The Upper Body Rowing Ergometer: validation of a new piece if fitness equipment for use as a research assessment tool.

Chayanika Sharma, Karen Troy, Thayne Munce

Department of Kinesiology and Nutrition, University of Illinois at Chicago, IL

Key Words: Cardio-vascular assessment, upper body rowing ergometer, arm crank ergometer, wheelchair-users, peak oxygen consumption, graded exercise test

INTRODUCTION:

In 1994 the National Health Interview Survey on Disability (NHIS-D) estimated that 1.6 million Americans used wheelchairs. It was also revealed by the NHIS-D that over 90% of wheelchair users used manual devices. More recently statistics provided by The National Institute of Neurological Disorders and Stroke show that between 15% and 25% of wheelchair users are individuals with spinal cord injury (SCI); one of a number of conditions that severely limit the ability of an individual to perform activities requiring use of the lower extremities. Therefore it is important that alternative forms of exercise and physical activity be developed to allow participation by individuals with such disabilities.

Numerous studies have shown the need for regular exercise and the effectiveness of physical activity programs in the improvement of quality of life of individuals using wheelchairs[1-3]. Although it has been over 18 years since the implementation of the Americans with Disabilities Act (ADA), exercise options for individuals in wheelchairs are still limited[4, 5]. Due to the nature of their disability, users of wheelchairs are unable to perform cardiovascular exercises using standard fitness equipment such as treadmills and fitness bikes. The use of arm crank

ergometers and wheelchair ergometers, neither of which are widely available at commercial fitness facilities, are the most common aerobic exercise prescriptions for individuals in wheelchairs[6, 7].

Both arm crank ergometers and wheelchair ergometers use the same muscle groups as those used by individuals in wheelchairs to propel themselves continually in activities of daily living (ADLs). These include the muscle groups of the posterior upper arm, chest, and mid and anterior shoulder. The high degree of use of these muscle groups within even a well designed aerobic exercise program, in addition to use in ADLs, can quickly lead to muscle imbalance and overuse injuries[8, 9]. Therefore it is crucial to find a widely available method of cardiovascular focused exercise that focuses on a different muscle groups than those previously described. The upper body rowing ergometer (UBRE), developed at the University of Illinois at Chicago, is an accessory unit that can be easily attached to a standard fitness bike at a commercial fitness facility. This device not only allows equal access to standard fitness equipment for individuals with limited lower body function, it also stresses the muscle groups of the anterior upper arm, mid and posterior shoulder, and the upper and lower back: the opposing groups to those used in ADLs[10]. Thus, the UBRE will allow individuals that use a wheelchair to perform an effect aerobic exercise routine without fear of experiencing overuse or muscle imbalance injuries.

The purpose of this study is to determine if the Upper Body Rowing Ergometer (UBRE), developed at the University of Illinois at Chicago, can be used as a research tool to assess an individuals aerobic fitness capabilities. As the UBRE is a newly developed device it is not yet known if it could be used in a research environment as a valid test of aerobic capacity. It is hoped that the information gained from the study will allow clinicians and future researchers to

have the option of using the UBRE to evaluate an individuals responses to upper body aerobic exercise.

The UBRE may also be used for research purposes when looking at aerobic exercise responses, especially VO2peak, in individuals with lower body impairments. However, if this is the case it must first be validated against current upper body tests for aerobic fitness to ensure that VO2peak testing using the UBRE will provide reliable data, which accurately represents and individuals aerobic capabilities. The purpose of this study is to demonstrate that the new prototype UBRE can be used in a research setting as a valid test for VO2peak, and can be used to look at the responses to aerobic exercise of individuals in wheelchairs.

The specific aims of the study are: (a) The study will compare the VO2 values of the subjects throughout 2 different graded exercise tests (and the VO2peak values achieved) in an attempt to fulfill the specific aim of the investigation:. (b) To validate that the UBRE may be used as a reliable alternative research assessment tool of aerobic fitness.

METHODS

SUBJECTS: Nine male and six female subjects volunteered for the study. Table 1 presents the physical characteristics of the subjects. All the subjects were health and physically active but not specifically trained. The Institutional Review Board at the University of Illinois, Chicago, approved the study. Upon the first visit to the lab, a coronary artery disease risk factor assessment was performed by guiding the subjects through an AHA/ACSM pre-participation questionnaire that included questions about family history, cigarette smoking and physical activity. The exclusion criteria for the study included pregnancy, smoking and two or more risk

factors for coronary artery disease (as per the recommendations of the American College of Sports Medicine).

Table 1 Physical characteristics of the subjects (mean ± SD)

Height (Inches)	66.07	3.85
Weight (Lbs)	175.13	39.88
BMI (Kg/m^2)	28.01	4.98
Resting heart rate (bpm)	77	7.69

PROTOCOL:

Following the completion of the informed consent forms and pre-exercise screening questionnaires, the subjects were given preliminary instructions on how to complete the different tests. The subjects were randomly assigned the initial graded exercise test (GXT) using either the arm crank ergometer or the novel equipment – upper body rowing ergometer (UBRE). The graded exercise test was used to determine physiological responses such as VO_2, VO_{2peak} and peak heart rate on each ergometer. The participants were familiarized with the testing equipment and the procedure before the test.

Arm Crank Ergometer Protocol:

Based on the previously conducted studies[11], the arm crank ergometer protocol consisted of progressively increasing power output (W) in 2-minute stages. A warm up period at a subject selected cranking cadence was performed for a minute before the commencement of the test. The initial power output was set at 20W and the subjects were instructed to maintain a cadence of 50 rpm throughout the test. The power output was increased in the increments of 10W at the end of each 2-minute stage. Throughout the test, heart rate was continually monitored by a Polar

heart rate monitor (Polar Electro, Kempele, Finland) and recorded at the end of each minute. The subject's rating of perceived exertion (RPE) was evaluated every minute using the 20-point Borg scale (Borg, 1970).

UBRE Protocol:

The GXT for the UBRE followed a similar protocol as that described for the arm crank ergometer. After a warm up period of 1 minute at a self-selected cadence the subjects began the test at the power output of 40 Watts which was the minimum power output that could be achieved with UBRE. The power was increased at the end of each 2-minute stage throughout the test. Heart rate was continually monitored by a Polar heart rate monitor (Polar Electro, Kempele, Finland) and recorded at the end of each minute. The subject's rating of perceived exertion (RPE) was evaluated every minute using the 20-point Borg scale (Borg, 1970).

All the 15 subjects were asked to return to the lab for a further GXT using the UBRE to determine test-retest reliability of the new device. The same protocol was used to conduct the GXT as described previously. The interval between 2 consecutive tests on a subject varied from 2 to 7 days.

The subject were encouraged to continue until exhaustion since no adverse signs or symptoms were present. Throughout the test, expired air was collected and analyzed for O2 and CO2 concentration and STPD ventilatory volume (Vmax Spectra 29c, Sensormedics, Yorba Linda, CA) to determine VO2peak. Oxygen consumtion, carbon dioxide production and minute ventilation volume were continuosly monitored throughout the test. Once the data collection was completed, the subjects performed a cool down at a reduced speed and power output (W) for

several minutes while their heart rate was being monitored. After a normal physiological recovery was confirmed, the trial was terminated.

STATISTICAL ANALYSES:

All data comparisons are reported as means ± standard deviations (SD). The analyses were performed using the Statistical Package for Social Sciences (SPSS, version 16; Chicago, IL, USA). VO_2 values, VO_{2peak} and heart rate were analysed using multivariate analysis of variance with repeated measures. Pearson product moment coefficient (r) were used to assess the significance of relationships. Statistical significance was set at $P < 0.05$ and all data comparisons are reported as means and standard deviations (SD). Multiple *post-hoc* pairwise comparisons with Bonferroni adjustments were used to locate significant differences when necessary.

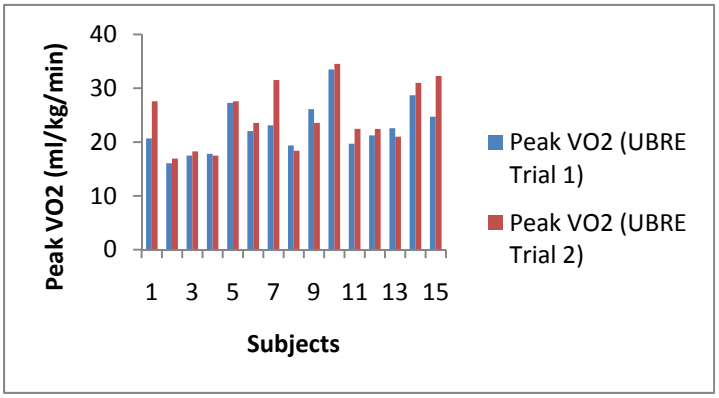
RESULTS:

The subjects completed graded exercise tests with both the devices with no problems. Table 2 presents the peak physiological responses during graded exercise tests with UBRE and ACE. Values for the two trials with UBRE are presented separately. VO_{2max} data obtained from the subjects during exercise on the 2 devices were strongly correlated when expressed in ml/kg/min. Pearson's coefficient of correlation between the peak VO_2 values between trial 1 and 2 with UBRE was 0.826, between trial 1 and ACE was 0.834 and between UBRE trial 2 and ACE it was 0.882. Similarly, strong positive correlations were found between the peak heart rate measured during graded exercise tests on the 2 devices.

Analysis of variance revealed that the values of VO_{2max} were thou only slightly but significantly ($P < 0.05$) higher on the ACE than UBRE trial 1. However, when the peak oxygen consumption on ACE was compared with the trial 2 on UBRE the differences were found to be statistically

insignificant (P > 0.05). The differences in the peak oxygen consumption during the 2 trials with UBRE were not significant (P > 0.05). Figure 1 presents the peak oxygen consumption during trial 1 and 2 using UBRE for each of the subjects individually. In most of the subjects, the peak $VO_{2\ was}$ higher in trial 2 as compared to trial 1. This increase in peak oxygen consumption implies a learning effect. The peak oxygen consumption was higher in trial 2 on UBRE as compare to trial 1. However, analysis of variance revealed that this difference was not significant.

Figure 1 Comparison of Peak VO_2 values for trial 1 and trial 2 with UBRE



No significant differences (P > 0.05) were found between the peak heart rate values on ACE, trial 1 and trial 2 on the UBRE .

Table 2 Peak physiological responses (mean ± SD) during maximal exercise on ACE and 2 different trials on UBRE (VO_{2peak} maximal oxygen uptake, HR_{peak} maximal heart rate, Power - maximal power)

	UBRE 1	UBRE 2	ACE
VO_{2peak} (ml/Kg/min)	22.691 (±4.71)	24.57 (±5.83)	25.43 (±5.57)
HR_{peak}	166 (±15.11)	165.05 (±16.44)	166.53 (±18.39)
Power (Watts)	82.67 (±14.37)	84.67 (±14.57)	67.33 (±14.37)
Time (min)	10.23 ± 3.12	10.6 ± 3.01	11.03 ± 3.11

The time to exhaustion was longer when using ACE because the test with this device started at the minimum power output of 20 W. Due to limitation of the new device, lower power output could not not be achieved so the minimum power at which the test began was 40 W when using UBRE. Starting the test at a higher lower with ACE can explain the difference in time to exhaustion between the 2 devices.

DISCUSSION:

Thou numerous studies have highlighted the importance of exercise for persons with wheelchairs, it is clear that there is a dearth of the exercsie equipments available to them[4, 5]. The most popular equipments – arm crank ergometer and wheelchair ergometers - use the same sets of muscles that are required to propel the wheelchair forward. This increases the possibility of muscle imbalances and overuse injuries. The UBRE has been developed to provide an alternative exercise equipment for people with wheelchairs. The purpose of this study is to determine if the Upper Body Rowing Ergometer (UBRE) can be used as a research tool to assess an individuals aerobic fitness capabilities. The major finding of our study is the strong correlations between the physiological measurements obtained using the upper body rowing ergometer and the arm crank ergometer. Arm crank ergometer has long been considered the standard exercise equipment for wheelchair users and is a reliable and valid tool. The results found in this study indicate that thou the $VO_{2\ peak}$ value obtained using UBRE is slightly lower than that obtained using ACE – the values are very strongly correlated. The second trial with the UBRE gave similar values for peak VO_2 as ACE. In our study, we found that peak physiological measurements taken with the UBRE on the first trial were significantly different from the peak oxygen consumption with the ACE. The difference has been quantified as 10.71% which means that the peak oxygen consumption with the novel device was 10.71% less than that achieved with

the arm crank ergometer. However, when the VO_{2max} values of ACE are compared with than obtained with trial 2 with UBRE, the difference is not significant (P> 0.05). This can be explained by the learning effect seen in case of the UBRE. This learning effect would be even more prominent considering the device is a prototype and involves unique movement pattern which is quite different arm cranking or movement that is done in propelling the hand-rim wheelchair forward.

The peak heart rate values were similar and were strongly correlated to each other and were close to those reported in earlier studies[12, 13]. The test lasted at least 8-10 minutes for all the subjects. This has been found to be the optimal time to assess VO_{2max} [14, 15] . The protocol that was used in this study was rapidly progressing protocol would enable subjects to elicit VO_{2max} before local muscle fatigue starts limiting exercise[16].

One of the limitations of our study was that we did only one trial with arm crank ergometer and 2 with UBRE. It is difficult to say whether or not a significant learning effect would be seen with the ACE. Another limitation of the study is the small sample size. The peak oxygen consumption values we found are lower as compared to values achieved using rowing ergometer in some of the previous studies[17] because the novel device we investigated in meant to exercise only the arms and the upper back unlike the traditional rowing device that works out legs in addition to the arms, trunk and the back muscles. If an exercise equipment employs a greater amount of muscle involvement as compared to upper body rowing the peak VO_2 values obtained are also higher[18]. Another reason for relatively lower peak oxygen consumption is possible contribution of muscle fatigue instead of only cardiovascular factors. Our subjects were normal healthy subjects but were not specifically trained in arm exercises. The results could possibly be different with wheelchair users - Due to the limited number of subjects, the analysis was done

with the gender factor blocked. However, descriptive statistics indicated that men reached higher values of VO_{2peak} as compared to women in all the tests.

We used healthy, physically active subjects for this study. The second part of the study is currently being carried out the University of Illinois, Chicago for which wheelchair users are being recruited to participate in a training study involving the UBRE and ACE.

In summary, our study is the first one to use and validate the newly developed upper body rowing ergometer. Thou it is possible to get higher values of VO_{2peak} in the subsequent trial due to the learning effect, the upper body rowing ergometer (UBRE) is a valid tool for the assessment of cardio-vascular fitness and to study physiological responses of individuals to upper-body exercise. It is also an alternative exercise equipment for the persons using wheelchairs as it would help in preventing over-use injuries which are very common in this population.

REFERENCES:

1. Harness, E.T., N. Yozbatiran, and S.C. Cramer, *Effects of intense exercise in chronic spinal cord injury.* Spinal Cord, 2008. **46**(11): p. 733-737.
2. Fernhall, B., et al., *Health implications of physical activity in individuals with spinal cord injury: a literature review.* J Health Hum Serv Adm, 2008. **30**(4): p. 468-502.
3. Valent, L.J., et al., *Influence of hand cycling on physical capacity in the rehabilitation of persons with a spinal cord injury: A longitudinal cohort study.* Archives of Physical Medicine and Rehabilitation, 2008. **89**(6): p. 1016-1022.
4. Rimmer, J.H., et al., *Accessibility of health clubs for people with mobility disabilities and visual impairments.* American Journal of Public Health, 2005. **95**(11): p. 2022-2028.
5. Riley, B.B., et al., *A conceptual framework for improving the accessibility of fitness and recreation facilities for people with disabilities.* J Phys Act Health, 2008. **5**(1): p. 158-68.
6. Mukherjee, G., P. Bhowmik, and A. Samanta, *Physical fitness training for wheelchair ambulation by the arm crank propulsion technique.* Clinical Rehabilitation, 2001. **15**(2): p. 125-132.
7. Jacobs, P.L. and M.S. Nash, *Exercise recommendations for individuals with spinal cord injury.* Sports Medicine, 2004. **34**(11): p. 727-751.
8. Curtis, et al., *Effect of a standard exercise protocol on shoulder pain in long-term wheelchair users*. Vol. 37. 1999, London, ROYAUME-UNI: Nature Publishing.
9. Taylor, D. and T. Williams, *SPORTS INJURIES IN ATHLETES WITH DISABILITIES - WHEELCHAIR RACING.* Paraplegia, 1995. **33**(5): p. 296-299.
10. Rumball, J.S., et al., *Rowing injuries.* Sports Medicine, 2005. **35**(6): p. 537-555.
11. Smith, P.M., M.P. Price, and M. Doherty, *The influence of crank rate on peak oxygen consummption during arm crank ergometry.* Journal of Sports Sciences, 2001(19): p. 955-960.
12. Weissland, T., et al., *Physiological effects of variations in spontaneously chosen crank rate during incremental upper-body exercise.* European Journal of Applied Physiology and Occupational Physiology, 1997. **76**(5): p. 428-433.
13. Sawka, M.N., et al., *DETERMINATION OF MAXIMAL AEROBIC POWER DURING UPPER-BODY EXERCISE.* Journal of Applied Physiology, 1983. **54**(1): p. 113-117.
14. Astrand, P.O. and B. Saltin, *MAXIMAL OXYGEN UPTAKE AND HEART RATE IN VARIOUS TYPES OF MUSCULAR ACTIVITY.* Journal of Applied Physiology, 1961. **16**(5): p. 977-&.
15. Buchfuhrer, M.J., et al., *OPTIMIZING THE EXERCISE PROTOCOL FOR CARDIOPULMONARY ASSESSMENT.* Journal of Applied Physiology, 1983. **55**(5): p. 1558-1564.
16. Brahler, C.J. and S.E. Blank, *VERSACLIMBING ELICITS HIGHER VO2MAX THAN DOES TREADMILL RUNNING OR ROWING ERGOMETRY.* Medicine and Science in Sports and Exercise, 1995. **27**(2): p. 249-254.
17. Arabi, H., et al., *Relationship between maximal oxygen uptake on different ergometers, lean arm volume and strength in paraplegic subjects.* European Journal of Applied Physiology and Occupational Physiology, 1997. **76**(2): p. 122-127.
18. Blomqvist, C.G., et al., *SIMILARITY OF THE HEMODYNAMIC-RESPONSES TO STATIC AND DYNAMIC EXERCISE OF SMALL MUSCLE GROUPS.* Circulation Research, 1981. **48**(6): p. 87-92.