running and elliptical exercise when exercising at the same rating of perceived exertion (RPE). Similarly, Dalleck and Kravitz (2006) found no differences in maximal HR or VO₂max, or the HR/VO₂ relationships between using an elliptical cross-trainer and treadmill running.

A new piece of elliptical equipment, known as the ElliptiGO (ElliptiGO LLC, San Diego, CA), came on the market in 2010 (Outdoor Elliptical Bikes - ElliptiGO). The ElliptiGO is a hybrid between a bicycle and an elliptical cross-trainer. It has a motion similar to an elliptical but is steered like a bicycle, and is meant to be used outdoors. The manufacturers claim that it mimics running, but without the impact. Testimonials claim that it produces the same, and sometimes higher, HR and energy expenditure responses than running. To our knowledge, there has been no scientific research conducted on the ElliptiGO to document the intensity of an ElliptiGO workout. Therefore, the purposes of this study were 1) to determine the relative exercise intensity and energy cost of exercise on the ElliptiGO, and 2) to determine if these values fall within ACSM guidelines for improving respiratory fitness and body composition.
METHODS

Subjects for this study included 16 apparently healthy adults from the greater La Crosse, WI area. Subjects were between 18-45 years of age and had previous experience using elliptical cross-trainers. Subjects were required to be physically active (at least 150 minutes of aerobic activity per week), and have no orthopedic or cardiovascular contraindications in order to participate in this study. Each subject completed a Physical Activity Readiness Questionnaire (PAR-Q, Canadian Society for Exercise Physiology, 2002) prior to participation. Each subject was provided with and completed written informed consent before beginning this study. This study was approved by the University of Wisconsin-La Crosse (UWL) Institutional Review Board for the Protection of Human Subjects prior to initiation.
PROCEDURES

Each subject completed three, 15-20 minute habituation sessions on the ElliptiGO in order to become more proficient in its use. Each subject then completed one 30-minute exercise session on the ElliptiGO and a graded maximal exercise test on the treadmill.

The graded exercise test was completed using the modified Balke protocol. Subjects walked on a treadmill at a constant walking speed and grade of the treadmill was increased 2.5% every two minutes until volitional fatigue. During the test subjects wore a Polar heart rate monitor (Polar Electro, Kempele, Finland) and were hooked up to an Oxycon™ Mobile Device (CareFusion Corporation San Diego, CA) to measure expired air and metabolic responses. At the end of each stage, RPE was assessed using the 6-20 Borg Scale. All maximal exercise tests were conducted in the Human Performance Laboratory in Mitchell Hall on the UWL campus.

Subjects also completed one 30-minute exercise session on the ElliptiGO once they were deemed proficient by the primary investigator. During this session subjects exercised on the ElliptiGO at a self-selected pace. Heart rate was recorded each minute using a Polar monitor and VO2 was again measured continuously using the Oxycon™ Mobile Device (CareFusion Corporation San Diego, CA). Session RPE was assessed at the end of the exercise session using the Borg Scale. Testing was done on a 400-meter outdoor track on the UWL campus (Roger Harring Stadium at Veterans Memorial Field Sports Complex).
STATISTICAL ANALYSIS

Statistical descriptive statistics were used to characterize the subject population and to quantify responses during the ElliptiGO exercise session. Independent t-tests were used to compare the responses between males and females. Alpha was set at .05 to determine statistical significance.
RESULTS

Descriptive characteristics of the subject population, sub-divided by gender, are presented in Table 1. Subjects included 7 males and 9 females.

Table 1. Descriptive statistics of the subject population (N=16).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Male X ± SD</th>
<th>Female X ± SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>23.6 ± 3.8</td>
<td>23.2 ± 1.0</td>
</tr>
<tr>
<td>Height (in)</td>
<td>69.7 ± 1.6</td>
<td>67.2 ± 2.0</td>
</tr>
<tr>
<td>Weight (lbs)</td>
<td>169.3 ± 19.8</td>
<td>149.8 ± 11.9</td>
</tr>
<tr>
<td>VO₂max (ml/kg/min)</td>
<td>55.7 ± 8.7</td>
<td>43.2 ± 4.8</td>
</tr>
<tr>
<td>HRmax (bpm)</td>
<td>188 ± 10.3</td>
<td>188 ± 5.3</td>
</tr>
</tbody>
</table>

Exercise responses to the ElliptiGO exercise session are shown in Table 2. There were no significant differences in the responses of males compared to females except for caloric expenditure. Males burned significantly more calories than females.
Table 2. Responses to the 30-minute exercise bout on the ElliptiGO

<table>
<thead>
<tr>
<th>Variable</th>
<th>ElliptiGO</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>X ± SD</td>
<td></td>
</tr>
<tr>
<td>HR (bpm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>153 ± 14.3</td>
<td>129-170</td>
</tr>
<tr>
<td>Females</td>
<td>163 ± 15.8</td>
<td>135-181</td>
</tr>
<tr>
<td>Overall</td>
<td>158 ± 15.4</td>
<td>129-181</td>
</tr>
<tr>
<td>%HRmax (bpm)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>82 ± 8.3</td>
<td>66-91</td>
</tr>
<tr>
<td>Females</td>
<td>86 ± 5.9</td>
<td>78-97</td>
</tr>
<tr>
<td>Overall</td>
<td>84 ±7.2</td>
<td>66-97</td>
</tr>
<tr>
<td>VO2 (ml/kg/min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>38.8 ± 8.72</td>
<td>24.1-50.7</td>
</tr>
<tr>
<td>Females</td>
<td>33.7 ± 3.96</td>
<td>28.1-38.4</td>
</tr>
<tr>
<td>Overall</td>
<td>35.9 ± 6.96</td>
<td>24.1-50.7</td>
</tr>
<tr>
<td>%VO2max (ml/kg/min)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>70.9 ± 17.29</td>
<td>38.7-92.3</td>
</tr>
<tr>
<td>Females</td>
<td>78.2 ± 8.82</td>
<td>67.6-88.5</td>
</tr>
<tr>
<td>Overall</td>
<td>75.0 ± 9.35</td>
<td>38.7-92.3</td>
</tr>
<tr>
<td>Kcal/min</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>14.5 ± 3.53*</td>
<td>8.6-17.9</td>
</tr>
<tr>
<td>Females</td>
<td>11.5 ± 1.09</td>
<td>9.7-13.2</td>
</tr>
<tr>
<td>Overall</td>
<td>12.8 ± 2.83</td>
<td>8.6-17.9</td>
</tr>
<tr>
<td>RPE</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td>13.6 ± 0.89</td>
<td>12-14.5</td>
</tr>
<tr>
<td>Females</td>
<td>13.7 ± 0.56</td>
<td>13-14.5</td>
</tr>
<tr>
<td>Overall</td>
<td>13.7 ± 0.70</td>
<td>12-14.5</td>
</tr>
</tbody>
</table>

*Significantly greater than females (p<.05)
Relative HR responses (%HRmax) during each minute of the 30-minute exercise session on the ElliptiGO are illustrated in Figure 1. The boxed area represents the current ACSM guidelines for eliciting a cardiorespiratory training benefit (64-94% of HRmax). Relative HR responses during each minute of ElliptiGO exercise were within the ACSM recommendations for the entirety of the workout (ACSM, 2010).

![Figure 1. Average percent of HRmax maintained during each minute of exercise on the ElliptiGO.](image)

Relative oxygen consumption (%VO₂max) of the subjects for every minute of the 30-minute ElliptiGO exercise session are illustrated in Figure 2. The current ACSM guidelines for maintaining or improving aerobic fitness are represented in the boxed area (40-85% of VO₂max). Subjects maintained an exercise intensity that fell within the current ACSM guidelines for improving aerobic fitness (ACSM, 2010).
Figure 2. Average percent of VO₂max maintained during each minute of exercise using the ElliptiGO.
DISCUSSION

The objectives of this study were twofold. The first objective was to determine the relative intensity and energy costs of exercising on the ElliptiGO at a self-selected pace. Secondly, we aimed to see if exercising on the ElliptiGO meets the ACSM guidelines for improving cardiorespiratory fitness and controlling body weight (ACSM, 2010).

The ACSM guidelines suggest that healthy adults work out between 64-94% of HRmax or 40-85% of VO2max in order to maintain and/or improve cardiorespiratory fitness. The findings of this study demonstrate that exercising at a self-selected intensity on the ElliptiGO met ACSM guidelines on both accounts. Subjects exercised at an average of 84% of HRmax and 75% of VO2max during the 30-minute exercise session.

If used appropriately and consistently, exercising on the ElliptiGO has the ability to provide positive gains in cardiorespiratory fitness.

Current guidelines also suggest that individuals burn 200-300 kcal/session in order to manage weight or see improvements in weight loss (Thompson, Gordon & Pescatello, 2010). For the 30-minute exercise bout, male subjects burned an average of 436 kcal (14.5 kcal/min), while females burned 345 kcal (11.5 kcal/min), which meet
these guidelines. It is likely that males burned more calories than females due to their larger body mass (169.3 lbs vs. 149.8 lbs).

Subjects exercised at an average RPE of 13.7 on the 6-20 RPE scale, which is indicative of a “somewhat hard” intensity. ACSM guidelines recommend that a moderate intensity workout be within the range of 11-15 on the 6-20 RPE scale.

These results are comparable to other studies that looked at elliptical-type modalities like the StreetStrider and regular elliptical cross-trainers. Becker, Porcari, Foster and Doberstein (2011) compared StreetStrider exercise to an exercise test on an elliptical cross-trainer and found that the StreetStrider elicited a higher exercise intensity than exercising on the elliptical cross-trainer (85% HRmax). His findings also show that subjects achieved a higher %VO₂max (75% VO₂max) and burned more calories on the StreetStrider. The average %HRmax achieved on the StreetStrider was 85%, which is similar to the ElliptiGO, with subjects averaging 84%. Subjects on the StreetStrider averaged a %VO₂max was 71%, which is also similar to the ElliptiGO with subjects averaging 75% VO₂max.

Another study assessed the physiological responses of regular exercisers at a prescribed RPE of 6 (0-10 scale, “somewhat hard”) on elliptical cross-trainers after having subjects complete a maximal test for comparison (Batte et al., 2003). VO₂ and HR were measured during this time and they found that once subjects reached steady-state, they were exercising at approximately 75% of their VO₂max and 91% of HRmax. These results are similar to what was found on during ElliptiGO exercise. Average %HRmax on
the ElliptiGO was slightly lower reaching 84%, and average %VO$_2$max was the same reaching 75%. Findings on both of these modalities are within ACSM’s guidelines for maintaining and/or improving cardiorespiratory fitness.

Brown, Cook, Krueger and Heelan (2010) studied the oxygen consumption, energy expenditure and HR between a treadmill and an elliptical cross-trainer while exercising at the same RPE of 12-13 (Borg scale). Maximal tests were done on both modalities prior to moderate intensity exercise testing. The researchers did not find any significant mode-related differences in VO$_2$max or HRmax. They did note that submaximal HR was higher on the elliptical cross-trainer (164±16 beats/min) than the treadmill (145± 15 beats/min), however, energy expenditure and oxygen consumption were still similar between the two. They concluded that individuals can rotate between elliptical-cross training exercise and treadmill exercise and still experience the same benefits. The same can potentially be expected of the ElliptiGO as well due to the similar aspects it shares with elliptical-cross trainers, however, more research should be conducted in order to confirm that.

Anecdotally, subjects reported that they enjoyed exercising on the ElliptiGO for a variety of reasons. First and foremost, they enjoyed the benefits of exercising on an elliptical-type machine with the bonus of being able to be outdoors. Subjects also enjoyed the ability to change the resistance (by changing gears), which made it easier to alter the intensity of the workout. Many subjects stated that it is seemed like a great way to strengthen the abdominal region and other stabilizing muscles because of the level of balance that is required to ride it, without having to perform other exercises. Subjects did report that they became a bit bored during testing due to the necessity of testing on an
outdoor 400-meter track. However with general use, an ElliptiGO can be ridden anywhere with a hard or paved surface.

Learning to use the ElliptiGO proved to be relatively simple for all subjects as they all mastered its use within two practice sessions. The practice sessions helped them become familiar with the modality by practicing pedaling, turning/steering, and adjusting the gears. The practice sessions also ensured that subjects would be comfortable during testing and would know which settings worked best for them for a 30-minute exercise session.

Future research may want to study the differences in exercise responses between the ElliptiGO and similar products like the StreetStrider (StreetStrider International LLC, Carson City, NV). Factors from exercise enjoyment, to physiological responses, to muscle usage could be compared between modalities. This would be helpful for exercise professionals when prescribing exercise and/or adding variety to someone’s exercise routine. Because these types of products are becoming more popular for a wide variety of individuals, it may also be beneficial to research the effects of different types of workouts on the ElliptiGO such as interval training, hill workouts, tempo training, etc. Those could then be compared to values derived from similar workouts to determine if one is superior to the other.

In conclusion, it was found that exercising at a self-selected intensity on an ElliptiGO provides a moderate intensity workout that meets the current ACSM guidelines for improving aerobic fitness. Additionally, it also meets the recommendations for caloric expenditure relative to weight management and weight loss. Thus, the ElliptiGO appears to be an effective exercise modality for apparently healthy adults looking to maintain or
improve cardiorespiratory fitness and control body weight. When used regularly, healthy adults can experience the many benefits of physical activity, while simultaneously enjoying exercise on the ElliptiGO.
REFERENCES


ElliptiGO LLC, San Diego, CA (2010)


INFORMED CONSENT

THE EFFECTIVENESS OF THE ELLIPTIGO AS AN EXERCISE MODALITY IN HEALTHY ADULTS

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

Purpose and Procedures

- The purpose of this study is to examine the effectiveness of a newer exercise device, the ElliptiGO, as an exercise modality for healthy adults.
- My participation in this study will consist of five separate sessions, each lasting between 15-30 minutes.
- The first three sessions will be 15-20 minute practice sessions during which I will practice using an ElliptiGO.
- During the final two sessions, I will complete a 30-minute bout of exercise using either the ElliptiGO or do a graded maximal exercise test. During these sessions, I will wear a heart rate monitor and facemask to measure heart rate and expired air.
- Research assistants will be conducting the research under the direction of Dr. John Porcari, a professor in the Department of Exercise and Sport Science.

Potential Risks

- Fatigue, arm and leg tiredness, muscle soreness and shortness of breath similar to any form of aerobic exercise are possible as a result of participating in this study.
- The risk of serious or life-threatening complications is very low (<1/10,000 tests) in apparently healthy, regularly exercising adults.
- The test will be stopped immediately upon the development of any complications.
- There will be persons trained in CPR and Advanced Cardiac Life Support available for every testing session.

Benefits of Participation

- By volunteering to participate in this study, I will benefit myself by understanding more about my personal responses to exercise.
- This study will be important to exercise professionals and researchers who want to know more about the responses of the general public to exercise on the ElliptiGO.

Rights and Confidentiality

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

I have read the information provided on this consent form. I have been informed of the purpose of this study, the procedures, and the 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 the study.

If I have any more questions that arise I may feel free to contact John Porcari, the principal investigator, at (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:__________________
REVIEW OF LITERATURE

Engaging in habitual aerobic exercise has been shown to improve one’s longevity and all around health and wellness. To date, there is a large amount of research involving large populations and laboratory studies in which the findings attribute many physiological benefits to increased aerobic exercise and general physical activity. These benefits include decreased risk of CVD/CAD and other co-morbidities, maximal oxygen uptake (VO₂max), decreased resting heart rate and blood pressure, improvement in body composition-decreased body fat, increased lean body mass, and a better sense of overall well-being (Lippincott, Williams & Wilkins). In order for individuals to effectively prevent obesity and work at optimal energy expenditures for themselves, they need to train and/or be trained in an environment that they enjoy as well as train with modalities that are best suited to them. This will create a positive stimulus for them, and therefore it will likely increase exercise adherence. (Brown, Cook, Krueger, Heelan, 2009).

For well over a decade, elliptical cross-trainers have increased in popularity. The most common reason for this is, that unlike running and walking, an elliptical cross-trainer produces less stress to the lower extremities. There is a new piece of elliptical training equipment on the market known as the ElliptiGO (ElliptiGO LLC, San Diego, CA). The ElliptiGO is a hybrid between a bicycle and an elliptical, and is designed to be used outdoors. To our knowledge, there is no scientific research on this product at the current time, and due to its growing popularity, research needs to be conducted to determine if this is indeed a viable form of aerobic exercise. From this research, we
should also be able to determine if the use of this product meets the fitness guidelines from the American College of Sports Medicine (ACSM). Therefore, the purpose of this study is to determine if exercising on the ElliptiGO at a self-selected pace meets the American College of Sports Medicine guidelines for improving cardiorespiratory fitness.

The American College of Sports Medicine (ACSM) has set forth guidelines recommending that adults engage in a minimum of 150 minutes of aerobic activity per week, and at 64-94% of their heart rate max or 40-85% VO₂ max (maximum aerobic capacity). This can be broken up into 30-minute (minimum) bouts of moderate activity five days per week, or 20-minute bouts of vigorous activity on three days of the week, all of which can be divided into 10-minute sessions. According to a study from the Center for Disease Control and Prevention (CDC), only one in five adults (20%) are currently meeting these recommendations for aerobic fitness. That statistic seems odd given the fact that there are many different avenues for people to engage in physical activity, especially cardiorespiratory physical activity.

Westscott et al. (2009) studied the effects of the ACSM physical activity guidelines for both aerobic and strength activity on body fat percent, fat weight, and lean weight in previously active adults in three separate exercise groups. Each exercise session in all of the groups was estimated to burn approximately 300 calories. Not surprisingly, they found that participants who exercised three days a week (as compared to one or two), had more significant decreases in percent body fat and fat weight. The less apparent finding was that both the participants in the two days per week and three days per week programs increased the same amount in lean body mass. This substantiates ACSM’s
stance that exercising (both aerobic and resistance training) more than once a week is needed in order to have physiological benefits.

Rating of perceived exertion (RPE) fluctuates among individuals of varying fitness levels when performing the same and/or different physical activity. An assumption would be that at the same RPE, lower fit individuals would have less physiological and metabolic demands than highly trained individuals. Berg, Kaufman, Noble and Thomas (2006) conducted a study using a protocol design in which they controlled RPE instead of oxygen consumption or heart rate between highly fit/highly active (HF) and low fit/inactive (LF) men. They designed it in this manner because it is more common to measure RPE in both clinical and recreational fitness settings. They found that when exercising at an RPE of 13 (somewhat hard), LF individuals exercised at a higher percentage of VO$_2$max than the high fit individuals; they also saw that the LF group was above their lactate threshold (LT) for the last 10 minutes of exercise at an RPE of 13, while the HF group was consistently below their LT. These results indicate that when working at the same intensity level (RPE), individuals who are less fit will have higher physiological demands than higher fit individuals.

For well over a decade, elliptical cross-trainers have increased in popularity. “These machines are more attractive to a recreational exerciser for many reasons. A few of these being the sole fact that it is not running, and it was something different than traditional exercise. Its use is relatively simple for apparently healthy adults, and because of its increased popularity, one would hope that physical activity participation statistics would go up. Before that data could be collected, however, the physiological responses to elliptical cross training (oxygen consumption, heart rate, energy expenditure, force
production, etc.)” were needed in order to validate the effectiveness of these machines. Furthermore, for clinical use and general exercise prescription, a prediction equation (like many that are seen with sub-maximal tests) was needed as well.

Perception of how hard one is working during exercise compared to how hard they are actually working can vary among individuals. This perception serves as a major intrinsic factor that can affect how one chooses intensity levels during exercise. Batte et al. (2003) conducted a study in which they assessed the physiological responses of regular exercisers at a prescribed level of perceived exertion (RPE) on elliptical cross trainers. After doing maximal tests for comparison, the subjects completed a 15-minute exercise session on the elliptical at a prescribed RPE of six (0-10 scale), and adjusted their machines accordingly to maintain that RPE; VO₂ and heart rate (HR) were observed during this time.

The results of this research demonstrated that once exercisers reached steady state (~4 minutes), they were exercising at approximately 75% of their relative VO₂ and approximately 91% of their relative maximal HR. When compared to another study that measured RPE in 20 recreational exercises, it was shown that the elliptical in this study elicited significantly higher intensities. These findings validate the use of RPE as a marker for intensity, however it must be properly understood in order to be used effectively.

As of 2013, an estimated 6.2 million individuals of the general exercise population have taken up elliptical cross-training exercise. However, according to Brown et al. (2013), there are no graded exercise protocols/equations that could properly estimate peak oxygen consumption (VO₂ peak). Brown et al. (2013) conducted a cross-
validation (XVAL) study to measure VO\textsubscript{2}peak by using indirect calorimetry on an elliptical cross trainer. The validation included a stepwise regression analysis in order to predict VO\textsubscript{2}peak by using resistance, maximal heart rate, body mass index, and gender. From that data, the researchers produced this equation:

\[
\text{VO}_2 \text{ peak} = 187.39403 + 12.97271( \text{gender} ) - 1.45311( \text{height} ) - 1.21604( \text{BMI} ) - 0.19613( \text{HR}_{\text{max}} ) + 1.57093( \text{resistance} )(R^2=0.76, \text{SEE}=4.47)
\]

Using this equation, predicted VO\textsubscript{2}peak was 45.18 for the XVAL group, while the actual VO\textsubscript{2} peak was 43.55. These results indicate that there was no significant difference between the predicted and actual values, which confirms the use of this equation for the general population. Accordingly, this equation can help physicians and exercise professionals better prescribe exercise to those who are seeking an alternative form of aerobic exercise other than running, biking, swimming, or walking. The authors did note that while it eliminates the use of direct calorimetry, more research should be done in order to substantiate the results of this study, especially due to the popularity of elliptical cross-trainers.

In 2006, Mier and Fieto tested the effects of stride rate, resistance, and combined arm/leg use on energy expenditure and physiological responses during elliptical cross trainer exercise. Their secondary aim was to evaluate the accuracy of the manufacturer’s calculations in regards to energy expenditure. They found that an increase in stride rate and resistance increased VO\textsubscript{2} with the combined arm and leg use, and from levels 2-8 on the machine, VO\textsubscript{2} increased by 25 percent for both leg only and combined limb use. These responses are indications that elliptical cross-trainers can provide a quality workout for people of different fitness levels.
After analyzing the metabolic data, Mier and Fieto also discovered that this particular elliptical cross-trainer over-estimated energy expenditure at higher levels of resistance. The researchers attribute this to not factoring in arm use on the machine. However, the over-estimation decreased at higher resistance during the combined limb protocols.

There seems to be an ongoing debate about treadmill use versus elliptical use, and which one reigns superior over the other in regards to physiological and metabolic demands. It has been difficult to determine which one is “better” because both machines utilize similar body motions and involve full body movements in all of the limbs. Facilities such as athletic training rooms and rehabilitation clinics generally have a variety of cardiorespiratory equipment to choose from, but oftentimes it is difficult to reproduce the same/similar intensities between modalities. Prior to the popularity of elliptical cross-trainers, there were many studies conducted comparing these same variables between cycle ergometers and treadmills. However, new comparisons are needed for ellipticals and treadmills; because they are so similar in movement, it is possible that there might not be much of a difference metabolically and physiologically.

In 2010, Brown et al. studied the oxygen consumption (VO$_2$), energy expenditure and heart rate (HR) between a treadmill (TM) and an elliptical (EL) while exercising at the same RPE in healthy college students. According to the authors, a comparison like this had not been done before. After completing a maximal treadmill and a maximal elliptical VO$_2$ max test, subjects completed two separate, randomized 15-minute submaximal exercise tests; one TM and one EL at an RPE of 12-13. Following these tests, their data showed no significant mode-related differences in VO$_2$ peak or maximal
HR. The results of this study suggest that when healthy young adults exercise at the same intensity level on each of these modalities, they will have the same physiological benefits. Thus, this population has the ability and convenience to rotate between two different types of exercise, which may positively affect exercise adherence.

Similarly in 2001, Mercer, Dufek and Bates compared peak oxygen consumption and HR during TM running and ET exercise. Their aim was to determine whether or not the intensity levels and physiological responses on an ET correlated with those during TM exercise. They conducted two graded exercise tests (GXT) on physically-active college students on both the TM and the ET. There were no differences in VO2peak or peak HR, and all of the physiological responses were similar during all stages of the GXT. Just like the previous study by Brown et al. (2009), this demonstrates that healthy young adults do not need to adjust target heart rate ranges when switching exercise from a TM to an ET (or vice versa). This study also suggests that ET exercise is a viable alternative to running, which again could promote exercise adherence in those who are not able to run.

Much of the initial research on ellipticals looked solely at the physiological and metabolic responses in comparison to that of a treadmill. However, there was not anything done regarding exercise prescription.

Dalleck and Kravitz (2006) wanted to study a relationship between heart rate reserve (HRR) and VO2 reserve (VO2R) as they related to ET exercise in order for clinicians and exercise specialists to accurately prescribe exercise to those who were using them. Their other purpose was to compare these relationships to TM exercise. Their results showed that %HRR is indeed more closely related to %VO2R instead of VO2max;
these results also demonstrated equal physiological values between the TM and ET, which substantiates the evidence in prior studies that one does not need to adjust target HR or RPE when switching from a TM to an ET.

In 2004, Green, Crews, Pritchett, Mathfield and Hall studied the perceptual responses to intensity levels during ET exercise. Perception of how hard someone is working could be quite different than how intense it actually is, so gauging how individuals feel at a given RPE can assist in properly prescribing and regulating exercise across modalities. In this study they compared HR response with overall and differentiated RPE between individuals exercising on both a TM and an ET; the researchers also took into account RPE of arms and legs on the ET, and RPE of just legs on the ET as well. They did not find any significant differences between the two modalities.

Much of the research done on elliptical cross-trainers (ET) up to this point has been based around how they compare and contrast to treadmill exercise. Another common ground for these studies is that they all utilized apparently healthy [young] adults with exercise experience. Due to this fact, Sweitzer et al. (2002) studied the cardiopulmonary effects of elliptical cross-training (ET) versus treadmill (TM) walking in patients with coronary artery disease (CAD). Each subject (ages 47-79) completed multiple ET and TM exercise sessions at an RPE of 10 and an RPE of 14. They did not find any significant differences in VO₂ data between the two modalities at an RPE of 14, however they did see a significant difference between modes in absolute and relative VO₂ at an RPE of 10. ET exercise ended up producing higher metabolic and physiological (cardiovascular and ventilatory) results than TM exercise at an RPE of 10, and they did
observed significantly different HR values between modes at both RPE levels. These results demonstrate that ET exercise is a more effective form of exercise than TM exercise for patients with CAD when working at equal RPE levels. However, elderly patients may not be as comfortable using doing ET exercise as it requires more stabilization and balance, so they may be partial to TM exercise.

The elliptical cross trainer (ET) has increased in popularity over the years for many reasons, a big one being that it causes less impact on the lower extremities than running and is relatively easy to use. Elliptical exercise also produces similar physiological and metabolic responses to treadmill (TM) running, which has also made it an appealing exercise modality. The low impact of ET exercise is great for lower extremity longevity and orthopedic issues; however, it is still wise to compare the force of impact on ET to different modes of exercise, and to also evaluate the simplicity (or difficulty) of its use for different populations. People with physical disabilities routinely encounter barriers when it comes to exercise, as there are not as many options for them as compared to a healthy individual. This is another reason for more research to be done on the force of impact and accessibility of ET.

Burnfield, Shu, Buster and Taylor (2010) evaluated the joint kinematics and muscle activation of both walking on a TM and ET training in order to produce data that could be utilized in clinical and rehabilitation decision making. In this study they had 20 adults without physical disabilities that would negatively affect their gait walked and also trained on four different ET devices while measurements of electromyography (EMG) and kinematic and stride data were collected. They found that ET and walking produced similar movement patterns as was displayed by the high coefficients of multi-correlation
analysis for the hip, thigh, knee and ankle. They also observed larger flexion in the trunk, pelvis, hip and knee during ET exercise than walking, which could be attributed to the conscious effort to push the arm pieces forward. This study provides more insight for clinicians, practitioners and therapists on the differences, in regards to EMG, between walking and ET exercise. This affords them more evidence when making clinical decisions regarding the practicality of one mode over the other for their patients.

A similar study by Moreside and McGill (2012) analyzed the effect of different hand positions, speed and stride lengths on spine kinematics and compatible muscle activity on an ET compared to normal walking. The researchers collected EMG data from multiple trunk and gluteal sites from 40 healthy subjects across two stride lengths, two speeds (self-selected), and three different hand positions. The results displayed larger flexion angles and lumbar rotation when performing ET exercise, yet they saw more frontal plane motion in walking. Total lumbar flexion and extension motion was comparable amongst the two exercise modes, and they also noticed that different hand positioning had an effect on lumbar flexion and extension. Spinal motion is different in ET exercise than what is seen in traditional walking, which is something to consider when prescribing exercise to an individual; it is also important to consider hand placement on the ET as well as it can alter lumbar flexion and extension, which may or may not have adverse affects on a person’s spinal health.

In 2000 during the boom of elliptical (ET) popularity, Porcari, Foster and Schneider evaluated the effectiveness of ET exercise in a two-part study: first, comparing workout intensity between ET and several other exercise modalities, and second examining the vertical ground reaction forces in the feet between all of these modalities.
Much of this was driven by the fact that many types of exercise, like running, for example, produce much more force for the body to absorb upon impact, which has been linked to a variety of orthopedic issues. Subjects in this study completed 20-minute exercise sessions on each modality (separate days) at a self-selected exercise intensity. It was found that HR and oxygen consumption was essentially the same on both the ET and TM, with similar RPE values. However, the impact forces in the ET were more closely related to walking. In fact, the researchers saw impact of 2.5 times body weight greater in TM running. The results of this study demonstrate an elliptical’s ability to provide a wide range of workout intensities without the increased risk of orthopedic and overuse injuries. Since middle-aged adults and older adults often seek out activities that are low impact (often times walking and swimming), ET exercise can now serve as an aerobic alternative for them that is physiologically and metabolically just as good as running, without the wear and tear on their bodies.

As mentioned previously, ET has become a desirable exercise mode in rehabilitation and clinical settings because it is a low-impact exercise modality.

Burnfield, Shu, Buster, Taylor and Nelson (2011) examined the accessibility of this modality on adults with diverse medical conditions and functional capabilities. They analyzed data on the participant’s perceptions of safety, comfort, workout and usability of four elliptical cross-trainers before and after of low-cost adaptations were made to the machines. Before modifications (bench, steps, side rails, handles) were made, researchers found that 25 percent of the subjects required assistance to get on and off of the machine. After modifications were made, only one person required assistance. The data in this study demonstrates that ET machines have access barriers for those with diverse medical
and physical conditions. It would be beneficial for these individuals to have modifications set in place so that they can access them with ease and maintain or increase their physical fitness.

As has been stated, there is currently no research regarding the effectiveness of the ElliptiGO as an exercise training device. There are, however, numerous studies that have studied traditional indoor elliptical cross-trainers. Many of these studies were comparing ET exercise to treadmill (TM) exercise and the physiological responses produced from each. As a whole, it has been found that ET exercise affords individuals the same benefits as TM running, and better yet, the intensity levels overlap each other between modes. Other research that was conducted also evaluated the force produced during ET exercise as compared to other modes, and how much stress that puts on the body. As many often claim, elliptical cross-trainers do indeed place less orthopedic stress on the lower extremities, with the same physiological benefits experienced from running.

An exercise modality that is low-impact is usually more appealing to the general population. Enjoying exercise then, should lead to exercise adherence, and furthermore to meeting- and possibly exceeding-ACSM guidelines for cardiorespiratory fitness and strength training. Despite the popularity of elliptical cross-trainers though, the numbers are still looking grim; only 20 percent of U.S. adults are meeting physical activity recommendations. It is possible the ElliptiGO has the ability to relieve people of that boredom that often shies them away from exercise. If this product is very similar to its indoor counterpart (as far as its motions), it is promising that it can help people achieve the ACSM guidelines for physical fitness and beyond.
REFERENCES


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