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THE RELATIVE EXERCISE INTENSITY OF A KRANKCYCLE WORKOUT

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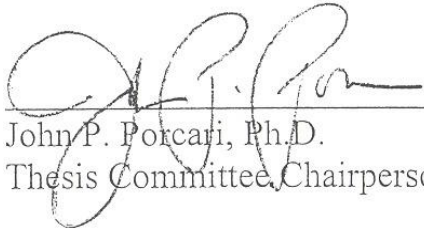
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THE RELATIVE EXERCISE INTENSITY OF A KRANKCYCLE WORKOUT

By Blake A. Boyer

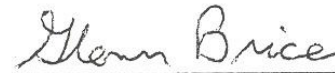
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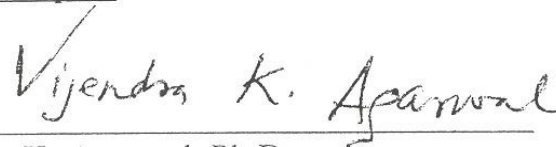
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ABSTRACT

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Purpose: The purpose of this study was to determine the relative exercise intensity and caloric expenditure of a 30-minute Krankcycle workout. **Methods:** Twelve physically active subjects age 23.8 ± 2.60 years volunteered for the study. Subjects performed three 15-minute practice trials and a maximal exercise test on the SCIFIT upper body ergometer (Tulsa, Oklahoma) to find HRmax, VO₂max, and the HR/VO₂ relationship. HRmax (179 ± 14.0 bpm) was measured with a Polar monitor while VO₂max (34.7 ± 7.15 ml/kg/min) was measured continuously on an AEI metabolic system (Naperville, Illinois). Subjects then performed a 30-minute instructor-led Krankcycle workout. HR and RPE were measured during the workout. **Results:** The average HR for the trial was 154 ± 10.0 bpm, corresponding to 86 ± 4.0 % HRmax. The average VO₂ for the workout was 25.0 ± 5.90 ml/kg/min, relating to 72 ± 10.0 % VO₂max. On average subjects burned 9.0 Kcal/min, 269 Kcal total, and spent approximately 90% of the time above 70% HRmax during the trial. **Conclusions:** It is concluded that a 30-minute Krankcycle workout is of moderate to very high intensity, and is capable of eliciting high enough HR and VO₂ values to cause cardiovascular and body composition changes.

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INTRODUCTION

Seventy-eight percent of all adults in the United States do not get adequate amounts of physical activity (16) and nearly one-third of all adolescents have low fitness (5). This is disappointing since there are many attainable benefits from regular exercise such as increased cardiorespiratory endurance, reduced blood pressure, decreased body weight, and increased glucose tolerance (16, 18). In attempts to try and interest more people to exercise, and to increase adherence to an exercise program, fitness professionals and health clubs are always looking for the next “fitness craze”. Many times these activities center around instructor led classes such as spinning, Tae Bo, yoga, Body Pump, kickboxing, and aerobic dance.

In the past decade there has been an increase in the popularity of indoor instructor-led cycling classes such as spinning. Many studies, such as Battista et al. (2), have found that spinning is a moderate to high intensity exercise and meets the American College of Sports Medicine guidelines for improving cardiorespiratory endurance (1). However, a typical class can have intense segments that exceed VO_{2max} , and could present a risk for sedentary or aged populations (2, 4).

A new cycle-type product is called the Krankcycle. The Krankcycle is a hand powered cycle similar to an arm ergometer. It works by providing a rhythmical rotational exercise using the muscles of the core and upper body. Possible uses for this machine are

vast. It could be used in cross-training for endurance athletes (15), could be useful for special populations such as people with disabilities, lower limb injuries, or obesity, and could benefit the average fitness club member.

Many studies have shown benefits associated with arm crank training programs using an arm ergometer. These benefits include improvement in work capacity and maximal oxygen uptake in the elderly (17), walking improvement in hip replacement patients (12), increased force generation and reducing spasticity in stroke victims (8), and increased arm endurance while modulating hyperinflation and reducing dyspnea in COPD patients (9). Studies done with subjects that are paraplegic have shown that normal wheelchair use does not provide adequate cardiovascular training. However, by adding exercise from an arm ergometer, pulleys, or wheelchair sports, paraplegics can improve their physical condition (6). Few if any studies have been done on younger and healthy populations.

Traditionally $VO_2\text{max}$ is determined by a maximal exercise test on a treadmill or a cycle ergometer; the values commonly used for exercise prescription. $VO_2\text{max}$ protocols on these modalities have been shown to be efficient, valid, and reproducible measures of maximal oxygen consumption (10, 11, 13). However, $VO_2\text{max}$ can also be determined using an arm ergometer. Smith et al. (22) showed that both step and ramp protocols for the arm ergometer are valid for the testing of $VO_2\text{max}$ and other physiologic markers. Smith et al. (23) also performed another study demonstrating that the optimal crank rate for $VO_2\text{max}$ testing on an arm ergometer is between 70-80 rpm (21).

VO₂max values obtained from the arm ergometer are usually less than those of lower body modalities (7, 20). Secher and Volianitis (20) concluded that arm VO₂max is typically about 30 percent lower than that of the leg. However, in highly trained arm athletes like rowers or swimmers, arm VO₂max can reach or surpass that of the leg.

Many beneficial claims are made on the Krankcycle's company website (Five Giri, Inc.) including statements that the product improves cardiovascular fitness, provides effective cross-training, improves upper body strength, improves core strength, promotes weight management, and improves selected sports performance (15). To date, no known research has been conducted on the Krankcycle. The purpose of this study is to determine the hemodynamic responses and relative intensity of a typical Krankcycle workout.

MATERIALS AND METHODS

Subjects

The selected subjects for this study will be 12 apparently healthy, college-aged men and women. These volunteers will be recruited through announcements to classmates, as well as word of mouth invitations to other friends and UW- La Crosse students.

Procedures

After approval to perform the study from the University of Wisconsin-La Crosse Institutional Review Board for the Protection of Human Subjects, subjects will provide informed consent prior to the completion of any testing procedures. This group of participants was chosen because it most closely resembles the average, relatively fit and

relatively young, fitness center user. Subjects will be asked to come into the laboratory to perform 3-5 habituation trials, prior to a maximal test. An initial maximal exercise test will be performed in the Human Performance Laboratory in Mitchell Hall on the SCIFIT UBE machine (Tulsa, Oklahoma) in order to determine the maximal HR and VO_2 of the subjects. The test will also be used as a basis to determine the HR/ VO_2 relationship of the subjects during typical upper body aerobic type exercise. The test will start at an initial load of zero watts, and increase by 20 watts every 2 minutes until volitional exhaustion. The machine will be electrically braked, and subjects will be encouraged to try to keep the RPM's between 70 and 80. During this test, HR will be measured using a Polar monitor and oxygen consumption will be measured continuously using an AEI metabolic system (Naperville, Illinois). Ratings of perceived exertion will also be assessed during each stage and at maximal exertion using the Borg 6-20 scale (3).

After the maximal test, the subjects will perform a 30-minute Krankcycle training bout led by a trained Krankcycle class instructor. The class will be held at the Wisconsin Athletic Club in Milwaukee, Wisconsin. During the class, RPE will be measured every five minutes using the Borg 6-20 stage and heart rate will be measured continuously using Suunto heart rate telemetry (Ogden, Utah). These HR values will be inserted into the HR/ VO_2 regression equation developed during the UBE VO_2 max test to predict oxygen consumption and caloric expenditure throughout the exercise bout. Additionally, an analysis will be conducted to determine the percentage of time subjects spend in various heart rate zones. Five zones will be divided up into the following categories; less than 60% HRmax, from 60-70% HRmax, from 71-80% HRmax, between 81-90% HRmax, and above 90% HRmax.

Statistical Analysis

Standard descriptive statistics were used to characterize the subject population. Comparisons between gender were made using independent T-tests. Regression equations to determine the HR/VO₂ relationship for arm ergometry and treadmill exercise were developed for each subject. Statistical analysis was conducted using SPSS Statistical Software, Version 16.0. Alpha was set at .05 to achieve statistical significance.

RESULTS

The subject demographics are presented in Table 1. The males and females were similar in age and maximal heart rate. However, the men were taller, heavier, and had higher VO₂max values than the women. Six of the subjects had also completed a treadmill maximal test and the treadmill maximal values were compared to their measured arm ergometer maximal values. This data is presented in Table 2. There was not a significant difference between treadmill and arm ergometer maximal heart rates, but VO₂max was significantly higher on the treadmill by an average of 33%.

Table 1. Demographics of the Subject Population (N = 12)

| Variable | Total N = 12 | Males n = 5 | Females n = 7 |
|--------------------------------|----------------------------|------------------------------|----------------------------|
| Age (yrs) (range) | 23.8 ± 2.60 (20-30) | 23.4 ± 1.67 (22-26) | 24.0 ± 3.21 (20-30) |
| Height (in) (range) | 69.0 ± 4.43 (63-75) | 73.4 ± 1.52* (71-75) | 65.9 ± 2.61 (63-70) |
| Weight (lbs) (range) | 156.8 ± 32.05 (110-215) | 181.0 ± 31.52 * (142-215) | 139.6 ± 19.65 (110-160) |
| HRmax (bpm) (range) | 179 ± 14.0 (150-196) | 181 ± 7.5 (168-186) | 177 ± 17.7 (150-196) |
| VO ₂ max (range) | 34.7 ± 7.15 (22.6-51.0) | 40.3 ± 6.36* (34.0-51.0) | 30.6 ± 4.57 (22.6-37.1) |

*Significantly higher than females (p < .05)

Table 2. Arm Ergometer and Treadmill Maximal Values

| | Arm Ergometer n = 6 | Treadmill n = 6 |
|---------------------------------|------------------------|--------------------|
| HR max (bpm) | 179 ± 15.8 | 187 ± 9.8 |
| VO ₂ max (ml/kg/min) | 34.5 ± 9.47 | 51.7 ± 15.60* |

*Significantly higher than Arm Ergometer (p < .05)

Table 3 presents the minute-by-minute HR response during the 30-minute Krankcycle workout. Overall, heart rate averaged 154 bpm, which corresponded to 86% of HRmax, indicating that the Krankcycle workout was of high intensity. There were times when subject's heart rates actually exceeded their HRmax determined from the

maximal arm ergometer test. The exercise intensity of the workout is shown graphically in Figure 1.

Five different heart rate zones were pre-established before the workout. These zones correspond to 0-60%, 61-70%, 71-80%, 81-90%, and $\geq 91\%$ of maximal heart rate. Table 4 shows the number of minutes and percentage of time that subjects spent in the five different heart rate zones. Approximately 90% of the workout time was spent over 70% of HRmax.

Table 3. Minute-by-Minute Heart Rate Response During the 30-Minute Trial

| | <u>Heart Rate</u> | <u>(Range)</u> | <u>% HRmax</u> | <u>(Range)</u> |
|-----------|-------------------|----------------|----------------|----------------|
| Minute 1 | 111 \pm 12.2 | (88-127) | 62 \pm 4.3 | (56-70) |
| Minute 2 | 117 \pm 11.6 | (91-133) | 65 \pm 4.7 | (58-73) |
| Minute 3 | 130 \pm 12.1 | (110-149) | 73 \pm 5.7 | (59-80) |
| Minute 4 | 131 \pm 7.1 | (115-140) | 73 \pm 4.4 | (67-84) |
| Minute 5 | 135 \pm 8.8 | (116-147) | 76 \pm 4.2 | (69-84) |
| Minute 6 | 143 \pm 12.5 | (124-162) | 80 \pm 5.8 | (67-88) |
| Minute 7 | 150 \pm 8.8 | (135-163) | 84 \pm 3.8 | (77-90) |
| Minute 8 | 154 \pm 13.1 | (127-173) | 86 \pm 5.3 | (74-91) |
| Minute 9 | 159 \pm 14.7 | (136-186) | 89 \pm 8.3 | (70-97) |
| Minute 10 | 146 \pm 18.0 | (125-173) | 81 \pm 8.5 | (68-95) |
| Minute 11 | 149 \pm 23.7 | (117-180) | 83 \pm 12.5 | (62-97) |
| Minute 12 | 143 \pm 15.1 | (126-178) | 80 \pm 7.7 | (69-91) |
| Minute 13 | 153 \pm 12.3 | (129-171) | 86 \pm 5.2 | (78-95) |
| Minute 14 | 166 \pm 16.3 | (128-185) | 93 \pm 8.2 | (82-109) |
| Minute 15 | 166 \pm 9.5 | (142-177) | 93 \pm 5.4 | (87-105) |
| Minute 16 | 165 \pm 17.2 | (135-194) | 92 \pm 8.0 | (76-100) |
| Minute 17 | 163 \pm 19.3 | (132-195) | 91 \pm 9.2 | (77-102) |
| Minute 18 | 167 \pm 16.8 | (138-195) | 93 \pm 7.8 | (81-101) |
| Minute 19 | 170 \pm 13.1 | (150-192) | 95 \pm 6.2 | (84-102) |
| Minute 20 | 155 \pm 12.0 | (131-169) | 87 \pm 7.3 | (81-96) |
| Minute 21 | 148 \pm 13.6 | (122-164) | 83 \pm 7.3 | (74-96) |
| Minute 22 | 155 \pm 20.0 | (126-185) | 87 \pm 10.2 | (74-101) |
| Minute 23 | 164 \pm 16.1 | (130-185) | 92 \pm 8.4 | (82-106) |
| Minute 24 | 172 \pm 12.9 | (150-187) | 96 \pm 6.2 | (87-107) |

| | | | | |
|-----------|------------|-----------|-----------|----------|
| Minute 25 | 167 ± 12.1 | (138-184) | 94 ± 5.6 | (88-105) |
| Minute 26 | 171 ± 12.3 | (142-188) | 96 ± 4.7 | (88-105) |
| Minute 27 | 180 ± 11.1 | (159-200) | 101 ± 4.8 | (89-106) |
| Minute 28 | 172 ± 18.1 | (137-201) | 96 ± 9.0 | (78-107) |
| Minute 29 | 161 ± 27.8 | (120-199) | 90 ± 15.2 | (62-109) |
| Minute 30 | 151 ± 32.1 | (112-197) | 85 ± 17.9 | (58-108) |
| <hr/> | | | | |
| Average | 154 ± 10.0 | (137-172) | 86 ± 4.0 | (78-91) |

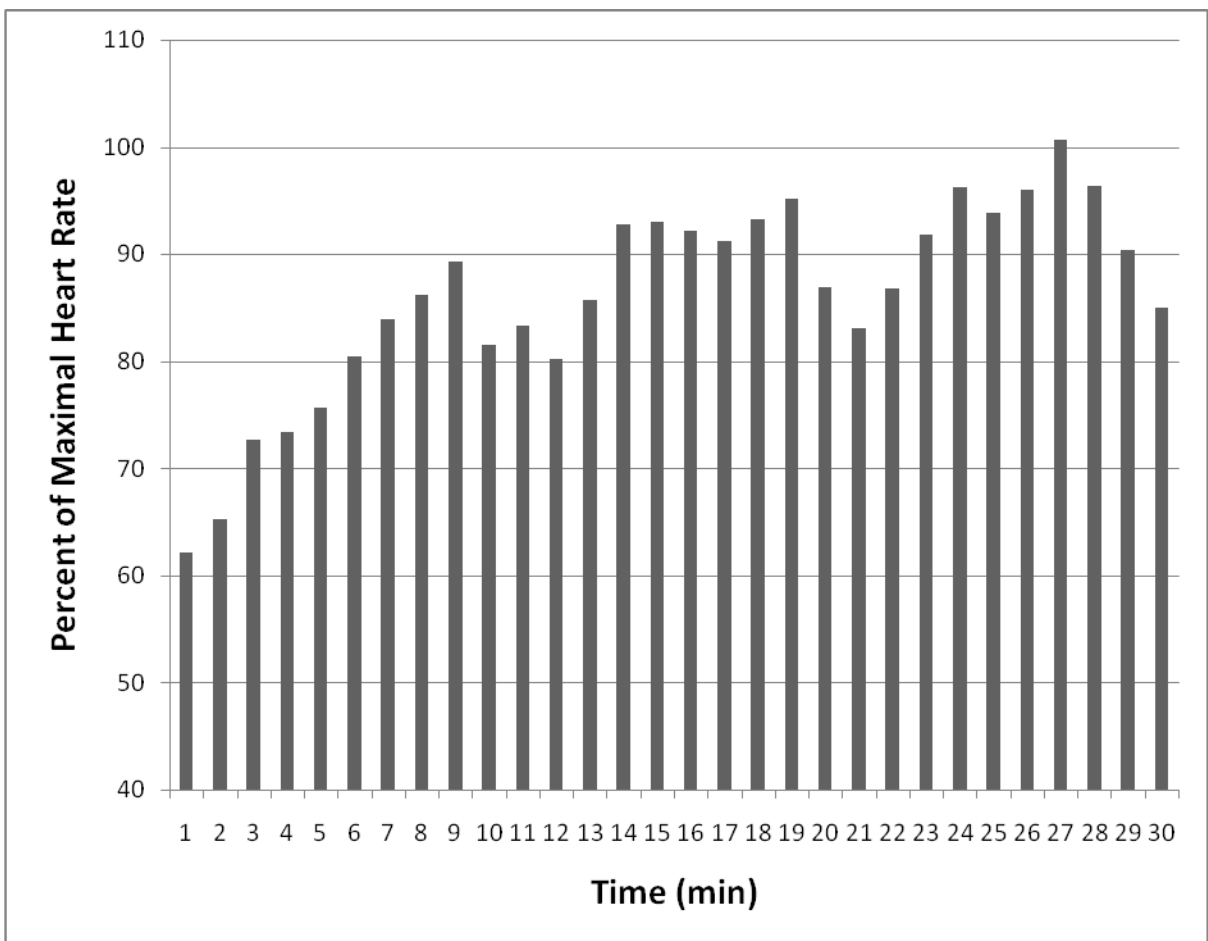


Figure 1. Average Exercise Intensity During the 30-Minute Krankcycle Workout

Table 4. Percentage of Time and Number of Minutes Spent in Each Heart Rate Zone

| | Percent of Time | Number of Minutes |
|-----------------|-----------------|-------------------|
| Zone 1 (0-60%) | 2.7 ± 2.64 | 0:49 ± 0:47 |
| Zone 2 (61-70%) | 9.0 ± 5.31 | 2:42 ± 1:35 |
| Zone 3 (71-80%) | 21.0 ± 4.97 | 6:18 ± 1:29 |
| Zone 4 (81-90%) | 31.9 ± 5.06 | 9:34 ± 1:31 |
| Zone 5 (≥ 91%) | 35.4 ± 11.14 | 10:37 ± 3:20 |

Table 5 presents VO₂ and calorie expenditure data for the 30-minute workout. Predicted VO₂ was determined from the individual linear HR/VO₂ relationships developed from the subjects' arm ergometer maximal test data. Figure 2 presents an example of maximal test data used to develop the HR/VO₂ relationship for an individual subject. Calorie expenditure was calculated from the predicted VO₂ data. The average VO₂ during the workout was 25.0 ml/kg/min, which corresponded to 72% of VO₂max. The average calorie expenditure was 9.0 Kcal/min, which corresponded to an average of 269 Kcal burned during the entire 30-minute workout.

Perceived exertion was collected at 5-minute intervals during the 30-minute Krankcycle workout using the 6-20 Borg scale (). Figure 3 presents the overall and arm RPE values gathered during the trial. At every interval, arm RPE was significantly higher than overall RPE.

Table 5. VO₂ and Calorie Expenditure During the 30-Minute Krankcycle Workout

| | |
|---------------------------------------|-------------|
| Predicted VO ₂ (ml/kg/min) | 25.0 ± 5.90 |
| % VO ₂ max | 72 ± 10.0 |
| Calorie Expenditure (Kcal/min) | 9.0 ± 2.93 |
| Calorie Expenditure (30 min) | 269 ± 87.8 |

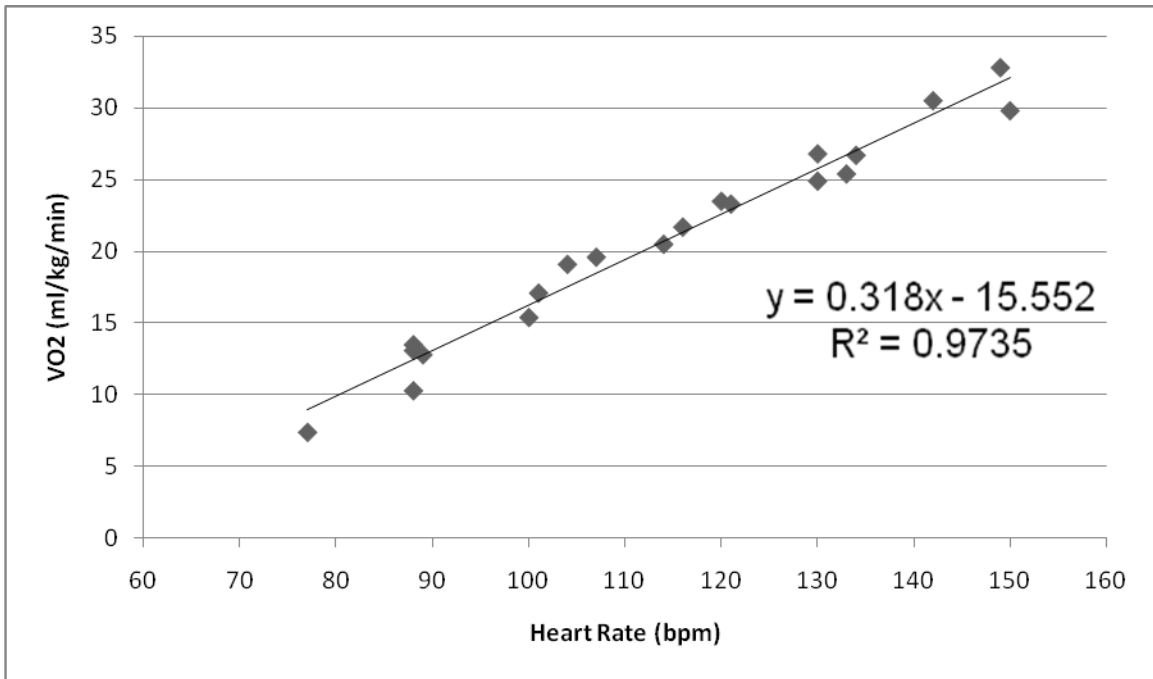


Figure 2. A Subject's Maximal Arm Ergometer Test Data and HR/VO₂ Relationship

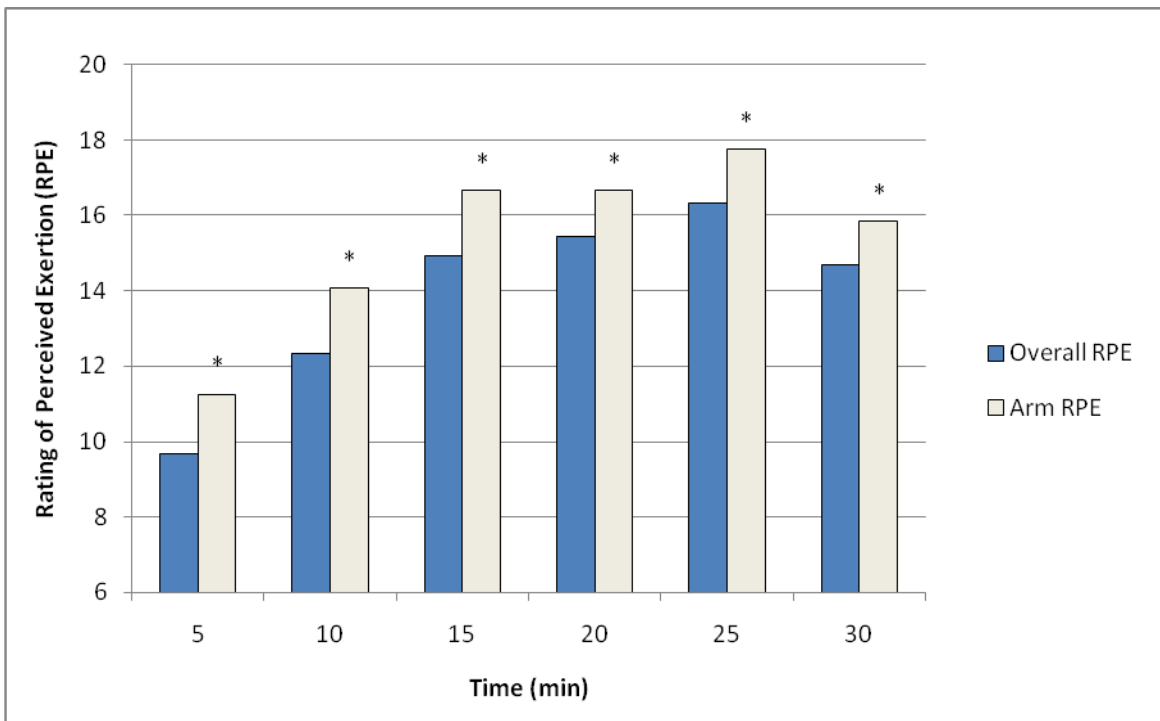


Figure 3. Overall and Arm Perceived Exertion During the 30-Minute Krankcycle Trial

*Significantly different than overall RPE at the same time period ($p < .05$)

DISCUSSION

The main purpose of the study was to determine the relative exercise intensity and calorie expenditure of a 30-minute Krankcycle workout. Our data found that the average heart rate for the trial was 154 bpm, which corresponded to 86% of HRmax. We also discovered that the subjects' average VO_2 during the workout was 25 ml/kg/min, which corresponded to 72% of VO_2max . These HR and VO_2 values are within ACSM's guidelines for eliciting a cardiorespiratory benefit. A difference between % HRmax and % VO_2max is normal and can be exacerbated with arm work compared to leg work due to the pressor response. Because the arms are a smaller muscle mass compared to the legs and are working at a higher % of MVC, HR are disproportionately elevated related to oxygen consumption (14, 19).

During the Krankcycle workout, it was noticed that many of the subjects actually surpassed the maximal heart rate obtained on the arm ergometer test. This could be due to a number of factors. First it is possible that subjects did not achieve their true maximal heart rate during the arm ergometer test due to arm fatigue. However, this is unlikely because all subjects had practiced adequately for at least three sessions of fifteen minutes on the machine prior to the maximal test. Secondly, higher HRs are often attained during a workout, compared to a maximal exercise test, due to the higher body temperature and cardiac drift. Battista et al. (2) and Caria et al. (4) saw similar heart rate responses in spinning, where subjects surpassed their tested maximal values.

When looking at intensity zones, on average subjects spent approximately 12% of the workout (3 minutes; 31 seconds) at intensities of 70% HRmax or lower. As a result, they spent roughly 88% of the workout (26 minutes; 29 seconds) at intensities over 70% of maximal heart rate. This data indicates that the Krankcycle workout was very intense, as further evidence by the RPE data.

Each subject gave two RPE ratings at each interval; first for overall RPE and secondly for just arm RPE. This was done to try and determine if arm fatigue limited the ability of the subject to effectively complete the workout. It was discovered that on average, overall RPE was above a rating of 12 for 25 of the 30 minutes during the workout. This indicates that intensity was perceived between “somewhat hard” and “hard” for the majority of the trial (3). Arm RPE averaged about two RPE units higher at each interval, indicating that there was local peripheral muscle fatigue on top of an effective cardiovascular workout. Most subjects at some point in the workout had an RPE rating of 18 or above.

Based upon the high HR and VO₂ ratings, the large amount of time in high intensity zones, and its high RPE ratings, we were able to determine that the relative exercise intensity of a typical 30-minute Krankcycle workout is moderate to intense, and is capable of eliciting cardiovascular improvements and possibly increases in upper body strength. Our results are similar to those of Caria et al. (4) and Battista et al. (2) in that Krankcycling, like spinning, is a moderate to very high intensity exercise, which at periods can exceed tested maximal heart rate. Therefore, kranking must be considered a high intensity exercise mode of training that has possibilities for benefits, but could also pose significant risks for sedentary, unhealthy, or aged populations (2).

During the 30-minute Krankcycle workout, subjects were monitored by a Suunto telemetry system, which allowed each subject's heart rate and intensity zone to be shown visually on a large screen in front of the class. The instructor could then use visual and verbal instructions to make the subjects increase and decrease their intensity level throughout the workout. This system made the session fun and very competitive, as subjects wanted to reach their target zones. However, a couple of problems arose with this system. Maximal heart rates needed to be put into the Suunto system prior to the workout in order for it to display the desired intensity zones. Initially only about half of the subjects had arm ergometer derived maximal heart rates, so age predicted heart rates ($220 - \text{age}$) were put into the system. Many of the people had a difficult time just reaching, let alone maintaining the upper values. On average, age predicted HRmax was 17 bpm above those measured on the arm ergometer and 9 bpm above those measured on the treadmill, which explains why subjects had difficulty reaching the highest HR zone. Therefore, it is imperative that subjects have an actual measured HRmax on an upper body modality for exercise prescription on the Krankcycle.

Another thing that was found was that the system overestimated the subject's energy expenditure. We found that on average subjects burned 9.0 Kcal/min and 269 Kcals over the entire 30-minute workout, with some subjects burning as many as 400 Kcals. The Suunto system found that on average the subjects burned 393 Kcals, a difference of 124 Kcals. A potential problem is that our energy expenditure was calculated from the arm ergometer HR/ VO_2 relationship which may be different than that of a Krankcycle. The Krankcycle workout utilized more standing positions and whole body motion than the arm ergometer; therefore, the higher energy expenditure found by

the Suunto system may more closely reflect the subjects' actual energy expenditure. Future research needs to be done to develop a HR/VO₂ regression equation for the Krankcycle to make more accurate energy expenditure conclusions.

The subjects selected for this study were chosen because they represent the healthy, relatively fit, average fitness club member. Because the Krankcycle is only located in select fitness clubs around the country, we wanted a subject group to resemble the type of exercisers that would routinely use the machine. The arm ergometer modality was selected for the maximal exercise test, in which all subjects completed, because it uses mainly the muscles of the upper body, and most closely resembles the motion of the Krankcycle. In a side observation, six of the subjects also completed a maximal treadmill exercise test in order to compare maximal treadmill and arm ergometer values. We found that arm ergometer VO₂max values were 33% lower than treadmill VO₂max values, which strongly agrees with the results found by Secher and Volianitis (20) who state that arm VO₂ is typically 30% lower than that of the leg. We also found that treadmill maximal heart rates were about 8 bpm higher than arm ergometer achieved HRmax, however this difference was not significant.

There were a number of limitations to consider in this study. First, the maximal exercise test was performed on an arm ergometer and not the Krankcycle, which may have a slightly different HR/VO₂ relationship than the machine used for the 30-minute trial since it elicits more of a total body workout. Second, since VO₂ was not measured directly during the 30-minute trial, oxygen consumption and energy expenditure information had to be estimated from the HR/VO₂ relationship derived from the arm ergometer. Lastly, the subjects had never used a Krankcycle until the day of the workout,

so despite a training session there was still a learning curve. Many opportunities for future research exist on this exercise machine. The results of a prolonged training program have not yet been determined as well as the affects on different subject populations. Also, muscle activity should be looked at to determine exactly which muscles are active during the workout and at what percent of maximal contraction they are working at.

CONCLUSION

There has been an increase in the popularity of instructor led exercise classes. The Krankcycle, which resembles an upper body spinning bike, is the latest indoor cycle-type exercise machine. In this study, 12 subjects were tested to find the relative exercise intensity and energy expenditure of a typical 30-minute Krankcycle workout. On average, exercisers can expect a moderate to high intensity workout burning an average of 9.0 Kcal/min. We conclude that a typical 30-minute Krankcycle workout is an effective workout for healthy fitness enthusiasts and is capable of eliciting high enough heart rate and VO_2 levels to result in cardiovascular fitness improvements and positive changes in body composition. Since the machine is still very new, there has not been much research performed on the effects of training program or in special populations, but we believe that if utilized correctly the possible uses for the machine are vast.

REFERENCES

1. American College of Sports Medicine (2006). *ACSM's Guidelines for Exercise Testing and Prescription* (7th ed.). Philadelphia: Lippincott Williams & Wilkins.
2. Battista R.A., C. Foster, J. Andrew, G. Wright, A. Lucia, and J.P. Porcari. Physiologic responses during indoor cycling. *J Strength Condit Res.* 22(4): 1236-1241, 2008.
3. Borg G.A. Perceived exertion: a note on "history" and methods. *Med Sci Sports Exerc.* 5: 90-93, 1973.
4. Caria M.A., F. Tangianu, A. Concu, A. Crisafulli, and O. Mamei. Quantification of spinning bike performance Turing a standard 50-minute class. *J Sports Sci.* 25(4): 421-429, 2007.
5. Carnethon M.R., M. Gulati, P. Greenland. Prevalence and cardiovascular disease correlates of low cardiorespiratory fitness in adolescents and adults. *JAMA.* 294 (23): 2981-2988, 2005.
6. Davis G.M., P.R. Kofsky, J.C. Kelsey, and R.J. Shephard. Cardiorespiratory fitness and muscular strength of wheelchair users. *Can Med Assoc J.* 125(12): 1317-1323, 1981.
7. Dekerle J., L. Dupont, I. Caby, G. Marais, J. Vanvelcenaher, J.M. Lavoie, and P. Pelayo. Ventilatory thresholds in arm and leg exercises with spontaneously chosen crank and pedal rates. *Percept Mot Skills.* 95: 1035-1046, 2002.
8. Diserens K., N. Perret, S. Chatelain, S. Bashir, D. Ruegg, P. Vuadens, and F. Vingerhoets. The effect of repetitive arm cycling on post stroke spasticity and motor control: repetitive arm cycling and spasticity. *J Neurol Sci.* 253(1-2): 18-24, 2007.

9. Gnocchi F.D.C. Arm exercise and hyperinflation in patients with COPD: effect of arm training. *Chest*. 128(3): 1225-1232, 2005.
10. Hawkins M.N., P.B. Raven, P.G. Snell, J. Stray-Gundersen, and B.D. Levine. Maximal oxygen uptake as a parametric measure of cardiorespiratory capacity. *Med Sci Sports Exerc*. 39(1): 103-107, 2007.
11. LeMura L.M., S.P. von Duvillard, S.L. Cohen, C.J. Root, S.A. Chelland, J. Andreacci, J. Hoover, and J. Weatherford. Treadmill and cycle ergometry testing in 5-to-6 year-old children. *Eur J Appl Physiol*. 85(5): 472-478, 2001.
12. Maire J., B. Dugue, A. Faillenot-Maire, J. Smolander, N. Tordi, B. Parratte, C. Grange, and J. Rouillon. Influence of a 6-week arm exercise program on walking ability and health status after hip arthroplasty: a 1-year follow-up pilot study. *J Rehabil Res Devmnt*. 43(4): 445-450, 2006.
13. McConnell T.R. Practical considerations in the testing of VO₂max in runners. *J Sports Med*. 5: 57-68, 1988.
14. McConnell T.R. Selecting training workloads using treadmill test heart rate/oxygen uptake regressions. *Exercise Physiology- J Cardiopulm Rehabil*. 16: 160-162, 1996.
15. Official Krankcycle website: www.krankcycle.com
16. Pate R.R., M. Pratt, S.N. Blair, W.L. Haskell, C.A. Macera, C. Bouchard, D. Buchner, W. Ettinger, G.W. Heath, and A.C. King. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA*. 273, (5): 402-407, 1995.
17. Pogliaghi S., P. Terziotti, A. Cevese, F. Balestreri, F. Schena. Adaptations to endurance training in the healthy elderly: arm cranking versus leg cycling. *Eur J Appl Physiol*. 97: 723-731, 2006.
18. Pollock M.L., G.A. Gaesser, J.D. Butcher, J. Despres, R.K Dishman, B.A. Franklin, and C.E. Garber. ACSM Position Stand: The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and

Muscular Fitness, and Flexibility in Healthy Adults. *Med Sci Sports Exerc.* 30:975-991, 1998.

19. Porcari J., J. Curtis. Can you work strength and aerobics at the same time? *Fitness Management.* 26-29, 6/1996.
20. Secher N.H., S. Volianitis. Are the arms and legs in competition for cardiac output? *Med Sci Sports Exerc.* Review. 38(10): 1791-1803, 2006.
21. Smith P.M., E. McCrindle, M. Doherty, M.J. Price, and A.M. Jones. Influence of crank rate on the slow component of pulmonary O₂ uptake during heavy arm-crank exercise. *Appl Physiol Nutr Metab.* 31: 292-301, 2006.
22. Smith P.M., M. Doherty, D. Drake, and M.J. Price. The influence of step and ramp type protocols on the attainment of peak physiological responses during arm crank ergometry. *J Sports Med.* 25: 616-621, 2004.
23. Smith P.M., M.J. Price, and M. Doherty. The influence of crank rate on peak oxygen consumption during arm crank ergometry. *J Sports Sci.* 19: 955-960, 2001.

APPENDIX A
INFORMED CONSENT DOCUMENT

INFORMED CONSENT DOCUMENT

Protocol Title: Relative Exercise Intensity of a Krankcycle Workout

Principal Investigator: Blake A. Boyer
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La Crosse, WI 54601
Phone #: 902-740-1664

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John P. Porcari
Phone #: 608-785-8684

- **Purpose and Procedure**

- The purpose of this study is to determine the hemodynamic responses and relative exercise intensity of a typical 30-minute Krankcycle workout.
- My participation will involve 5-7 laboratory sessions; 3-5 will be 15-minute habituation trials on an upper body ergometer, one will be a maximal exercise test on an upper body ergometer, and the other will be a 30-minute Krankcycle exercise class led by a trained instructor.
- The total time requirement, including laboratory and traveling time, is roughly 5 to 6 hours over a 3-4 week period.
- Maximal testing, as well as the habituation trials will take place in the Human Performance Laboratory in Mitchell Hall at the University of Wisconsin- La Crosse. The exercise class will take place at the Wisconsin Athletic Club in Madison Wisconsin.
- I will be responsible for providing my own transportation to and from the exercise class in Madison, Wisconsin. I will be reimbursed for fuel costs and will be notified of all attempts to carpool.
- During all lab sessions, I will be exercising on the Krankcycle exercise machine or an upper body ergometer. During the maximal test, I will be wearing a snorkel-like device over my face to measure my breathing and a heart rate monitor around my chest to measure my heart rate. During the 30-minute exercise class, I will be wearing just the heart rate monitor.
- I will be asked to point to numbers on a chart corresponding to my perceived difficulty level.

- **Potential Risks**

- I will feel substantial fatigue on at least one, and probably most of the laboratory sessions.
- Individuals experienced in laboratory techniques, trained in CPR, and certified in Advanced Cardiac Life Support and First Aid will be in the

laboratory during all testing. Testing will be terminated if complications occur.

- As with any exercise, there is risk of injury or life-threatening complications. However, for healthy individuals like myself this risk is very near to 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 may benefit by understanding the potential benefits of exercising on the Krankcycle.

- **Liability**

- Neither the investigator nor The University of Wisconsin-La Crosse is liable for any personal injury that may occur during testing, and by participating I understand this and accept all responsibility.

Questions regarding study procedures may be directed to Graduate Student Blake A. Boyer (920-740-1664), 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
KRANKCYCLE PHOTOS

KRANKCYCLE PHOTOGRAPHS

Figure 4.



Figure 5.



APPENDIX C

RATING OF PERCEIVED EXERTION SCALE

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 D
REVIEW OF RELATED LITERATURE

REVIEW OF RELATED LITERATURE

Introduction

Seventy-eight percent of all adults in the United States do not get adequate amounts of physical activity (22) and nearly one-third of all adolescents have low fitness (8). This is disappointing since there are many attainable benefits from regular exercise. In attempts to try and interest more people to exercise, and to increase adherence to an exercise program, fitness professionals and health clubs are always looking for the next “fitness craze”. Many times these activities center around instructor led classes such as spinning, Tae Bo, yoga, Body Pump, kickboxing, and aerobic dance. The newest of these exercises is a cycle-type machine called the Krankcycle. In the following review of the literature we will examine the need for exercise, current exercise recommendations, exercise prescription, maximal oxygen consumption testing, spinning workouts, benefits from arm crank exercise, and finally the Krankcycle itself.

The Need For Exercise

Seventy-eight percent of all adults in the United States do not get adequate amounts of physical activity (22) and nearly one-third of all adolescents have low fitness (8). Carnethon et al. (8) showed that there was no difference in the prevalence of low fitness between male and female adolescents; however, adult females are significantly less fit than adult males. In general, minorities such Mexican Americans and non-Hispanic blacks have lower fitness than non-Hispanic whites (8).

This lack of exercise is disappointing because regular exercise is an important component to long-term health and well-being. In general, some benefits associated with aerobic exercise are strengthening of the cardiovascular system, reducing blood pressure, cholesterol reduction, increased glucose tolerance, decreased risk for chronic diseases like diabetes, increasing physiologic markers, and weight management. Other benefits such as increasing lean muscle mass, increasing strength, improving balance, fall prevention, and increasing functionality can result from resistance training (22, 24). Blair et al. (5) found a lowered rate of cardiovascular mortality in individuals who had moderate to high amounts of physical activity in their leisure time (5).

Exercise Recommendations

To attain these potential health benefits, the American College of Sports Medicine (ACSM) recommends 30-60 minutes of moderate intensity aerobic exercise on most, if not all days of the week (22). More recently they have specified 5 days a week (1, 2, 24). This recommendation is also attainable through 20 minutes of vigorous intensity aerobic exercise at least 3 days a week. These health benefits can also be met through accumulation of multiple shorter bouts of at least 10 minutes in duration throughout the day. For resistance exercise, ACSM recommends exercise on 2-3 days a week. It is suggested to complete at least 1 set of between 8-15 repetitions of 8-10 different exercises, focusing on the major muscle groups (1, 2, 24). The routine should be progressive in nature (24), meaning it should increase in weight and duration over time.

Exercise Prescription

Exercise prescription techniques are used to design exercise programs for people and to instruct them on correct ways to exercise (on an individual basis). Exercise prescription is usually based upon maximal oxygen consumption ($VO_2\text{max}$), maximal heart rate, or perceived exertion (RPE) values or zones. ACSM generally recommends exercising between 40-85% of $VO_2\text{max}$. The lower end, between 40-60%, is considered the moderate intensity zone and is for achieving health benefits. The upper range, from 60-85%, is more intense exercise and is considered better for increasing or building fitness. Recommended RPE ranges are from 11-16 on the Borg 6-20 scale, with 11-13 being for moderate intensity exercise and 14-16 being higher intensity exercise (24).

Helgerud et al. (15) performed a study to compare the results of aerobic training at different intensities which were matched for total work and frequency. Their subjects were 40 healthy, moderately trained males who were randomly assigned into four different exercise groups: one long distance slow running group, one group running at lactate threshold, and two groups running different intervals at 90-95% $VO_2\text{max}$. Maximal oxygen uptake, stroke volume, blood volume, lactate threshold, and running economy were measured and the results indicated that interval training at higher exercise intensities increased $VO_2\text{max}$ and stroke volume more than either the long slow group or the lactate threshold group (15). Therefore, aerobic exercise is able to increase physiological markers such as $VO_2\text{max}$ and stroke volume, and training at higher exercise intensities is more effective than moderate aerobic exercise intensities.

$VO_2\text{max}$ Testing

Traditionally VO_2max is determined by a maximal exercise test on a treadmill or a cycle ergometer, and these are the values commonly used for exercise prescription. VO_2max protocols using these modalities have been shown to be an efficient, valid, and reproducible measure of maximal oxygen consumption (14, 16, 19). LeMura et al. (16) compared treadmill and cycle ergometer protocols in 48, 5-6 year old children. They found that even though the children had significantly higher VO_2max and heart rate values on the treadmill, both modalities achieved the criteria for a maximal effort. They also saw no gender differences and concluded that both modes are effective for testing VO_2max in children (16).

Hawkins et al. (14) tested the validity of two different VO_2max treadmill protocols on adult competitive middle distance runners. They found no difference in the results and concluded that VO_2max is a valid way of measuring cardiorespiratory capacity to transport oxygen throughout the body during exercise (14). However, Ashe et al. (3) showed with 10 physically active young men that body position matters on cycle ergometer tests. Untrained athletes achieved greater VO_2max , ventilation, and heart rate values in the upright position (3).

Maximal oxygen consumption can also be tested with the upper body using an arm ergometer. There are two common types of testing protocols which are called step or ramp protocols. Step protocols start at an initial load and then increase in difficulty by a prescribed amount every few minutes. Ramp protocols start at an initial load then increase linearly in difficulty by lesser amounts every few seconds. Smith et al. (28) showed that both step and ramp protocols on the arm ergometer are valid for testing VO_2max and other physiologic markers. In their study, 14 physically active men

completed a VO_2max test on the arm ergometer using each protocol. Many of the submaximal physiological values such as VO_2 and heart rate were similar; however, peak VO_2 values were poorly correlated. Smith et al. also performed another study in which they confirmed that the optimal crank rate for VO_2max testing on an arm ergometer is between 70-80 rpm. VO_2max was higher using high cranking rates, but they also showed that there could be an upper limit with cranking rates of over 90 rpm being too high (27, 29). McKeough et al. (20) compared the responses to a constant load protocol (at 80% peak work rate) to an incremental protocol in patients with COPD. They found that the constant load protocol produced higher ventilatory, dyspnea, and RPE values than the incremental session (20). Some research may still need to be done to find the ideal VO_2 testing protocol for the arm ergometer.

VO_2max values obtained from the arm ergometer are usually less than those from lower body modalities (11, 25). Lower body exercise, such as running on a treadmill or riding a cycle, is commonly called whole body exercise because it uses many of the large muscle groups in the legs, core, and upper body all at the same time. Most upper body exercises like the arm ergometer, and some lower body exercises, are referred to as single muscle group exercises because they only use a single large muscle group at a time. Though VO_2max values from an arm ergometer testing the upper body are usually lower than values from lower body modalities, Liguzinski and Korzeniewski (17) explain that oxygen consumption per unit of muscle mass is actually greater during a single muscle exercise, or small group of muscles.

Another study was done on 20 males in their early twenties, where the participants had to perform a maximal test on an arm and a leg exercise. They measured

VO₂max and identified ventilatory thresholds 1 and 2 (VT1 and VT2). Their results showed that VO₂ values at VT1, VT2, and peak workload were significantly lower for the arm exercise than the leg exercise; however, when expressing VO₂ values at VT1 and VT2 as a percent of VO₂max, the arm and leg values were the same (11). This means that even though the overall values for maximal oxygen uptake are lower for arm exercise as compared to leg exercise, VT1 and VT2 occur at the same percentage of VO₂max.

Treadmill running usually elicits the highest values for VO₂max in most subjects (19, 26). However in highly trained athletes, higher VO₂max values can be obtained during performance of the athlete's specific sporting activity (26). Secher and Volianitis (25) found that arm VO₂max is typically about 30 percent lower than that of the leg, but in highly trained arm athletes like rowers, cross country skiers, or swimmers, arm VO₂max can reach or surpass that of the leg. With arm training the ratio between arm and leg VO₂max increases. In rowers this ratio was measured at .90, and in swimmers arm values may actually surpass leg values. Another observation was that when combining arm and leg exercise, VO₂max was not significantly increased in the untrained person and remained similar to measured leg values alone, which suggests a central or cardiac limitation. When intense arm exercise is added to a leg exercise, leg blood flow was seen to be reduced by 10% compared to leg exercise alone. The opposite was true when intense leg exercise was added to an arm exercise, and the decrease in arm blood flow suggests that the arms and legs are in competition for cardiac output (25). Another problem with arm ergometer maximal testing is that the treadmill and the arm ergometer have different heart rate to VO₂ ratios; therefore, it is difficult to use heart rate training

zones obtained from the treadmill for exercise prescription on the arm ergometer and vice versa.

Spinning

Lately there has been an increase in the popularity of indoor cycling type exercises such as spinning and arm cranking. Caria et al. (7) found that spinning is a moderate to very high intensity exercise, which meets the ACSM exercise recommendations for improving cardiorespiratory endurance. They discovered that spinning can also include periods that exceed tested VO_2 max or maximal heart rate (4, 6, 7, 31), which could pose a risk for sedentary or aged populations (4, 7). Battista et al. (4) found similar results with 20 female students from the University of Wisconsin- La Crosse who performed an incremental exercise test to find VO_2 max, maximal heart rate, and ventilatory threshold. They then performed two videotaped spinning classes of 45 and 35 minutes in duration while measuring VO_2 , heart rate, and RPE. The average VO_2 was at 74% and 66% of VO_2 max for the two videos, respectively. Between 35-52% of the workout time was spent at intensities higher than the ventilatory threshold, and 35-38% of the time was spent over the VT heart rate. Amazingly, in 10 of the 40 video sessions there were moments where the subjects achieved VO_2 values which surpassed their measured VO_2 max. They concluded that the majority of the intensity of indoor cycling is moderate, but there are frequent bouts where VO_2 can surpass maximal values, and a substantial portion of the exercise bout is at intensities greater than VT. Therefore,

indoor cycling must be considered a high intensity exercise mode of training with possibilities for both benefits and risks (4).

Benefits from Arm Cranking

Many studies have shown benefits associated with arm cranking using an arm ergometer. Pogliaghi et al. (23) conducted a 12-week training program with healthy elderly subjects on arm and cycle ergometers. Subjects tested on both modes but only trained on one or the other. At the end of the 12 weeks, maximal heart rate remained unchanged, but they found significant improvements in peak work capacity and $VO_2\text{max}$ on their individual modality. They also saw transfer effects with improvements on the other modality as well. The arm crank group improved slightly more than the cycle group. Specific test improvement was greater than cross test improvement, 20% versus 9% respectively. The cross test improvement was thought to be from central or cardiovascular adaptation/improvement and accounted for nearly half of the noticed improvement, while the rest of the specific improvement was attributed to peripheral muscle adaptation (23).

Other studies have shown benefits from upper-body arm crank training programs in patients following hip replacement surgery (18), in stroke victims (12), and in COPD patients (13). The latter of these studies was done by Gigliotti et al. (13) on 12 patients with moderate to severe COPD. First they had the subjects perform an incremental symptom-limited exercise test on the arm ergometer, then an arm crank program was

instituted. Following the 12-week training program they found a significant increase in exercise capacity, as well as a significant decrease in ventilation rate and exercise dyspnea at a standardized work rate. They concluded that an arm training program increases arm endurance, modulates dynamic hyperinflation, and reduces symptoms in COPD patients (13). Cycling on an arm ergometer is believed to be an effective and useful tool for pulmonary rehabilitation patients (12, 18).

Studies done on paraplegics in wheelchairs have shown that normal wheelchair use does not provide adequate cardiovascular training, but with the addition of exercise from an arm ergometer, pulleys, or wheelchair sports, paraplegics can improve their physical conditioning (9). Other studies have found that paraplegic subjects can increase VO_2 max and other physiological markers consequent to an arm ergometer training program just like non-handicapped subjects (10, 30). Davis et al. (10) demonstrated that a 16-week training program involving 9 paraplegic wheelchair subjects exercising increased VO_2 max by 30% and stroke volume by 12-16% (10).

The Krankcycle

The newest of these cycling type exercise machines is called the Krankcycle. The Krankcycle is a hand powered cycle similar to an arm ergometer. It works by providing a rhythmical rotational exercise with the muscles of the core and upper body using independent crank arms. Possible uses for this machine are vast. It could be used in cross-training for endurance athletes, which would provide a different exercise modality and transfer effects. It could be also useful for special populations such as people with disabilities, lower limb injuries, or obesity who cannot get an aerobic workout with the

lower limbs. Lastly, it could be useful for the average fitness club member who wants to get a good upper body workout. Many beneficial claims are made by the company on their website including statements such as it improves cardiovascular fitness, provides effective cross training, improves upper body strength, improves core strength, promotes weight management, and improves selected sports performance (21). To our knowledge, there has not been any substantial research done on this machine.

Summary

As we have seen, not nearly enough Americans are exercising on a regular basis. Because of the vast benefits associated with exercise, health professionals and fitness enthusiasts alike are always looking for the next fitness craze. Recently, instructor led classes such as yoga and spinning have become immensely popular. A new indoor cycling-type exercise machine to hit the market is called the Krankcycle. Like other arm cranking upper body exercises, this machine has many possible uses and benefits; however to our knowledge there is no research to test its claims.

REFERENCES

1. American College of Sports Medicine Official Website [Internet]: ACSM; [cited 2008 July 29]. Available from:
http://www.acsm.org/AM/Template.cfm?Section=Home_Page&TEMPLATE=/CM/HTMLDisplay.cfm&CONTENTID=7764
2. American College of Sports Medicine (2006). *ACSM's Guidelines for Exercise Testing and Prescription* (7th ed.). Philadelphia: Lippincott Williams & Wilkins.
3. Ashe M.C., G.C. Scroop, P.I Frisken, C.A. Amery, M.A. Wilkins, and K.M. Khan. Body position affects performance in untrained cyclists. *Br J Sports Med.* 37(5): 441-444, 2003.
4. Battista R.A., C. Foster, J. Andrew, G. Wright, A. Lucia, and J.P. Porcari. Physiologic responses during indoor cycling. *J Strength Condit Res.* 22(4): 1236-1241, 2008.
5. Blair S.N., H.W. Kohl, R.S. Paffenbarger, D.G. Clark, K.H. Cooper, and L.W. Gibbons. Physical fitness and all-cause mortality: A prospective study of healthy men and women. *JAMA.* 262: 2395-2401, 1989.
6. Bradford A., M. Scharff-Olson, H.N. Williford, S. Walker, and S. Crumpton. Cardiorespiratory responses to traditional and advanced group cycling techniques. *Med Sci Sports Exerc.* 31(5) Supplement: S113, 1999.
7. Caria M.A., F. Tangianu, A. Concu, A. Crisafulli, and O. Mamei. Quantification of spinning bike performance Turing a standard 50-minute class. *J Sports Sci.* 25(4): 421-429, 2007.
8. Carnethon M.R., M. Gulati, P. Greenland. Prevalence and cardiovascular disease correlates of low cardiorespiratory fitness in adolescents and adults. *JAMA.* 294 (23): 2981-2988, 2005.

9. Davis G.M., P.R. Kofsky, J.C. Kelsey, and R.J. Shephard. Cardiorespiratory fitness and muscular strength of wheelchair users. *Can Med Assoc J.* 125(12): 1317-1323, 1981.
10. Davis G.M., R.J. Shephard, and F.H. Leenen. Cardiac effects of short term arm crank training in paraplegics: echocardiographic evidence. *Eur J Physiol Occup Physiol.* 56(1): 90-96, 1987.
11. Dekerle J., L. Dupont, I. Caby, G. Marais, J. Vanvelcenaher, J.M. Lavoie, and P. Pelayo. Ventilatory thresholds in arm and leg exercises with spontaneously chosen crank and pedal rates. *Percept Mot Skills.* 95: 1035-1046, 2002.
12. Diserens K., N. Perret, S. Chatelain, S. Bashir, D. Ruegg, P. Vuadens, and F. Vingerhoets. The effect of repetitive arm cycling on post stroke spasticity and motor control: repetitive arm cycling and spasticity. *J Neurol Sci.* 253(1-2): 18-24, 2007.
13. Gigliotti F., C. Coli, R. Bianchi, M. Grazzini, L. Stendardi, C. Castellani, and G. Scano. Arm exercise and hyperinflation in patients with COPD: effect of arm training. *Chest.* 128(3): 1225-1232, 2005.
14. Hawkins M.N., P.B. Raven, P.G. Snell, J. Stray-Gundersen, and B.D. Levine. Maximal oxygen uptake as a parametric measure of cardiorespiratory capacity. *Med Sci Sports Exerc.* 39(1): 103-107, 2007.
15. Helgerud J., K. Hoydal, and E. Want. Aerobic high intensity intervals improve VO₂max more than moderate training. *Med Sci Sports Exerc.* 39:665-671, 2007.
16. LeMura L.M., S.P. von Duvillard, S.L. Cohen, C.J. Root, S.A. Chelland, J. Andreacci, J. Hoover, and J. Weatherford. Treadmill and cycle ergometry testing in 5-to-6 year-old children. *Eur J Appl Physiol.* 85(5): 472-478, 2001.
17. Liguzinski P., B. Korzeniewski. Oxygen delivery by blood determines the maximal VO₂ and work rate during whole body exercise in humans: in silico studies. *Am J Physiol Heart Circ Physiol.* 293(1): H343-353, 2007.
18. Maire J., B. Dugue, A. Faillenot-Maire, J. Smolander, N. Tordi, B. Parratte, C. Grange, and J. Rouillon. Influence of a 6-week arm exercise program on walking

ability and health status after hip arthroplasty: a 1-year follow-up pilot study. *J Rehabil Res Dev.* 43(4): 445-450, 2006.

19. McConnell T.R. Practical considerations in the testing of VO₂max in runners. *J Sports Med.* 5: 57-68, 1988.
20. McKeough Z.J., J.A. Alison, B.A. Speers, and P.T. Bye. Physiological responses to high intensity, constant-load arm exercise in COPD. *Respir Med.* 102(3): 348-353, 2007.
21. Official Krankcycle website: Montecito (CA): Five Giri, Inc; [cited 2008 July 29]. Available from: www.krankcycle.com.
22. Pate R.R., M. Pratt, S.N. Blair, W.L. Haskell, C.A. Macera, C. Bouchard, D. Buchner, W. Ettinger, G.W. Heath, and A.C. King. Physical activity and public health. A recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA.* 273, (5): 402-407, 1995.
23. Pogliaghi S., P. Terziotti, A. Cevese, F. Balestreri, F. Schena. Adaptations to endurance training in the healthy elderly: arm cranking versus leg cycling. *Eur J Appl Physiol.* 97: 723-731, 2006.
24. Pollock M.L., G.A. Gaesser, J.D. Butcher, J. Despres, R.K Dishman, B.A. Franklin, and C.E. Garber. ACSM Position Stand: The Recommended Quantity and Quality of Exercise for Developing and Maintaining Cardiorespiratory and Muscular Fitness, and Flexibility in Healthy Adults. *Med Sci Sports Exerc.* 30:975-991, 1998.
25. Secher N.H., S. Volianitis. Are the arms and legs in competition for cardiac output? *Med Sci Sports Exerc.* Review. 38(10): 1791-1803, 2006.
26. Shephard R.J. Tests of maximum oxygen intake- a critical review. *J Sports Med.* 1: 99-124, 1984.
27. Smith P.M., E. McCrindle, M. Doherty, M.J. Price, and A.M. Jones. Influence of crank rate on the slow component of pulmonary O₂ uptake during heavy arm-crank exercise. *Appl Physiol Nutr Metab.* 31: 292-301, 2006.

28. Smith P.M., M. Doherty, D. Drake, and M.J. Price. The influence of step and ramp type protocols on the attainment of peak physiological responses during arm crank ergometry. *J Sports Med.* 25: 616-621, 2004.
29. Smith P.M., M.J. Price, and M. Doherty. The influence of crank rate on peak oxygen consumption during arm crank ergometry. *J Sports Sci.* 19: 955-960, 2001.
30. Taylor A.W., E. McDonell, and L. Brassard. The effects of an arm ergometer training programme on wheelchair subjects. *Paraplegia.* 24(2): 105-14, 1986.
31. Williford H.N., M. Scharff-Olson, A. Bradford, S. Walker, and S. Crumpton. Maximum cycle ergometry and group cycle exercise. A comparison of physiological responses. *Med Sci Sports Exerc.* 31(5) Supplement: S113, 1999.