Cardiopulmonary Measures for Submaximal Arm and Leg Ergometer Tests

This project makes no effort to suggest generalizability. Instead, it was designed to demonstrate competency using lab equipment, capacity to integrate knowledge with application, and understanding of the scientific method.

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INTRODUCTION

Arm ergometry (*Figure 1*) is an important training method for people who do not have function in their legs or athletes who primarily use their upper body in sports such as rowing (Brooks, Fahey & Baldwin, 2005). Leg ergometry (*Figure* 2) places a considerable load on the quadriceps depending on the wattage and revolutions per minute (RPM) that the individual is performing the exercise. It has been affirmed by studies that both ergometry tests are accurate and reliable representations of physical fitness (Eston & Brodie, 1986; Vander, Franklin, & Wrisley, 2016). Oxygen consumption (VO_2) reveals the cardiovascular system's ability to deliver oxygenated blood to exercising skeletal muscles and the capacity to extract oxygen from capillaries for the mitochondria to make adenosine triphosphate (ATP) for energy (Porcari, Bryant & Comana, 2015). Heart rate (HR) is is the amount of times a person's heart beats per minute (bpm), which is dependent on exercise intensity and duration (McArdle, Katch & Katch, 2015). Rate of perceived exertion (RPE) is a subjective way to measure physical activity intensity level based on how the individual feels while they are exercising. It can be influenced by a number of physiological responses including perceived heart rate, breathing rate, sweating, and muscle fatigue (Porcari, Bryant & Comana, 2015).

According to Eston & Brodie (1986), submaximal heart rates, oxygen consumption, minute ventilation, and rate of perceived exertion (RPE) at the same power output are higher in arms than during leg exercise, but work efficiency is lower in arm ergometry. VO_2, relative to body mass, is higher during arm ergometry because of the increased energy cost of stabilizing the upper body during this type of exercise (Brooks, Fahey & Baldwin, 2005). Additionally, Vander, Franklin, & Wrisley (2016) stated that cardiorespiratory responses for arm exercises produced a higher VO_2 than leg exercises at any given submaximal workload. Thus, the purpose of this study was to determine the differences in oxygen uptake between arm and leg ergometry, independent of gender and age. It was hypothesized that arm ergometry will display a higher oxygen uptake, heart rate, and RPE values than leg ergometry.

Figure 1. Subject performing arm ergometer test

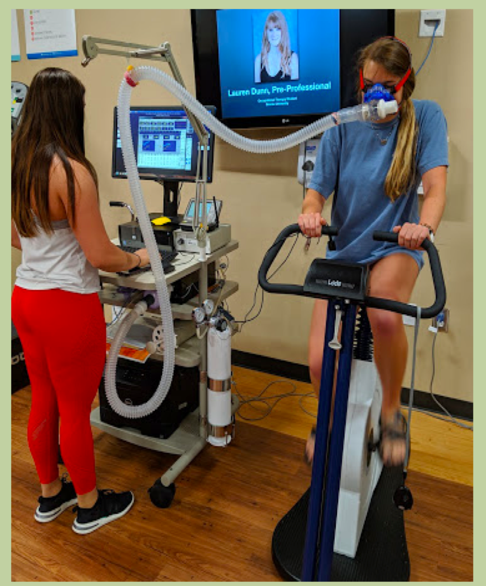

Figure 2. Subject performing leg ergometer test

METHODS

The four subjects were healthy college-aged female individuals. Parvo Medics TrueOne 2400 Metabolic Measurement System was warmed up 30 minutes prior to exercise testing, and subjects were debriefed on lab procedures. The Hans Rudolph mask was built and the seat height was adjusted for the leg ergometer. Two subjects exercised on the Monark arm ergometer and two subjects exercised on the Lode leg ergometer during the first testing day. The submaximal exercise tests served as the study's independent variable. The alternate test occurred on the second testing day at least 48 hours after the first testing day. Polar Heart Rate monitors were placed below the sternum on each subject and their target submaximal heart rate was calculated using the following maximal HR equation: 220 – Age. The dependent variables were HR, relative VO_2, and RPE.

Each subject warmed up for 2 minutes on the designated machine (either arm or leg ergometer), then the subject had a max of 5 minutes to reach 65% of their maximal heart rate through increased wattage and remained at this target heart rate for 10 minutes. For the arm ergometer, the subject started at 0 watts (W), then increased by 5 W every minute for five minutes or until the submaximal heart rate level was achieved. For leg ergometry, the subjects started at 50 W, then increased wattage by 10 W every minute for five minutes or until submaximal heart rate was achieved.

METHODS

The wattage remained consistent for the 10 minute steady-state exercise within ± 5 beats for submaximal heart rate. Participants were asked for RPE during the 10 minute steady-state. The Borg's RPE scale of 6-20 was used. For both tests, subjects were instructed to stay between 60 and 90 revolutions per minute (RPM) during the entirety of the tests. Following the 10-minute steady-state exercise, the participants began a 5-minute cool down. At this point, wattage was lowered to 0 W for the arm ergometer and 20 for the leg ergometer.

Following the exercise, the subjects were monitored for 5 minutes. The metabolic cart data was collected for each subject. Heart rate (HR), relative oxygen consumption (VO_2), and RPE were analyzed and compared between the arm and leg ergometry tests for each subject. Equipment was cleaned to rid it of any germs or potential biohazards. The process was repeated for each subject.

RESULTS

In *Table 1*, the mean, standard deviation, and range for relative VO_2, HR, and RPE are displayed. Subject 2 exhibited the highest VO_2 for both tests, with an average of 13.73 ml/kg/min and 22.52 ml/kg/min for arm and leg ergometer tests, respectively. Subject 1 had the lowest VO_2 for both tests, with an average of 7.34 ml/kg/min for arm ergometry and 3.73 ml/kg/min for leg ergometry. Heart rate averages remained between 130 and 140 BPM except for Subject's 4 arm ergometer HR average of 113 BPM. The correlations between all subjects' HR and VO_2 for arm and leg ergometry was -0.18 and 0.28, respectively.

Table 1. *Arm and Cycle Ergometry Descriptive Statistics*

		Subject 1		Subject 2		Subject 3		Subject 4	
		Arm Ergometer	Leg Ergometer	Arm Ergometer	Leg Ergometer	Arm Ergometer	Leg Ergometer	Arm Ergometer	Leg Ergometer
VO_2 (ml/kg/m)	Mean	7.34	3.73	13.73	22.52	7.46	10.44	10.33	14.35
	Standard Deviation	1.27	1.26	1.20	1.17	0.52	1.96	0.55	1.42
	Range	4.17-9.27	1.65-6.60	10.91-15.53	20.64-24.37	6.34-8.41	5.34-12.63	8.96-11.19	11.57-16.26
HR (BPM)	Mean	141	135	133	143	131	132	113	137
	Standard Deviation	4.96	1.69	6.01	7.50	3.46	8.39	3.09	4.93
	Range	126-146	133-138	119-144	127-151	124-136	118-145	106-117	125-143
RPE	Mean	14	11	12	12	11	12	15	10
	Standard Deviation	1.22	0.54	0.60	1.04	2.16	1.33	0.83	1.21
	Range	12-15	10-12	11-13	10-13	8-14	10-14	9-12	13-16

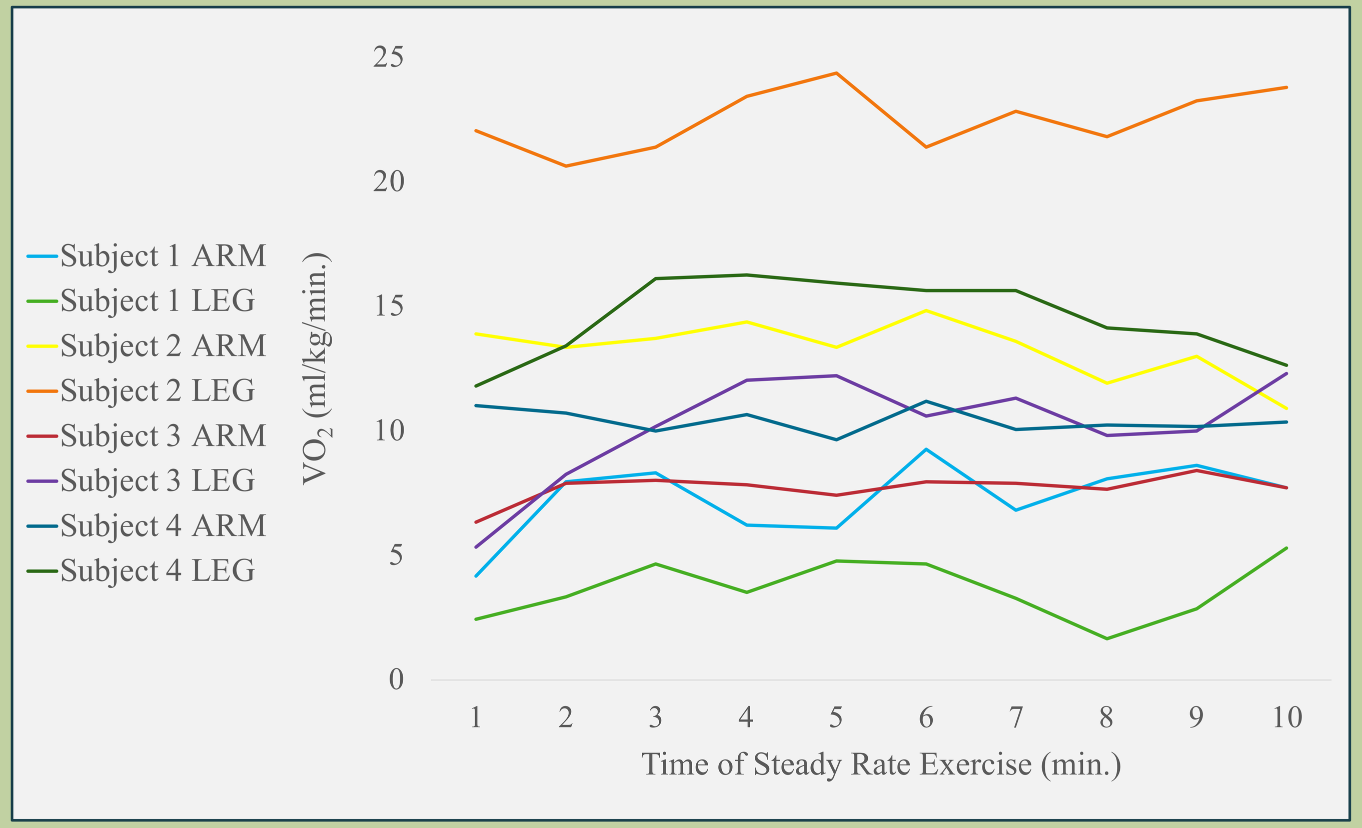

Figure 3. Arm and Leg Ergometer Results During Steady State Exercise

The VO_2 results for each subject during the 10-minute period of steady rate exercise is displayed in *Figure 3*. The first 7 minutes of the test, which included the 2-minute warm-up and 5 minutes of exercise to achieve target HR, were disregarded because the data collected during this time span did not reflect VO_2 at the target HR. In the figure, the significant difference in VO_2 during the leg ergometer test in Subject 2 as compared to the other subjects is quite evident.

DISCUSSION

The purpose of this study was to determine the difference in oxygen uptake between arm and leg ergometry. According to Bennett and authors (2015), submaximal testing is a valid means of assessing oxygen uptake. Oxygen consumption is defined as the amount of oxygen consumed by the tissues of the body (Thompson, 2010). At rest, the norm value of oxygen consumption is 3.5 ml/kg/min, or 1 MET (Thompson, 2010). Relative VO_2 is a better representation of true oxygen consumption because it accounts for an individual's body weight (Thompson, 2010). Additionally, at rest, HR for adults typically ranges from 60 to 100 beats per minute (BPM) with a lower HR implying a more efficient HR and better cardiovascular fitness (Shaffer & Ginsberg, 2017).

According to Brooks and colleagues (2005), the norm relative VO_2 during submaximal leg ergometry for an individual that is 70 kg, which is approximately the weight of the four subjects, is 11.9 ml/kg/min. The norm values for the submaximal arm ergometer test for a 70 kg individual is 12.6 ml/kg/min (Swain and authors, 1997). The results from this study did not support the hypothesis or past literature that arm ergometry will produce a greater oxygen uptake compared to leg ergometry. Three of the four subjects displayed a higher relative VO_2 during the leg ergometer test as compared to the arm ergometer test. Only Subject 1's results reflected the hypothesis. Equipment difficulties, the small sample size of four subjects, and the fact that the participants only completed one trial per test were all limitations and may explain why the results did not match the hypothesis.

The study has multiple real-life applications. In sports medicine, assessing the functional capacity of the cardiovascular system is essential (Sartor, Vernillo, Morree, Bonomi, Torre, Kubis, & Veicsteinas, 2013). Since this test directly measures oxygen consumption, the aerobic endurance capacity of each subject can be measured via arm ergometry or leg ergometry. Further, the study can be applied to clinical populations, such as patients with heart failure or coronary artery disease, or even asymptomatic adults. The calculated VO_2max from submaximal tests can be used for diagnostic and prognostic purposes (Sartor et al., 2013).

CONCLUSION

The data did not support the hypothesis of arm ergometry providing a higher VO_2, HR, and RPE than leg ergometry. Only one of the four subjects exhibited an average VO_2 and HR that could support this study's hypothesis. In this study, HR and VO_2 were shown to have a weak correlation for both arm and leg ergometry. The study was limited to one trial per test. If the participants perform additional tests, the data may more closely reflect the hypothesis. Additionally, the study was limited to four female participants. In order to improve the experiment, a greater number of subjects and an increased number of trials could be employed to provide additional data points.

REFERENCES

Bennett, H., Parfitt, G., Davison, K., & Eston, R. (2015). Validity of submaximal step tests to estimate maximal oxygen uptake in healthy adults. *Sports Medicine, 46*(5), 737-750. doi: 10.1007/s40279-015-0445-1

Brooks, G. A., Fahey, T. D., & Baldwin, K. M. (2005). *Exercise physiology: Human bioenergetics and its application, fourth edition.* New York, NY: The McGraw-Hill Companies, Inc.

Eston, R. G. & Brodie, D. A. (1986). Responses to arm and leg ergometry. *British Journal of Sports Medicine, 20*(1), 4-6. doi: 10.1136/bjsm.20.1.4

McArdle, W. D., Katch, F. I., & Katch, V. L. (2015). *Exercise physiology: Nutrition, energy, and human performance, eighth edition*. Baltimore, MD: Lippincott Williams & Wilkins.

Porcari, J., Bryant, C., & Comana, F. (2015). *Exercise physiology*. Philadelphia, PA: F. A. Davis Company.

Sartor, F., Vernillo, G., Morree, H. M., Bonomi, A. G., Torre, A. L., Kubis, H., & Veicsteinas, A. (2013). Estimation of maximal oxygen uptake via submaximal exercise testing in sports, clinical, and home settings. *Sports Medicine, 43*(9), 865-873. doi:10.1007/s40279-013-0068-3

Shaffer, F., & Ginsberg, J. P. (2017). An overview of heart rate variability metrics and norms. *Frontiers in Public Health, 5.* doi:10.3389/fpubh.2017.00258

Thompson, D. (2010). What is oxygen consumption? *ACSM's Health & Fitness Journal, 14*(1), 4. doi:10.1249/FIT.0b013e3181c63f46

Vander, L. B., Franklin, B. A., & Wrisley, D. (2016). Cardiorespiratory responses to arm and leg ergometry in women. *The Physician and Sports Medicine Journal, 12*(5), 101-106. doi: 10.1080/00913847.1984.11701848