

UNIVERSITY OF WISCONSIN-LA CROSSE

Graduate Studies

EXERCISE RESPONSES DURING A MAXIMAL KRANKCYCLE AND CYCLE
ERGOMETER TEST

A Manuscript Style Thesis Submitted in Partial Fulfillment of the Requirements for the Degree
of Masters of Science

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College of Science and Health
Clinical Exercise Physiology

December, 2010

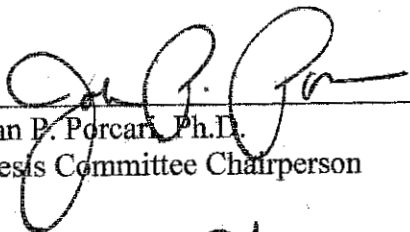
EXERCISE RESPONSES DURING A MAXIMAL KRANKCYCLE AND CYCLE

ERGOMETER TEST

By Chad R. Johnson


We recommend acceptance of this thesis in partial fulfillment of the candidate's requirements for the degree of Masters of Science in Clinical Exercise Physiology

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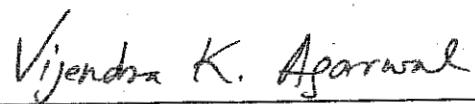
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ABSTRACT

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Purpose: The purpose of this study was to compare exercise responses during maximal Krankcycle and cycle ergometer tests. **Methods:** Fourteen apparently healthy subjects, aged $22.9 \pm .95$ years, volunteered for the study. The subjects performed five 10-minute habituation trials on a Krankcycle prior to performing their maximal exercise tests. Subjects then completed a maximal Krankcycle and cycle ergometer test in random order. HRmax was measured with radiotelemetry while VO_2 was measured using an AEI metabolic system. RPE was assessed using the 6-20 Borg RPE scale at the end of each stage. During the Krankcycle test, arm specific RPE was measured to assess upper body fatigue in addition to total body RPE.

Results: VO_{2max} for men and women was 12% and 16% higher on the cycle ergometer, respectively. No difference in HRmax was seen between tests. Higher HRs and lower O_2 pulse values were seen at submaximal workloads on the Krankcycle, indicating a pressor response. Maximal workload was 261 watts for the cycle ergometer test compared to 151 watts during the Krankcycle test. **Conclusions:** On average, subjects had lower VO_{2max} values on the Krankcycle compared to the cycle ergometer. Higher HRs were seen on the Krankcycle at any given submaximal workload, indicating that exercise prescription on a Krankcycle should not be prescribed based on lower body workloads.

ACKNOWLEDGEMENTS

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INTRODUCTION

Regular physical activity is important in order to maintain good health and physical independence. The Centers for Disease Control (CDC) and the American College of Sports Medicine (ACSM) recommend that all healthy adults between 18-65 years of age should perform moderate-intensity aerobic physical activity for a minimum of 30 minutes on 5 days each week or vigorous-intensity activity for a minimum of 20 minutes on 3 days each week (6). Regular exercise can elicit many health benefits such as reduced blood pressure and cholesterol, increased cardiorespiratory endurance, and has been shown to reduce the incidence for chronic diseases such as coronary heart disease, hypertension, and osteoporosis (11). Regular physical activity is also considered essential for weight management and reducing the incidence of obesity (9).

Individuals are always searching for new and effective ways to exercise and become more physically fit. Instructor-led fitness classes are very popular and are being offered more frequently in fitness clubs and college recreational facilities across the country. One of the more recent instructor-led exercise classes to emerge is indoor cycling (spinning). Research has found that spinning training bouts have elicited exercise intensities ranging from moderate to high intensity (2, 4, 5) which meets the ACSM guidelines for improving cardiorespiratory endurance (1). The high intensity intervals during a typical class have been shown to exceed VO_{2max} , which could be detrimental in

sedentary and aged populations that may have reduced exercise tolerance or undetected cardiovascular disease (2, 4, 5).

A new type of instructor-led fitness class that has recently emerged is a cycle-type exercise known as Kranking (9). Similar in concept to an upper body ergometer, the Krankcycle has independent crank arms and a rhythmical rotating fly wheel with a resistance knob to provide an upper body and core workout. The independent crank arms allow for a variety of movement patterns on the Krankcycle. Some of the movement patterns include single arm cycling, synchronization using double arm cycling, and split arm pattern cycling. Whether using one or both arms at a time, difficulty levels may vary depending on the position of the body during exercise. For example, Kranking while standing and/or staggering the feet will engage the whole body, which may utilize different muscles, compared to the same exercise performed while sitting. Kranking while standing on one foot can help enhance coordination and balance during a workout. Some of the potential uses of Kranking include core and upper body strengthening, balance and coordination development, and cross-training for total body endurance. Kranking may also be beneficial for special populations, such as those with disabilities or lower extremity injury (9).

Historically VO_2max has been measured using exercise modalities such as a treadmill or cycle ergometer. However, VO_2max can be measured using an upper body ergometer and has shown to provide valid VO_2 values (13). In addition, arm cranking, in particular, standing arm cranking, has become increasingly popular as a means of assessing upper limb performance (12). When using arm ergometry, certain variables

need to be taken into consideration during maximal testing. Some factors that may influence the performance and reproducibility of maximal arm ergometry testing include cadence (crank-rate), differences in muscular strength, localized muscular fatigue, body position, arm movement/pattern, crank length and crank-axle height. Secher and Volianitis (12) found that arm VO_2 max is around 30% lower than that of the leg. Although in some highly trained athletes such as rowers, swimmers, bodybuilders and elite yacht racing grinders, arm VO_2 max may surpass that of the leg. Neville et al. (8) performed a study showing that changes in crank length and crank-axle height attenuate performance during maximal standing arm-crank ergometry. It was found that the best performance utilized a crank length of 12 to 12.5% of arm span and a crank-axle height of 50 to 60% of stature (8).

Because Kranking is relatively new, to our knowledge no studies have been published on this exercise modality. A recent thesis conducted by Boyer et al. (4) at the University of Wisconsin-La Crosse documented the relative exercise intensity and energy expenditure of a Krankcycle workout. The study found that subjects worked at an average of 86% of maximal heart rate (HRmax) and 72% of maximal oxygen consumption (VO_2 max) (4). During segments of the workout, HR and VO_2 exceeded maximal values obtained during laboratory testing.

Even though Kranking provides a high intensity workout (4), HR and VO_2 responses during a maximal exercise test have not been reported. Additionally, caloric expenditure during Kranking was estimated using the HR/ VO_2 regression equation developed from each subject's maximal arm ergometer test, not a Kranking test. The

purpose of this study is to evaluate and compare the physiologic responses (HR, VO₂, and RPE) during maximal Kranking and cycle ergometer tests.

MATERIALS AND METHODS

Subjects

The study population consisted of 14 men and women between the ages of 22 to 25 years, who were apparently healthy. These volunteers were recruited from the University of Wisconsin-La Crosse campus through word of mouth and personal invitation from the researcher. This population was selected for the study due to the high exercise intensity of the workouts required and because they represent healthy, physically fit individuals who might take part in a Kranking class at a local gym. After approval from the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects, individuals provided informed consent prior to beginning any testing procedures.

Procedures

Over the course of the study subjects performed two exercise tests: an incremental cycle ergometer maximal test and an incremental Krankcycle maximal test. Subjects were asked to perform five 10-minute habituation trials prior to their maximal tests to help develop the necessary muscular endurance and skills to complete the Krankcycling test. The habituation trials were performed on an instrumented Matrix Krankcycle (Johnson Health Tech North America, Inc, Cottage Grove, WI). After the habituation trials were completed, subjects performed the two maximal exercise tests in random order.

Men and women used protocols that accommodated for the differences in arm and leg strength between genders. This was done to keep the overall test times between the cycle ergometer and Krankcycle as close as possible.

The cycle ergometer test was performed on an electrically braked cycle ergometer (Lode Excalibur, Groningen, NL). For men, the test started at 35 watts and increased by 35 watt increments each stage. Women started at 30 watts and increased by 30 watt increments each stage. All tests went to volitional exhaustion.

For the Krankcycle test each subject used a specially designed Krankcycle, which was instrumented to give a visual display of workload. In addition, the protocol was adjusted to match total cycle ergometer time knowing that upper body strength is approximately 30% lower than that of the lower body in the average individual (12). Ideally, total test times of 8 to 12 minutes (1) are preferred, assuming the endpoint is volitional exhaustion. Similar to the cycle ergometer test, the test progressed differently for men and women to account for differences in upper body strength between genders. Thus, work rate increments of 25 and 20 watts were utilized by men and women, respectively. In order to control workload, subjects were encouraged to maintain cadence during each stage of the maximal exercise test. Subjects utilized a cadence of 70 revolutions per minute (rpm) for the first stage, 80 rpm for the next three stages (2, 3, and 4 stages), 90 rpm for the following two stages (5 and 6 stages) and 100 rpm for higher workloads. Due to the influence of crank-axle height on performance during maximal standing arm-crank ergometry, crank height was set to at least 50% of stature (8). During

the test subjects utilized a standing, staggered stance with synchronizing (doubles) arm movement.

For all testing, expired gases were measured using an AEI metabolic system (Naperville, Illinois) and HR was measured using a Polar HR monitor. Perceptual responses were assessed using the 6-20 Borg Ratings of Perceived Exertion (RPE) scale at the end of each 2-minute stage and at maximal exertion (3). During the Krankcycle workout, subjects indicated an overall RPE value and an upper body specific RPE.

Statistical Analysis

Descriptive statistics were used to characterize the subject population. Comparisons between genders for pre-testing variables were made using independent t-tests. Repeated measures ANOVA were performed to compare Krankcycle and cycle ergometer maximal exercise performance between genders. Statistical analysis was conducted using SPSS Statistical Software, Version 17.0. Alpha was set at .05 to achieve statistical significance.

RESULTS

Subject demographics are presented in Table 1. Males and females were similar in age, but males were heavier and taller than the women. All 14 subjects completed a maximal cycle ergometer and maximal Krankcycle test. The maximal values for the cycle ergometer and Krankcycle tests are presented in Table 2.

Table 1. Demographics of the Subject Population

Variable	Females (n=7)	Males (n=7)	Total (N=14)
Age (yrs)	22.7 ± .49	23.0 ± 1.29	22.9 ± .95
Height (in)	66.3 ± 1.89 *	71.9 ± 2.27	69.1 ± 3.52
Weight (lbs)	149.6 ± 15.95 *	202.6 ± 23.66	176.1 ± 33.64

*Significantly different than males (p < .05)

Table 2. Physiologic Responses to the Maximal Cycle Ergometer and Krankcycle Tests

Variable	Cycle Ergometer		Krankcycle	
	Females	Males	Females	Males
HRmax (bpm)	173 ± 15.0	180 ± 7.1	172 ± 17.1	178 ± 10.9
VO ₂ max (ml/kg/min)	44.3 ± 3.62	49.6 ± 9.31 *	36.9 ± 4.09 #	44.2 ± 6.59 **
V _E max (L/min)	102 ± 16.9	158 ± 24.2 *	89 ± 18.2 #	148 ± 14.6 **
RERmax	1.03 ± .050	1.05 ± .041	1.00 ± .058	1.07 ± .051
Test Time (min)	14:18 ± 2:17	16:57 ± 1:32 *	12:34 ± 1:17 #	15:35 ± 1:50 **
MaxWatts	223 ± 38.2	300 ± 27.5 *	118 ± 15.3 #	184 ± 19.7 **
MaxRPE (Total Body)	19.3 ± 1.11	19.0 ± 1.16	16.9 ± 1.35 #	16.9 ± 1.07 #
MaxRPE (Arm Specific)			19.4 ± .79	19.3 ± .76

* Significantly different than females (p < .05)

Significantly different than cycle ergometer (p < .05)

There was no significant difference between cycle ergometer and Krankcycle HRmax values. VO_2 max was significantly higher on the cycle ergometer compared to the Krankcycle by 12% and 16% for males and females, respectively. Men had higher a VO_2 max than females on both tests. Maximal power output on the cycle ergometer test was significantly higher than the Krankcycle test (261 vs. 151 watts), and again males had significantly higher values than females. On average, maximal power output values were 73% higher during the cycle ergometer test. Test time for the Krankcycle test was significantly lower than the cycle ergometer test for both males and females. Total body RPE for the cycle ergometer was significantly higher than the Krankcycle total body RPE. However, the Total Body RPE value on the cycle ergometer was not significantly different than the arm specific RPE on the Krankcycle. Maximal ventilation (V_E max) for males was significantly higher during both tests compared to females and ventilation was significantly higher during the cycle ergometer test compared to the Krankcycle test.

Figures 1 and 2 present the relationship between HR, VO_2 , and workload (watts) during the submaximal stages of the maximal cycle ergometer and Krankcycle tests. Because the Krankcycle and cycle ergometer tests used different workloads, regression equations were calculated from the Kranking VO_2 and HR data in order to extrapolate to equivalent stages on the cycle ergometer test. The submaximal relationships were not tested statistically; however, it can be seen that at any given workload, HR was higher on the Krankcycle compared to the cycle ergometer (Figure 1). Conversely, VO_2 was higher at any workload on the cycle ergometer compared to the Krankcycle (Figure 2). Calculated oxygen pulse (O_2 pulse) values are presented in Figure 3. At any given

workload, O₂ pulse values were higher on the cycle ergometer, indicating a more effective delivery of oxygen during exercise.

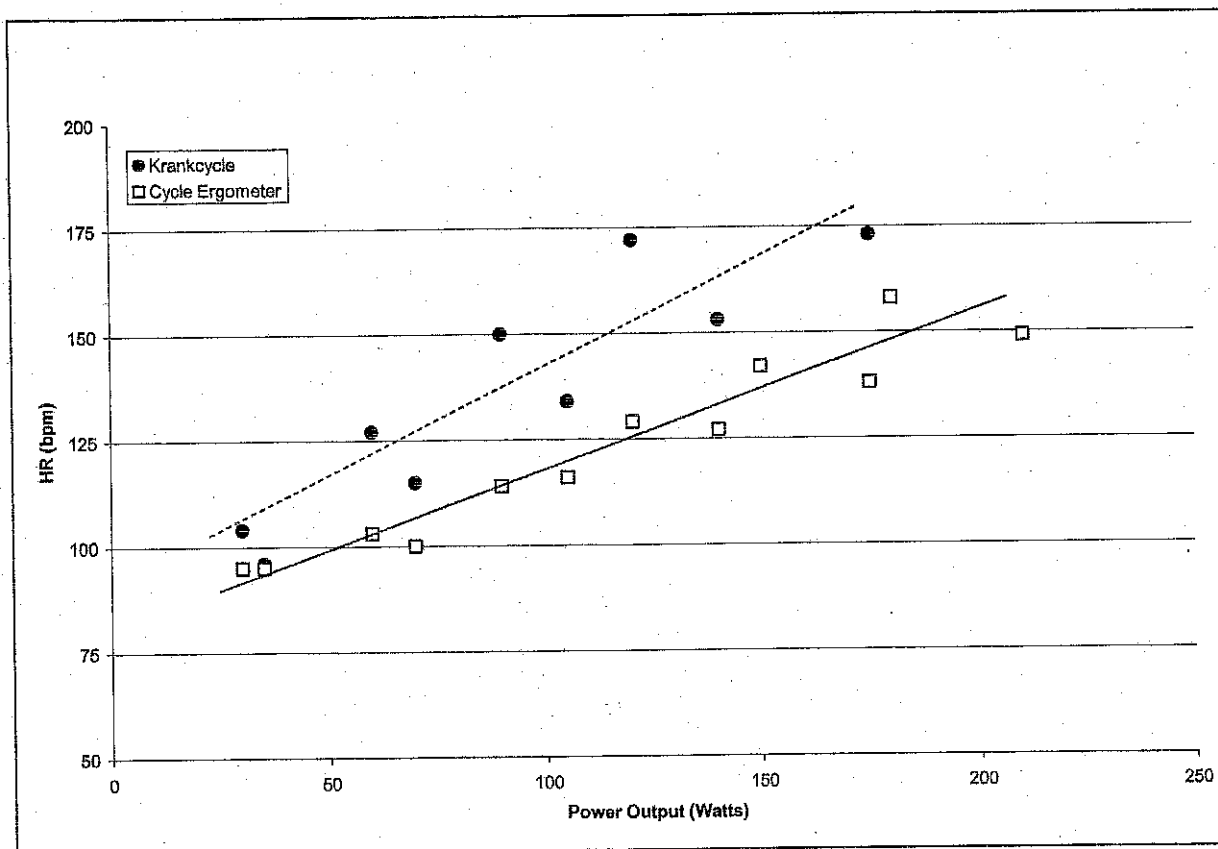


Figure 1. Average HR Responses at Submaximal Workloads During the Maximal Krankcycle and Cycle Ergometer Tests

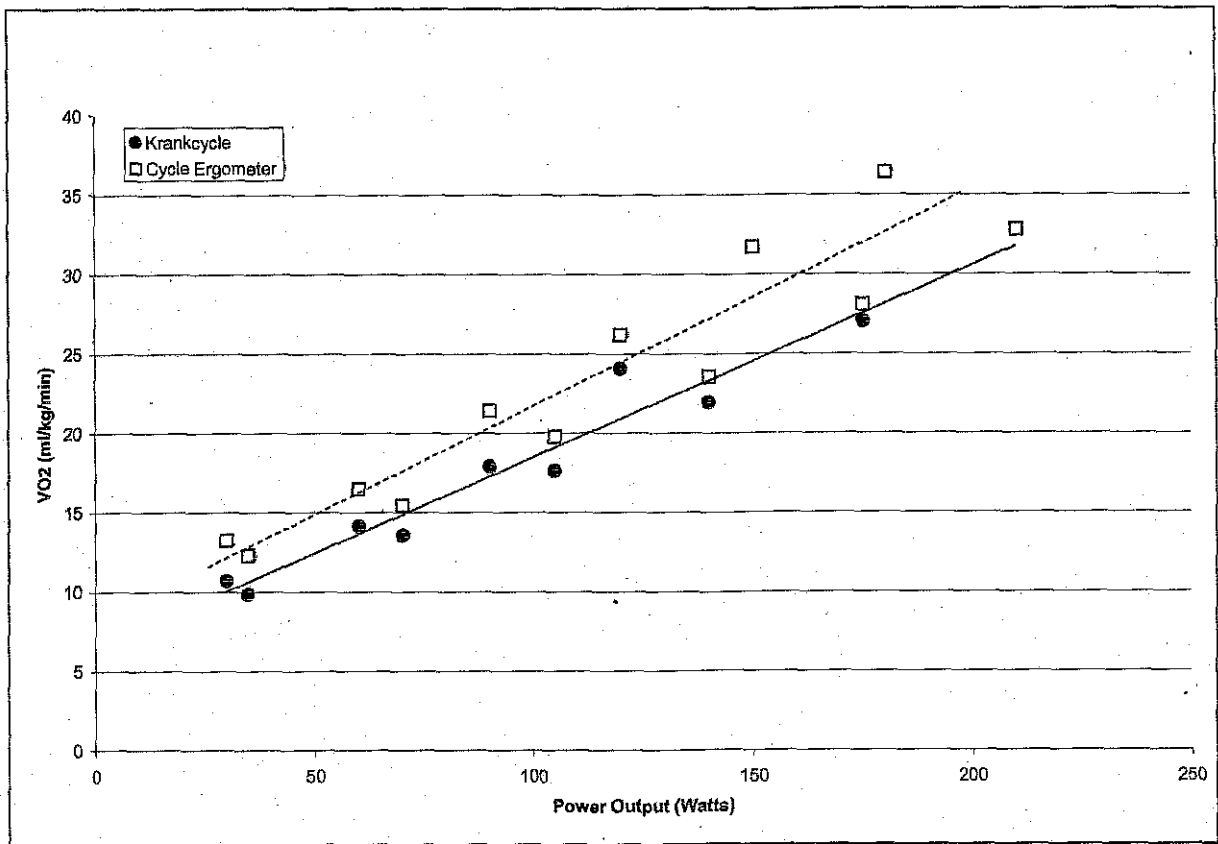


Figure 2. Average VO₂ Responses at Submaximal Workloads During the Maximal Krankcycle and Cycle Ergometer Tests

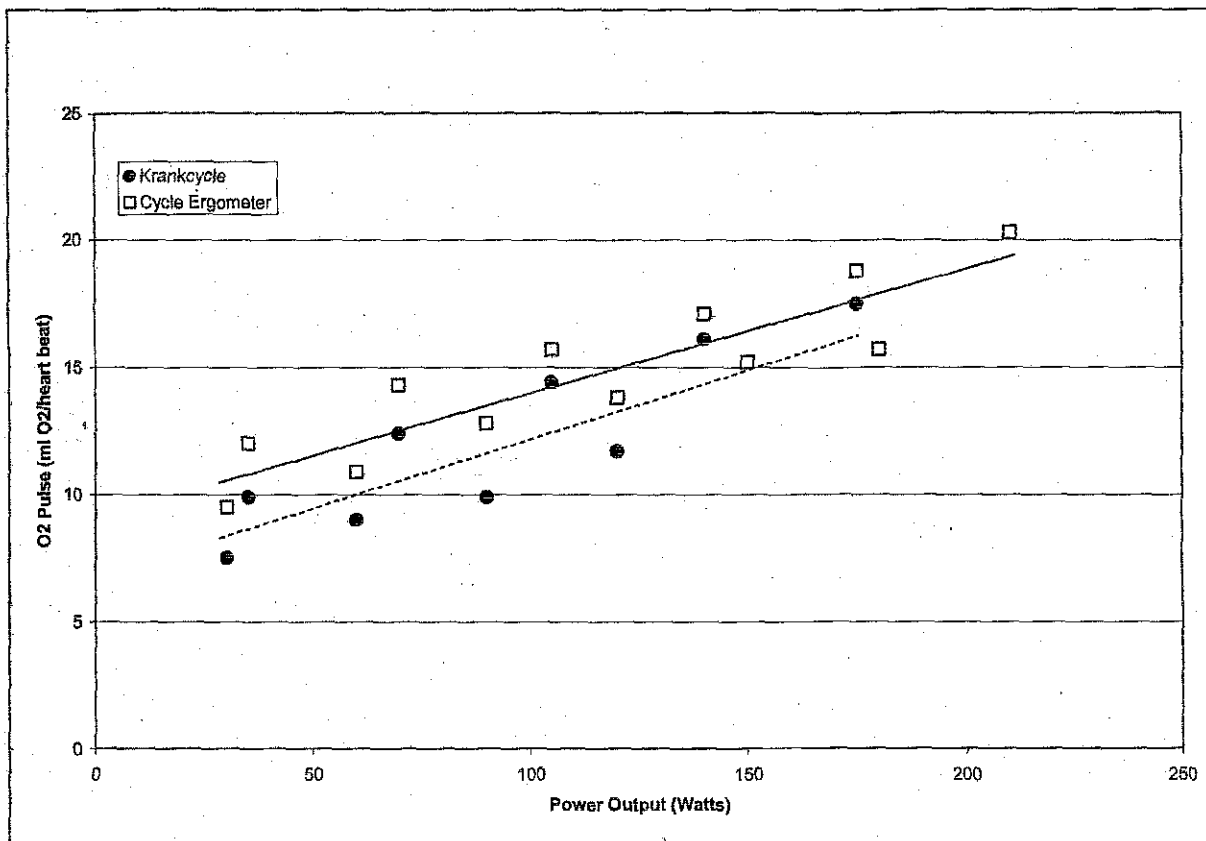


Figure 3. Average O₂ Pulse at Submaximal Workloads During the Maximal Krankcycle and Cycle Ergometer Tests

DISCUSSION

The main purpose of the study was to compare the exercise responses during a maximal Kranking and cycle ergometer test. VO_{2max} was 12% higher for men and 16% higher for women on the cycle ergometer compared to the Krankcycle. During traditional upper body ergometry (UBE) VO_{2max} is typically 30% lower than that of the leg (12). The smaller gap between leg and arm VO_{2max} in this study can be attributed to a number of factors. First, during the Krankcycle test subjects were in a standing position with a staggered stance. This allowed each individual to utilize more muscle mass (e.g., their legs, shoulders and core muscles) to generate force during the test. During

traditional arm ergometry, the subject is usually seated, which results in a lower amount of muscle mass involved in the exercise. Secondly, the Krankcycle allows subjects to adjust the crank-axle height to accommodate stature. Due to the influence of crank-axle height on performance during maximal standing arm-crank ergometry, crank height was set to at least 50 percent of stature (8) during all Kranking tests. Finally, subjects completed five training sessions on the Krankcycle prior to performing their maximal test. This helped each individual acquire the upper body coordination, skill, and endurance necessary to complete the Krankcycle test.

It was noticed that there was wide individual variation in the differences between the cycle ergometer and Krankcycle VO_2 max values. Two male subjects actually surpassed their cycling VO_2 max on the Krankcycle test. Both of these individuals were very strong and routinely performed a lot of upper body resistance training. Conversely, one female subject only achieved 70% of her cycling VO_2 max during the Krankcycle test. It was felt that her lack of upper body strength made it difficult to achieve and maintain the higher workloads, thus limiting her performance on the Krankcycle test.

The Krankcycle elicited higher HRs and lower VO_2 values at any absolute submaximal workload when compared to the cycle ergometer. This indicates that during arm Kranking the cardiovascular system was less efficient at delivering oxygen to the working muscles during the exercise. An indicator of oxygen delivery is oxygen pulse (ml O_2 /heart beat). During upper body exercise, like Krankcycling, small muscle groups are working at a higher percent of maximal voluntary contraction strength (%MVC) compared to larger muscle groups that are used during lower body exercise. In addition,

high intramuscular forces in these muscles increases total peripheral resistance (TPR). Because of increased TPR, HR must increase to compensate for a drop in stroke volume (SV). As a result, HR is disproportionately elevated relative to oxygen consumption. This has implications for exercise prescription. Because there is a difference in the HR/VO₂ relationship between arm work and leg work (e.g., stationary cycling or treadmill exercise), prescribing exercise heart rates based on these modalities may not be appropriate for individuals who are going to train on a Krankcycle.

During the Krankcycle test, subjects gave two RPE ratings at the end of each stage; first for total body RPE and second for arm specific RPE. This was done to determine if arm fatigue limited the ability of each subject to exercise to exhaustion. It was found that total body RPE was significantly greater at each submaximal stage and at maximal exercise during cycle ergometry compared to Kranking. However, arm specific and total body RPE were similar between males throughout the entire test. This indicates that arm fatigue was a major limiting factor during the test, which is consistent with a previous Kranking study (4).

There were a number of limitations to consider in this study. First, the instrumented Krankcycle used a traditional resistance flywheel to adjust the workload, instead of an electrically-braked system. The power tap (Saris CycleOps Inc, Verona, WI) used on the Krankcycle did not allow for fixed workloads, thus workload had to be controlled by using a resistance knob and cadence. As a result, sometimes it was difficult to achieve and maintain the targeted watt level. Maintaining an even cadence became even more of a problem as subjects attempted higher workloads.

For some women with less upper body strength, arm fatigue was more apparent and may have contributed to premature test termination and probably affected their maximal responses. Even though each subject practiced the Kranking protocol for five sessions prior to their maximal test, upper body fatigue might have affected performance. It is possible that with more practice training, there would have been less of a difference in VO_2 max between cycle ergometry and Krankcycling.

There remain many opportunities for future research on the Krankcycle. Currently, the only populations studied have been college-aged individuals that are apparently healthy. It would be interesting to study exercise responses in highly trained athletes such as rowers, swimmers, and elite yacht racing grinders. In addition, the versatility of the Krankcycle provides avenues for future research with special populations that have lower extremity disabilities. Another area for future research would be a training study on the Krankcycle. The company claims that using the Krankcycle can improve upper body and core strength, improve balance and coordination, and improve total body endurance. To date, these claims have not been verified. Directly measuring caloric expenditure during a typical 30-minute training session also remains to be determined, since the study by Boyer et al. (4) estimated caloric expenditure from HR/ VO_2 regression equations derived from a traditional arm ergometer test.

CONCLUSION

This study compared the maximal responses during a Krankcycle and cycle ergometer test. On average, VO_2 max values were lower during the Krankcycle test compared to the cycle ergometer test, but this can vary depending on the strength and

experience of the subject. There was also a potent pressor response during submaximal exercise, as indicated by higher HRs at any given workload and lower O₂ pulse values during Krankcycling compared to cycle ergometry. This has implications for exercise prescription and implies that target heart rates for Kranking can not be derived from exercise tests using lower body modalities.

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APPENDIX A

INFORMED CONSENT DOCUMENT

INFORMED CONSENT DOCUMENT

Protocol Title: Exercise Responses During a Maximal Krankcycle and Cycle Ergometer Test

Principal Investigator: Chad Johnson
225 Mitchell Hall
University of Wisconsin-La Crosse
La Crosse, WI 54601
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Emergency Contacts: Chad Johnson
Phone #: 608-844-0776
John P. Porcari
Phone #: 608-785-8684

I, _____ (print name) give my informed consent to participate in a research study designed to investigate the number of calories burned during a typical Krankcycling workout.

• *Purpose and Procedure*

- The purpose of this study is to determine the number of calories burned during a typical Krankcycle workout.
- My participation will involve a total of 6-8 laboratory sessions:
 - 4-6 will be 15-minute habituation trials on an upper body ergometer
 - One will be a maximal exercise test on a Krankcycle
 - The final session will be a maximal exercise test on a cycle ergometer.
- The total time requirement, including practice time will be approximately 3 hours over a 3-4 week period.
- Testing will take place in room 225 Mitchell Hall, at the University of Wisconsin-La Crosse.
- During all of the tests, I will be wearing a snorkel-like device to analyze my breathing and a strap around my chest to measure my heart rate.
- Periodically I will be asked to point to numbers on a chart to identify the difficulty of the exercise.

• *Potential Risks*

- I may experience substantial fatigue and muscle soreness during the practice and testing laboratory sessions.
- Individuals certified in CPR and Advanced Cardiac Life Support will be in the laboratory during all testing. Testing will be terminated if complications occur.

- The potential risk of serious or life-threatening complications, for healthy individuals, like myself, is near zero.

- ***Rights and Confidentiality***

- My participation is voluntary.
- I have the right to withdraw from the study at any time for any reason without penalty.
- The results of this study may be published in scientific literature or presented at professional meetings using grouped data only.
- All information will be kept confidential through the use of number codes. My data will not be linked with personally identifiable information.

- ***Possible Benefits***

- I will gain knowledge of my maximal aerobic capacity as well as my maximal heart rate.
- I and other exercisers or athletes may benefit by understanding the potential benefits of exercising on the Krankcycle.

Questions regarding study procedures may be directed to Graduate Student Chad Johnson (608-844-0776), the principal investigator, or the study advisor Dr. John P. Porcari, Department of Exercise and Sport Science, UW-L (608-785-4321). Questions regarding the protection of human subjects may be addressed to the UW-La Crosse Institutional Review Board for the Protection of Human Subjects, (608-785-8124 or irb@uwlax.edu).

Participant _____ Date _____

Researcher _____ Date _____

APPENDIX B

BORG'S RATING OF PERCEIVED EXERTION SCALE

Table 3. Borg's Rating of Perceived Exertion Scale

6	
7	Very, very light
8	
9	Very light
10	
11	Fairly light
12	
13	Somewhat hard
14	
15	Hard
16	
17	Very hard
18	
19	Very,very hard
20	

* Borg G.A. Perceived exertion: a note on "history" and methods. *Med Sci Sports Exerc.* 5: 90-93, 1973.

APPENDIX C

REVIEW OF RELATED LITERATURE

REVIEW OF RELATED LITERATURE

Introduction

Lack of physical activity remains a concerning public health issue. With advances in technology people are engaging in less activity and tend to favor a sedentary lifestyle (15). In addition, only 49% of U.S. adults are meeting the Centers for Disease Control and the American College of Sports Medicine's (CDC/ACSM) physical activity recommendations and roughly 23% of adults reported no leisure-time activity (15). Despite the overwhelming benefits associated with regular physical activity people fall far short of the recommended amounts of activity for a healthy lifestyle. While an impressive amount of new cutting-edge fitness equipment surface each year, fitness clubs and recreational centers across the country are always searching for the next best workout machine or routine to attract individuals to the gym. One area in fitness that has grown increasingly popular over the last decade is instructor-led classes that incorporate a group-oriented exercise to motivate the individual to push themselves through a workout. One of the most recent cycle-type classes to emerge is called Krankcycling. Similar in concept to an Upper Body Ergometry (UBE), the Krankcycle uses independent crank arms and a rhythmical rotating fly wheel to provide an upper body and core workout. Throughout the following review of literature we will address the need for exercise, specifically, physical activity that meets the American College of Sports Medicine's

recommendations. Current exercise prescription and testing used for maximal aerobic capacity (VO_{2max}) will be explored. An introduction to the benefits and risks of instructor led spinning classes will be discussed, and finally, a review of the benefits of arm cranking and the newest cycle-type machine known as the Krankcycle will be introduced.

Sedentary Lifestyle and the Need for Exercise

Sedentary lifestyles are a major public health issue that we face today. Unfortunately, only 49% of U.S. adults meet the Centers for Disease Control and the American College of Sports Medicine's (CDC/ACSM) physical activity recommendations and roughly 23% of adults reported no leisure-time activity (15). Increasing reliance on technology at work and home, more attractive sedentary options for leisure time, and the elimination of energy expenditure from activities of daily living have decreased the amount of physical activity for the majority of people (4). The challenge for the fitness industry is to develop programs that can attract and motivate individuals to become physically active in our increasingly sedentary society. Carnethon et al. (10) describe the prevalence of low fitness in one-third of adolescents and showed that adult females are nearly 16% lower than male fitness levels. In addition, more than one-third of the difference in life expectancy in U.S. African-American adults and White-Caucasian adults is attributed to cardiovascular diseases (9). Numerous risk factors for cardiovascular disease, including but not limited to hypertension, diabetes, and hypercholesterolemia, have been shown to be influenced by low fitness and their contribution to increased mortality (8). Despite the overwhelming benefits associated

with regular physical activity, people fall far short of the recommended amounts of activity for promoting a healthy lifestyle. Physical activity is important in order to maintain good health and physical independence. Regular exercise has elicited many health benefits such as reduced blood pressure and cholesterol, and increased cardiorespiratory endurance (15). People who obtain adequate aerobic exercise have shown a decrease risk for developing stroke, some forms of cancer, type 2 diabetes, obesity, osteoporosis, sarcopenia, and loss of function and autonomy in older ages (4). Other benefits associated with exercise in resistance training programs are weight management, increased physical autonomy and lean muscle mass, improved muscular strength, endurance, coordination and motor skills, increased flexibility, and strengthening of the cardiovascular system (15, 30). Recent studies have shown that reduced physical activity patterns and exercise capacity is a more powerful predictor of mortality than other established risk factors for cardiovascular disease (22, 26). Studies have also shown a lower rate of cardiovascular mortality in individuals who had moderate to high amounts of aerobic activity in their leisure time (4) and lower rates from all causes and cancer mortality (18).

ACSM Exercise Recommendations and Prescription

Exercise recommendations and prescription are an integral part of developing an effective program that helps meet the needs of each individual pursuing a fitness plan. In order to promote and maintain a healthy lifestyle, the American College of Sports Medicine (ACSM) has implemented recommendations that suggest 30 minutes or more of moderate-intensity physical activity on most, preferably all, days of the week (15).

Updated recommendations specify that all healthy adults aged 18 to 65 years of age need moderate-intensity aerobic physical activity for a minimum of 30 minutes on 5 days each week or vigorous-intensity activity for a minimum of 20 minutes on 3 days each week (1, 15). These guidelines established by the ACSM and the CDC are the minimum requirements in order to maintain health but if you want to further improve fitness, additional amounts of physical activity are recommended. Additionally, resistance training should be integrated into the fitness program that is progressive (increase in weight and length of time) and individualized to each person (15). ACSM recommends 1 set of 8 to 10 exercises and between 8 to 15 repetitions that works the major muscles groups 2 to 3 days a week (1, 15).

Exercise prescription is an important part of any effective fitness program. It is a detailed exercise program designed specifically for an individual that can improve physical fitness while keeping you safe and injury-free. Indicators of aerobic capacity that are used for prescribing exercise include maximal heart rate (HR_{max}), maximal oxygen uptake (VO_{2max}), and ratings of perceived exertion (RPE) values. In order to determine aerobic capacity, ACSM recommends exercising between 40 to 85% of VO_{2max} (1, 2, 15). The range of exercise intensity can be broken down further into lower (moderate) and upper training zones (intense) with 40 to 60% of VO₂ achieving health benefits and 60 to 85% of VO₂ improving fitness, respectively (15). ACSM recommends RPE values from 11-16 on the Borg Scale (6-20), with 11-13 being moderate exercise intensity (light to somewhat hard) and 14-16 being high intensity exercise (1, 15).

Despite the clear recommendations for frequency and duration of exercise for developing and maintaining cardiorespiratory fitness in healthy adults, exactly how intense a workout should be remains less defined by ACSM guidelines. Osteras et al. (28) performed a study to compare the effects of high-intensity endurance training on VO_2max in healthy elderly people. In their study, 21 healthy, untrained men and women volunteered and were randomly assigned to either a high-intensity training group (TG) or a control group (CG). The TG exercised three times a week for 10 weeks and each 60-minute training session included four intervals of 90 to 95% HRmax. Maximal oxygen consumption, walking economy, and maximal walking speed were assessed at the end of the 10 weeks. The results indicated that walking economy and maximal walking speed remained unchanged while VO_2 significantly improved during high-intensity endurance training in older adults. Other studies have shown similar results while exercising at higher exercise intensities rather than moderate levels of intensity (17, 35).

Lower body Versus Upper Body VO_2max Testing

VO_2max is regarded as the best single indicator of an individual's fitness capacity (2). Previous literature on the physiological responses during exercise has been documented extensively. Traditionally VO_2max has been identified by a maximal exercise test on a treadmill or lower body cycle ergometer. Treadmill VO_2max protocols have shown to be an effective and reproducible measure of VO_2 (2, 16, 20, 23). Schwarz et al. (35) investigated the cardiocirculatory and physiological responses at different walking intensities using an incremental treadmill walking test. In the study, 16 healthy, middle-age recreational athletes performed three randomized 30-minute walking tests at

70%, 80 %, and 90% of maximal velocity (V_{max}). During the exercise tests VO_2 , HR, blood concentrations of lactate and catecholamines, and RPE were recorded. They found that an incremental treadmill walking test is appropriate for deriving individual intensity recommendations for exercise and that the most effective intensity to elicit a exercise prescription is at 80% of V_{max} (34). However, Astrand et al. (2) made observations that certain populations may experience limiting factors during such a test. These factors include speed of treadmill, grade, weight of subject, hand rail support or not, and walking versus jogging which may affect the amount of oxygen uptake during a maximal exercise test.

Studies have shown that VO_{2max} can also be measured with upper body exercise using arm crank ergometry (ACE). Much of the work done on ACE testing has focused on the design in which peak VO_2 can be achieved. In order to collect more accurate and reproducible VO_2 values other investigators have considered the influence of exercise protocol. McKeough et al. (24) used constant-load arm protocol to investigate the physiological responses after high intensity exercise in patients with chronic obstructive pulmonary disease (COPD). During the bout of exercise VO_2 , ventilation (V_E), dyspnea, and RPE were measured. They found that the physiological responses to constant-load exercise were higher than incremental arm exercise in patients with COPD. Another study investigating ACE demonstrated the use of step and ramp protocols as a valid means of achieving peak physiologic responses (39). Fourteen physically active, male subjects performed two VO_{2max} tests using an arm ergometer. The tests consisted of a stepwise and rampwise incremental increase in workload. During the step protocol subjects performed increasing workloads of 20 Watts (W) every 2 minutes until volitional

exhaustion, whereas during the ramp protocol subjects started at an initial workload of 60 W, with increases of 1 W every 6 seconds. Results showed that the peak values of VO_2max achieved using the step and ramp protocols were similar but should not be used interchangeably. In addition, Smith et al. (38) researched the optimal crank rate that should be used to elicit VO_2max during incremental upper body ergometry. In their study, 21 physically active, males volunteered to participate in three randomized tests at crank rates of 60, 70, and 80 revolutions per minute ($\text{rev}\cdot\text{min}^{-1}$). The main finding showed that peak VO_2 was achieved at crank rates of 70 and 80 $\text{rev}\cdot\text{min}^{-1}$. Other studies conducted by Smith et al. (38, 39, 40, 41) have shown similar results.

Sedentary aging accompanied by a decline in maximal exercise capacity is often worsened by chronic disease (2). Many elderly that face such challenges are interested in finding easy pain-free means of exercising to improve their health and well-being. Pogliaghi et al. (29) studied the effects of lower body cycle ergometry and upper body arm ergometry on VO_2max in healthy elderly adults. In their study, 12-elderly men (between ages of 65 to 75) performed two incremental tests to volitional exhaustion, one on the arm cranking ergometer and one on the cycle ergometer. One week later the two tests were repeated in a randomized order, with stepwise increases of 5 W every minute for the arm crank ergometer and 10 W increases every minute for the cycle ergometer. Following the 12-week training program, significantly higher VO_2 were obtained on both ergometers which demonstrate improvements in exercise tolerance for the elderly population.

A plethora of research has been done demonstrating the benefits of regular exercise training with whole body or large muscle masses (such as cycling, running). So far, a lack of research on the use of regular exercise with small, single muscle masses (such as upper extremities) in healthy elderly adults as well as young subjects exist. VO_2 max measures obtained during upper body ergometry have been reported to be less than lower body ergometry. Secher et al. (35) reported that arm-cranking exercise elicits a VO_2 max that is approximately 70% of the value (30% less) than comparable lower body exercise protocol. However, highly-trained athletes such as rowers, swimmers, and cross-country skiers, the arm VO_2 max may come close or surpass the legs. In addition, Liguzinski and Korzeniewski (21) performed an in silico study in which VO_2 max per muscle mass was significantly higher during single-muscle exercise training than during whole body exercise. Another observation that Secher et al. (36) made was that when arm exercise was added to leg exercise, leg blood flow is approximately 10 percent less than during leg exercise alone. This same phenomenon was seen when leg exercise was added to arm exercise suggesting that the arms and legs are in competition with one another for cardiac output during high intensity exercise.

Indoor Cycling

Recently instructor led fitness classes are catching on with people of all ages to improve their cardiovascular fitness, quality of life, or simply to manage weight for many individuals. With the guidance of a fitness instructor, individuals have been able to achieve aerobic health benefits that meet ACSM's recommendations for physical activity. One of the more recent instructor led exercise classes to emerge is a type of indoor

cycling known as spinning. Currently, few studies have been published on the relative physiological responses during indoor cycling. Research has found that spinning elicits exercise intensities ranging from moderate to high intensity (3, 7, 19) which meets the ACSM guidelines for improving cardiorespiratory endurance (1). Unfortunately, for some populations with diminished exercise capacities or chronic diseases, a typical spinning class may be too demanding and dangerous for them to perform. The relative high intensity intervals during a typical class have been shown to exceed VO_2max (3, 6, 7, 43) which could be fatal for these individuals with underlying risk factors for cardiovascular disease (3, 7, 29). Battista et al. (3) performed a study on the physiological responses during a simulated indoor cycling class to try and confirm the findings of the relative high intensities experienced during a typical class training session. Twenty healthy, physically active, female university students and staff performed three exercise tests. First, they performed an incremental exercise test on a cycle ergometer to obtain VO_2max , ventilatory threshold (VT), and $HRmax$. Following the maximal exercise test subjects then performed two video-taped indoor cycling classes that were 45 and 35 minutes in duration with HR, VO_2 , and RPE assessment throughout the course of the testing. Battista et al. (3) found that in 10 of the 40 video sessions there were segments in which VO_2 exceeded maximal exercise values, and overwhelming portions surpassing VT. In addition, Robergs et al. (33) reported that spinning classes that are video-assisted elicit significantly higher exercise intensities compared with non-video-assisted classes. The use of training zones during these workouts, such as spinning, has shown to provide improved physiological responses during exercise and help augment post-exercise energy expenditure (19).

Benefits of UBE

Many investigators have published research on the benefits of arm ergometry programs that provide individuals with improved work capacity. Studies have shown that in healthy elderly adults or individuals with lower limb impairment, arm cranking was slightly more beneficial than leg cycling over the course of a 12-week program (29). Other documented benefits include individuals with coronary artery disease (CAD) or other cardiopulmonary conditions (26, 37), patients with ischemic signs and symptoms during lower body exercise (33), and in patients with COPD (25, 42). Spruit et al. (42) conducted a study that compared the use of resistance or endurance training in patients with COPD and peripheral muscle weakness. After a 12-week training period, similar improvements were obtained using resistance training and arm cranking endurance work. Both the quality of life and the exercise capacities of patients with COPD with peripheral muscle weakness demonstrated positive benefits.

UBE provides benefits to individuals without the habitual use of their legs in improving functional capacity and other physiological markers (11, 12, 13, 14). DiCarlo (14) demonstrated the effects of arm ergometry training on wheelchair propulsion endurance of individuals with quadriplegia. Eight adult men with quadriplegia performed eight weeks of arm ergometry training in which physiological markers such as VO_2 max, HR, physical work capacity, and distance propelled in 12 minutes were assessed. The results showed that increases in wheelchair propulsion correlated directly with increases in functional capacity. In addition, typical activities of daily living (ADL) for individuals with spinal cord injuries could be improved using arm ergometry.

The Krankcycle-Concept of Kranking

A new type of instructor led fitness class that has recently emerged is a cycle-type exercise known as Krankcycling (27). Similar in concept to an UBE, the Krankcycle uses independent crank arms and a rhythmical rotating fly wheel to provide an upper body and core resistance workout. The most recent study on Krankcycling was conducted by Boyer et al. (5) at the University of Wisconsin-La Crosse in which they researched the relative exercise intensity and energy expenditure of a Krankcycle workout. In their study, 12 apparently healthy, college-aged men and women volunteered to participate in two exercise tests. An incremental maximal exercise test was conducted using a step protocol on a UBE. The protocol started with an initial workload of 30 W and increased 20 W every 2 minutes until volitional exhaustion. During the test VO_2 , HR, and RPE were assessed. After the maximal exercise test, subjects performed a 30 minute instructor led Krankcycle session. The results were consistent with Battista et al. (3) in which participants experienced a moderate to high intensity workout with segments of exercise that exceeded VO_{2max} . On average, subjects experienced physiological responses of 86 % of HRmax and 72% of VO_{2max} (5), which meets ACSM's guidelines for improved cardiorespiratory fitness. Even though Krankcycling has shown to elicit high intensity exercise, exactly how much work or energy expenditure takes place during a training session remains to be answered. In addition, possible uses for the Krankcycle are notable given the versatility of the machine. Some of the potential uses include core and upper body strengthening, foot balance and coordination development, cross-training tool for endurance, special populations with disabilities, rehabilitation for patients with lower extremity injury or the average

physically active individual seeking a challenging upper body workout (27). To date no research on Krankcycling has been conducted to support their products potential benefits.

Summary

Despite the overwhelming health risks associated with physical inactivity, sedentary habits continue to be a concerning public health issue. ACSM's recommendations have been an integral part in developing guidelines for an effective program that meets the needs of each individual in maintaining cardiorespiratory fitness and a healthy lifestyle. With the plethora of literature on the benefits of regular exercise and the large market for exercise equipment, fitness professionals are constantly looking to attract and motivate individuals to try their product. Over the past decade instructor led classes, such as spinning, have been increasingly popular in many fitness clubs and recreational centers across the country. Most recently, a new type of instructor led fitness class that has been unveiled is an upper body cardiac machine called the Krankcycle. Previous studies have shown the benefits of arm Kranking and the ability to promote cardiovascular improvements. Similar in concept to an Upper Body Ergometer (UBE), the Krankcycle has many possible uses and benefits given the versatility of the machine but no research currently has been published on the product.

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