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A CADENCE BASED SUB-MAXIMAL FIELD TEST FOR THE PREDICTION OF PEAK OXYGEN CONSUMPTION IN ELITE WHEELCHAIR BASKETBALL ATHLETES

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ABSTRACT

A CADENCE BASED SUB-MAXIMAL FIELD TEST FOR THE PREDICTION OF PEAK OXYGEN CONSUMPTION IN ELITE WHEELCHAIR BASKETBALL ATHLETES. **James J. Laskin, Dustin Slivka, Michael Frogley**. **JEP**online. 2004;7(1):8-18. Twenty-four elite wheelchair basketball athletes were recruited to assess the feasibility and concurrent validity of a cadence based sub-maximal field test. Sub-maximal trials consisted of two, five-minute workloads at 60 and 80 pushes per minute (pushes/min). The field test was performed by wheeling around an indoor basketball court to the beep of a metronome. Peak oxygen consumption, while arm cranking, was determined using an automated metabolic measurement system. Stepwise forward linear regression was used to develop prediction equations for peak VO_2 (VO_2 peak) for both cadences, resulting in the following equations; 60 pushes/min VO_2 peak (L/min) = 0.74 + 0.31(classification) + 0.003(distance covered) – 0.15(RPE), $r^2 = 0.73$, SEE = 0.48 L/min; 80 pushes/min VO_2 peak (L/min) = 1.50 + 0.0029(distance covered) - 0.16(RPE) + 0.235(classification), $r^2 = 0.74$, SEE = 0.45 L/min. There were no significant differences between the actual and the estimated VO_2 peak values at either cadence. In addition the estimated VO_2 peak from both cadence equations were linearly correlated (r = 0.87). Bland-Altman plots revealed no cases where the difference between the actual and predicted VO_2 peak was greater than two standard deviations beyond the mean of the differences, demonstrating good agreement. Due to the homogeneity of the sample, the test-retest reliability (interclass correlation coefficients) was moderate to poor for select variables; HR = 0.42, RPE = 0.63, distance covered = 0.50 and HR = 0.65, RPE = 0.70, distance covered = 0.62 for 60 and 80 pushes/min, respectively. The results of this preliminary study indicate that this sub-maximal field test is efficient, simple to perform, and predicts VO_2 peak in competitive wheelchair basketball athletes with similar accuracy to prediction equations designed for able-bodied individuals.

Key Words: Cardiorespiratory fitness test, lower-limb disabled, rating of perceived exertion, wheelchair user.

INTRODUCTION

With improvements in the type and quality of medical interventions, the life span of individuals with a permanent physical limitation and associated mobility impairments has increased. However, due to a variety of psychosocial, economic, environmental, and societal factors, these individuals tend to adopt a sedentary lifestyle (1). An unfortunate consequence of this inactive lifestyle is the development of other chronic disabling conditions such as diabetes, coronary artery disease, and hypertension. Such conditions become the primary causes of mortality in this population (2). In order to appropriately prescribe, monitor, and evaluate exercise programs in this population, a reliable and valid exercise assessment is required.

Cardiorespiratory fitness assessment, whether maximal or sub-maximal, is a critical component in the development of an individual's exercise program. Exercise testing provides the clinician with baseline data that can be used to identify an individual's needs in order to develop an appropriate exercise program. (3) Standardized testing provides a tool to evaluate the effectiveness of the prescribed exercise program and gives the client motivating feedback.

Sub-maximal exercise testing has many advantages over maximal testing and is preferred by clinicians working with individuals with chronic pain or physical limitations, such as spinal cord injuries (4). Maximal tests tend not to be functional or accurate in specific populations such as children, the elderly, and individuals with disabilities or chronic diseases. In addition, many individuals, especially those who do not exercise regularly, are unwilling to participate in maximal fitness testing because of fear and/or intolerance of the pain and discomfort required to attain maximal effort. Sub-maximal testing is not associated with these anxieties or functional limitations, and therefore is the method of choice for those who are detrained, experience chronic pain, and/or have mobility impairments. Sub-maximal tests are also less labor intensive and generally require less staff and monitoring equipment (5).

Currently, there are a number of validated sub-maximal and maximal aerobic fitness tests designed for wheelchair users. Sub-maximal and maximal arm crank ergometry has been demonstrated to be a valid tool for assessing the cardiorespiratory fitness status of wheelchair users, but the arm cranking action is not functionally related to wheelchair mobility (3). Other tests, such as maximal and sub-maximal wheelchair treadmill tests and wheelchair ergometry based incremental speed tests, have also been shown to be valid and reliable (2). However, all of these tests must be done in a clinical or laboratory setting and this requires expensive equipment, trained administrators, and is often time consuming.

Field tests for wheelchair users have been developed in an attempt to address some of these issues. The 12 min Cooper test for distance was adapted for wheelchair users and found to be well correlated ($r = 0.84$) to peak oxygen consumption (VO_2 peak) as determined by a typical laboratory based graded max arm ergometry test. Although this modified protocol developed by Franklin et al. (5) meets the requirements of a simple field test, self-paced tests for distance, regardless of the target population, are motivation dependent and previous experience will often influence the results (5).

Vanlandewijck et al. (6) used a wheelchair version the 25 m shuttle run "beep test" and found that it correlated well ($r = 0.78$) with the peak heart rate (HR) measured in a maximal arm ergometry effort . Vinet et al. (7) found a moderate correlation ($r = 0.65$) between the laboratory derived VO_2 peak and an incremental field test using a 400 m tartan track. A multistage field wheeling test, a modified version of Leger and Boucher's (8) continuous incremental running test, was developed and tested by Vanderthommen et al (9). These authors found moderate to high correlations between the distance covered during the shuttle wheel and the arm crank determined VO_2 peak and maximum power output ($r = 0.64$ and $r = 0.87$ respectively). Although all of the aforementioned protocols meet the requirements of a field test, they require the maximal effort of the participant. Therefore, a sub-maximal field test for wheelchair users that is easy to administer, potentially self-administered, time efficient, and requires minimal equipment, is necessary in order to provide safer and more reliable exercise prescriptions in the current health care environment.

The purpose of this study was to determine the feasibility and concurrent validity of a cadence based, sub-maximal field test of VO_2 peak for wheelchair users that is easy to administer and time efficient. Having wheelchair users propel themselves at a specific cadence is a method of testing that is both exercise mode specific and functional.

METHODS

Subjects

Twenty-four male athletes were recruited from the Canadian National Men's Wheelchair Basketball and from the Men's University of Illinois-Champaign/Urbana Collegiate Wheelchair Basketball teams. Table 1 describes the participants' functional ability as assessed by the International Wheelchair Basketball Federation (IWBF) functional classification system (10,11). The IWBF classification system was designed to distinguish between the various physical and functional attributes among wheelchair basketball athletes. The system assesses the player's total volume of action versus technique or ability. There are four general classes (1 through 4), with half point designations for extenuating circumstances. This system allows for equitable comparisons between individuals with a wide range of neuromuscular and physical limitations.

Table 1. International Wheelchair Basketball Federation (10,11) classification characteristics of the study samples.

IWBF Classification	*Total Study Sample (n = 24)*	*Retest Sample – 2 days post (n = 16)*	*Retest Sample – 16 months post (n = 7)*
	Number of participants in class	Number of participants in class	Number of participants in class
1	4	3	2
1.5	0	0	0
2	5	3	1
2.5	3	1	1
3	4	6	1
3.5	2	0	1
4	2	1	0
4.5	4	2	1

IWBF = International Wheelchair Basketball Federation

The participants in this study included individuals with paraplegia, lower-limb amputations, spina bifida, congenital lower-limb joint deformities, and cerebral palsy. The inclusion criteria include the following: membership on the Canadian National or University of Illinois Men's Wheelchair Basketball teams, no acute illness or infections, no current upper-limb injury, and no contraindications for maximal exercise testing. The participants signed informed consent as per the regulations outlined by the Institutional Review Board of The University of Montana and The University of Illinois – Champaign/Urbana.

Protocol

Participants were required to attend two testing sessions. During the first session the participants' height, weight and other demographic data was recorded and they performed the cadence based sub-maximal field test. Participants used their own competition basketball chairs. The researchers ensured that the tires were inflated to the recommended pressure and that any unnecessary paraphernalia was removed. The researcher affixed the heart rate monitor (Polar Co., Port Washington, NY) and the credit card sized electronic metronome to the participant. The athlete then warmed-up by propelling his wheelchair around the perimeter of an indoor, hardwood, NCAA regulation sized basketball court at each of the two test cadences, 60 and 80 pushes per minute (pushes/min) for one minute each. Cones were placed at the four corners and pieces of white athletic tape were placed 2 feet out from the corner. The athletes were instructed to straddle the pieces of white tape with their front casters while negotiating each corner.

After the warm up, a five-minute rest period was completed prior to starting the sub-maximal testing session. The two cadences were completed sequentially beginning with the lowest workload of 60 pushes/min. Each workload was maintained for five minutes. The participant was instructed to try to cover as much distance as possible during the five-minute period while maintaining strict adherence to the beep of the metronome. At the end of each five-minute sub-maximal exercise bout, the participant rested for five minutes. During this time their rating of perceived exertion (RPE) using the 6-20 scale, and distance wheeled was recorded. The distance covered was measured using a wheeled measuring device, Measure Master MM-12 (Rolatape, Spokane, WA). Heart rate was recorded after every lap and the steady state HR was defined as the average HR during the final minute of the sub-maximal exercise bout. During this rest period, the metronome was set for the 80 pushes/min cadence and the procedures were repeated.

During the second session the participant's VO_2 peak was determined. At least 24 hours elapsed between the two sessions. A Cybex Isokinetic Arm Ergometer (Cybex, Chattanooga, TN) or Sci Fit Pro 1000 (Sinties Scientific Inc., Tulsa, OK) was used for this graded exercise test. All of the participants had previous experience using an arm ergometer as part of their regular training programs. The athlete sat in his own wheelchair with the axis of rotation of the cranks set just below shoulder level. Waist and chest straps were used to secure and stabilize the participant as needed. The athlete was connected via a mouthpiece and open circuit spirometry to a VO2000 metabolic measurement system (MedGraphics, Ann Arbor, Michigan). The VO2000 was manually calibrated as per the manufacture's instructions prior to every test. Heart rate was assessed using a Polarfavor HR monitor (Polar Co., Port Washington, NY).

Prior to the maximal exercise test a 3-minute warm-up was completed at 60 rev/min with the workload set at 25 Watts. The testing procedure consisted of one-minute bouts with increasing resistance until volitional fatigue was reached. The resistance was increased by 10 to 20 Watts/min according to the individual's response to the exercise and their level of functional impairment. Since the arm ergometer maintains a constant workload regardless of the cadence, the athletes were instructed to crank at their own self-selected pace. During the last 30 seconds of each minute HR, RPE, average VO_2, and respiratory exchange ratio (RER) were recorded. Once volitional failure was attained, a five-minute cool down was performed. Peak oxygen consumption, peak HR, and peak RER were defined as the peak values attained during the final workload of this graded exercise test.

A subgroup ($n = 16$) of the participants were available to perform the sub-maximal test a second time 2 days after the initial maximal testing session and a further subgroup ($n = 7$) was available to complete the both the sub-maximal and maximal tests 16 months after the initial study.

Statistics

Independent t-tests were performed to compare participant characteristics. Interclass correlation coefficients (ICC model 2,1 or 2, k) were calculated for HR, RPE, and distance covered for each cadence of the sub-maximal test to examine the reliability of these variables (12). Cadence specific Pearson's product-moment correlations were performed to ass the strength and appropriateness of the correlations between the various independent variables (steady state Hr, RPE, distance wheeled, length, weight, age, and function classification) and VO_2 peak.

All of the independent variables were included in a stepwise forward linear regression procedure that was used to develop the cadence specific equations used to predict VO_2 peak (12). The predicted VO_2 peak was calculated using the cadence specific prediction equations and the sub-maximal test results that were performed both 2 days and 16 months after the initial sub-maximal testing was completed. Comparing the actual versus the predicted VO_2 peak values was performed to assess concurrent validity. Bland-Altman plots graphically display the variability between the actual and the mean of the actual and predicted VO_2 peak values. The limits of agreement were defined as the mean difference plus or minus two standard deviations of the difference between the actual and predicted measurements (13). An independent t-test was used to appraise any differences between the actual and predicted VO_2 peak values (12). A p-value of ? 0.05 was considered as the statistical level of significance. Data are presented as mean?SD.

RESULTS

All of the athletes described in the two test-retest samples participated in the initial portions of this study. There were no significant differences in age, body mass, or length between the three samples (Table 2).

A synopsis of the data collected from the two sub-maximal protocols is detailed in Table 3. The HR, RPE, and distances covered were significantly greater at 80 pushes/min compared to 60 pushes/min. There were no significant differences ($p > 0.05$) in cadence specific HR, RPE, or the distance covered between the initial sub-maximal testing and the sub-maximal testing done 2 days later. The reliability, as evaluated by interclass correlation coefficients (ICC), was found to be moderate to poor for all the measured variables at each cadence. The ICC for the 60 pushes/min sub-max test were as follows: HR = 0.42, RPE = 0.63, and distance covered = 0.50. The ICC for the 80 pushes/min were as follows: HR = 0.65, RPE = 0.70, and distance covered = 0.62.

Table 2. Characteristics of the study samples.

Variable	*Total Study Sample (n = 24)*	*Retest Sample – 2 days post (n = 16)*	*Retest Sample – 16 months post (n = 7)*
Age (yr)	26.1 ? 6.6	22.6 ? 3.1	27.3 ? 4.2
Body Mass (kg)	80.2 ? 13.4	75.5 ? 15.0	73.8 ? 10.6
Height (cm)	177.9 ? 14.8	177.4 ? 16.1	173.4 ? 13.8

Table 3. Characteristics of the two sub-maximal testing protocols (60 and 80 pushes/min).

Pushes/min	*Parameter*	*Total Study Sample (n = 24)*	*Retest Sample – 2 days post (n = 16)*	*Retest Sample – 16 months post (n = 7)*
60	EXHR (beats/min)	124.6 ? 19.4	110.2 ? 9.7	130.3 ? 18.1
	RPE	9.29 ? 2.4	8.25 ? 1.6	10.4 ? 3.1
	Distance (m)	840.6 ? 189.0	695.3 ? 178.5	1104.3 ? 141.9
80	EXHR (beats/min)	141.4 ? 22.6	126.5 ? 13.4	144.1 ? 21.6
	RPE	11.8 ? 2.3	10.9 ? 1.8	12.9 ? 2.3
	Distance (m)	963.8 ? 204.4	818.0 ? 173.1	1171.8 ? 156.7

EXHR=exercise heart rate; RPE=rate of perceived exertion

Table 4 summarizes of peak performance parameters collected during the maximal graded arm crank ergometry test. The average VO_2 peak in this study was 2.89 ? 0.8 L/min or 36.4 ? 10.9 ml/kg/min. Using the arm ergometry equation for predicted maximum HR (210 beats/min – age), the peak HR found in this study was 102.2 ? 7.1 % of the estimated maximum. The RER for the group as a whole was 0.94 ? 0.06.

Of the performance variables recorded during the 60 pushes/min sub-maximal test, only functional classification ($r = 0.54$, $p = 0.00$), body mass ($r = 0.38$, $p = 0.03$), and the distance covered ($r = 0.49$, $p = 0.01$) were significantly correlated to the actual VO_2 peak (L/min). In the 80 pushes/min cadence trial functional classification (r = 0.54, p = 0.00), body mass (r = 0.38, p = 0.03), RPE (r = -0.36, p = 0.04), HR - 3 min post exercise (r = -0.40, p = 0.03), and the distance covered (r = 0.56, p = 0.00) were significantly correlated to the actual VO_2 peak (L/min).

Table 4. Characteristics of the total study sample (n = 24) for the arm-crank ergometry peak performance test.

	Parameter	Mean ? SD
Total Study Sample (n = 24)	Peak HR (beats/min)	187.1 ? 12.3
	Peak RER	0.94 ? 0.06
	Peak VO_2 (L/min)	2.89 ? 0.8
	Peak VO_2 (ml/kg/min)	36.4 ? 10.9
IWBF Classes 1 and 1.5 (n = 4)	Peak HR (beats/min)	186.3 ? 20.6
	Peak RER	0.96 ? 0.11
	Peak VO_2 (L/min)	1.78 ? 0.2
	Peak VO_2 (ml/kg/min)	28.1 ? 5.6
IWBF Classes 2 and 2.5 (n = 8)	Peak HR (beats/min)	186.1 ? 10.5
	Peak RER	0.94 ? 0.04
	Peak VO_2 (L/min)	3.19 ? 0.9
	Peak VO_2 (ml/kg/min)	42.8 ? 15.3
IWBF Classes 3 and 3.5 (n = 6)	Peak HR (beats/min)	187.4 ? 7.5
	Peak RER	0.93 ? 0.04
	Peak VO_2 (L/min)	2.75 ? 0.6
	Peak VO_2 (ml/kg/min)	32.0 ? 6.0
IWBF Classes 4 and 4.5 (n = 6)	Peak HR (beats/min)	188.7 ? 14.4
	Peak RER	0.93 ? 0.07
	Peak VO_2 (L/min)	3.37 ? 0.2
	Peak VO_2 (ml/kg/min)	37.9 ? 3.8

IWBF=International Wheelchair Basketball Federation; RER=respiratory exchange ratio
HR= heart rate; VO_2=oxygen consumption

Independent stepwise linear regression analyses were performed for each of the two cadences. The ratio of independent variables to sample size was 7:24. For both cadences the independent variables that contributed to the prediction model were the individual's functional classification, the distance covered in 5 min of wheeling, and the reported RPE. The prediction equations were as follows.

60 pushes/min
VO_2 peak (L/min) = 0.74 + 0.31(classification) + 0.003(distance covered) – 0.15(RPE), r^2 = 0.73, SEE = 0.48 L/min.

80 pushes/min
VO_2 peak (L/min) = 1.50 + 0.0029(distance covered) - 0.16(RPE) + 0.235(classification), r^2 = 0.74, SEE = 0.44 L/min.

These equations were then used to calculate the estimated VO_2 peak (L/min) based on the athletes' performance during the retest sub-maximal testing (2 days and 16 months samples). An independent t-test revealed that there was no significant difference between the actual VO_2 peak values and those estimated by either the 60 or the 80 pushes/min prediction equations; p = 0.70 and p = 0.42 respectively. In addition the estimated VO_2 peak from both cadence equations were linearly correlated (r = 0.87).

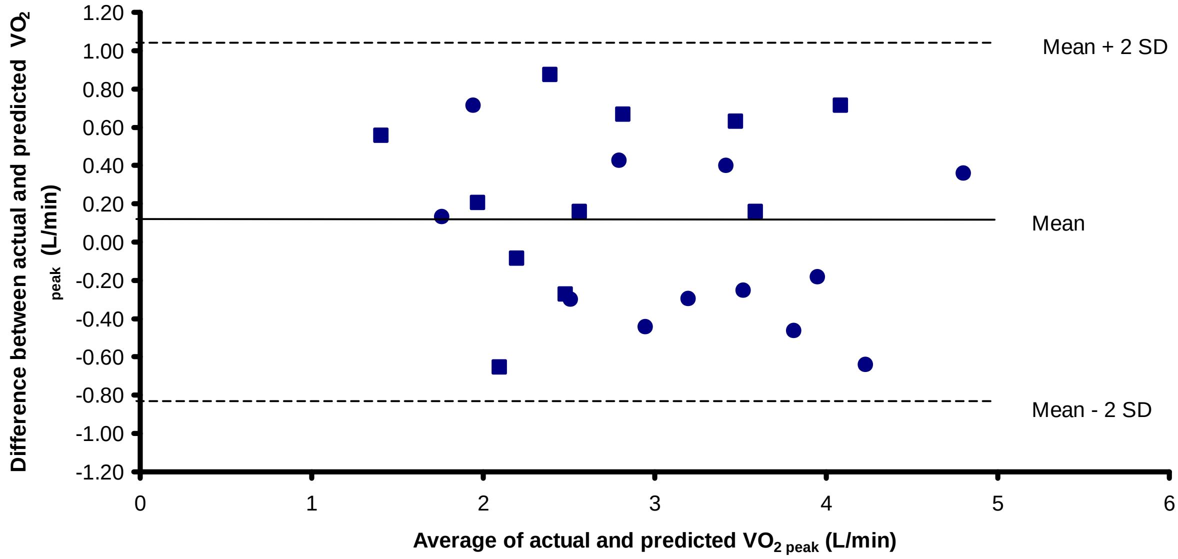

Figure 1. Bland-Altman plot illustrating the clinically relevant predictive ability of the 60 pushes/min regression equation. Closed square = IWBF classifications 1 – 2.5. Closed circle = IWBF classifications 3 – 4.5.

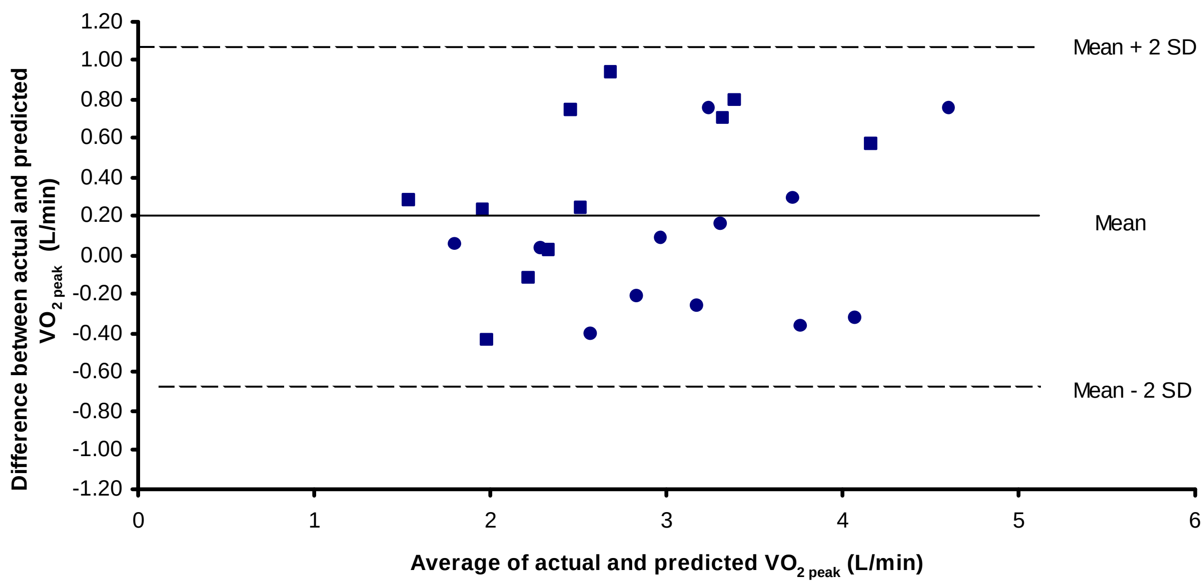

Figure 2. Bland-Altman plot illustrating the clinically relevant predictive ability of the 80 pushes/min regression equation. Closed square = IWBF classifications 1 – 2.5. Closed circle = IWBF classifications 3 – 4.5.

The variability of the estimated values is demonstrated in the Bland-Altman plots in Figures 1 and 2. The limits of agreement for the 60 and 80 pushes/min cadence were 0.11 ? 0.94 L/min and 0.20 ? 0.86 L/min respectively. There was no instance in which the difference between the actual and the predicted VO_2 peak values exceeded the limits of agreement. The 60 pushes/min prediction equation equally over and under predicted the higher (3 to 4.5) classified athletes' VO_2 peak whereas the 80 pushes/min equation tended (9 out of 12 times) to over predict this subgroup's VO_2 peak. Both equations tended (8 out of 11 times) to under predict the athletes with lower (1 to 2.5) functional classifications.

DISCUSSION

With the growing interest in health promotion and wellness, there has been a proliferation of assessment tools for fitness-oriented measurements for the able-bodied population. Many of these tools focus on simplicity and whenever possible can be self-administered. The assessment of cardiorespiratory fitness in wheelchair users, the focus thus far has been on reliability and standardization. Although this approach is well intentioned, it does not meet the greater needs of health promotion and wellness. For a field test to be broadly applicable, it must be valid, and accessible to the public. The advantages of this cadence based sub-maximal field test is its simplicity, ease of administration, minimal equipment requirements, applicability to a wide range of functional abilities, and appears to have reasonable predictive accuracy.

Sixteen of the 24 athletes in this study repeated the sub-maximal tests two days after the initial testing session which allowed for the test-retest reliability of these two cadence based tests to be determined. The ICC for HR, RPE, and the distance covered were found to be moderate to poor for both the cadences evaluated. Although initially concerning, upon reflection the low reliability of the ICCs was not surprising. Besides truly being an unreliable test, there are two primary reasons for finding low ICC values: either the pairs of ratings do not agree and/or the variability between participant scores is low (12). In this study both could potentially occur. The nature of a cadence based sub-maximal test is that the cadence is strictly controlled, while the participant is asked to cover as much distance as possible. Thus the only adaptations the participant can make in their effort to cover as much distance as possible are the amount of effort put into each push and the duration of contact on their wheels. However, there were no significant differences in the HR, RPE and the distance covered between the repeated efforts at either cadence (Table 3).

Though it appears that the low reliability was not due to poor agreement between the pairs of repeated measurements, one must keep in mind that the participants in this study were well-trained athletes and therefore the amount of "learning" between trials was probably minimal. This may not be the case if this study were conducted on non-athletes. Indeed, the learning response would have to be carefully considered and managed in the general population. The likely cause of the low reliability found in this study was the fact that we used a homogenous sample. Although the participants in this study differed in their functional classification, they were all male elite wheelchair basketball athletes. Data is currently being collected on low to moderately active male and female wheelchair users has demonstrated moderate to high reliability when combined with the data collected for this study. Therefore, as expected, as the sample becomes more heterogeneous the reliability improves. In spite of the low reliability reported in this study, we believe that the cadence-based sub-maximal field test at either 60 or 80 pushes/min has the potential to demonstrate good clinical reliability.

The VO_2 peak and peak HR values reported in this study were comparable to similar populations in the literature (5-7). Every athlete in this study reached volitional exhaustion, based on their inability to continue arm cranking and their reported RPE > 19. Based on the VO_2 peak and peak HR values there is no question that the participants were working at near maximal levels. There was no evidence of significant drift in any of the variables measured (VO_2, VCO_2, or VE). In addition all of the participants had previous experience with maximal testing. Although the peak HR values either approximated or exceeded the athletes' predicted maximum HR, the RER values recorded were lower than what has been found in previous studies (5-7). The most likely cause of the lower than expected RER values was that the testing occurred as a component of a training camp. Our experience has been that it is very difficult to control the composition and timing of the athletes' diet.

The prediction equations developed from this study using the individuals' functional classification, RPE, and the distance covered during the 5 minutes of cadence specific wheeling were able to estimate with good clinical precision the actual VO_2 peak. The R^2 for the 60 and 80 pushes/min, equations were 0.73 and 0.74 respectively. Rhodes et al. (14) reported that their regression equation based on blood pressure, distance covered in 12 minutes, age, height, and body mass could account for between 50% and 75% of the variance when predicting VO_2 max. They found that the VO_2 max for those with paraplegia could be better estimated than those with tetraplegia. In the study conducted by Franklin et al. (5) using a similar analogue to the Cooper 12 minute running test developed a regression equation using only the distance covered to predict VO_2 max with an R^2 = 0.70 (5). Vanlandewijck et al. (6) modified a standard progressive 20 m shuttle run (6). Although they did not attempt to create a predictive equation, they did find that the total distance covered was moderately well correlated to the participants' actual VO_2 max (r = 0.64). Vinet et al. (7) also developed a variation of a progressive multistage field test using 50 m increments on a 400 m track. These authors found that as a field test to directly assess VO_2 peak their protocol was a valid alternative to a traditional laboratory style protocol. However the able-bodied predictive equation using maximal speed achieved provided very poor predictive value for the wheelchair user. Vanderthommen et al. (9) also used a modified version of the shuttle run as a format to assess VO_2 peak directly and found that the test-retest reliability was excellent, with ICCs of 0.88, 0.96, and 0.99 for VO_2 peak, peak HR, and the number of stages successfully completed, respectively (9). They reported an $R^2 = 0.59$ with a predictive equation consisting of only using the number of exercise stages completed. Of the field tests reviewed either they are intentionally attempting to achieve volitional fatigue (6,7,8,9) or by requiring the individual to cover as much distance as possible (5,14) they are requiring a maximal effort. The current study is the only one that is truly sub-maximal in design and predicts VO_2 peak with good clinical precision.

The prediction equations developed in this study appear to be within an acceptable range when compared with other able-bodied, sub-maximal tests of aerobic capacity. The literature comparing actual versus predicted VO_2 peak using sub-maximal testing strategies demonstrated a wide variation with little consensus as to what is an acceptable level of variability. As expected, differences varied among testing procedures, number of participants, and between the variables collected. Swain and Wright (15) documented a similar study to ours in which able-bodied participants used a cycle ergometer. This study used speeds of 50 and 80 rev/min to predict VO_2 max. The correlations between the predicted and actual VO_2 peak was r = 0.79 and 0.81 with the SEE = 8.2 ml/kg/min and 7.4 ml/kg/min, respectively for the 50 and 80 rev/min speeds (15). Larson et al (16) used an incremental sub-maximal 1.5 km shuttle run to predict VO_2 peak. This test allowed the participants to self-select their pace, repeating this test at increasing intensities to predict maximal VO_2. The results of this study demonstrated a correlation between the predicted and actual VO_2 peak of r = 0.86 and SEE= 3.51ml/kg/min. The SEE was lower in this study because the testing protocol required a final intensity that approached a maximal effort. These two studies represent the range in SEE that can be found in the literature. The SEE for the current study was 0.48 and 0.45 L/min or 5.85 and 5.61 ml/kg/min, respectively for 60 and 80 pushes/min, thus well within the range that has been reported in the literature (17,18,19). The common denominator amongst most of them was that those that only required the participant to perform a true field test at a sub-maximal level demonstrated a greater SEE then those which required the participants to incrementally approach or reach volitional fatigue. The dilemma the clinician faces is are they willing to give up predictive accuracy for the sake of the ease of testing.

CONCLUSIONS

This cadence based sub-maximal field test is a convenient test that is simple to perform with minimal equipment and expertise. It allows the individual to use ones own every-day or sport specific wheelchair, and any indoor or outdoor location. This protocol can be used to test one individual or potentially a large group at the same time. In its present form the prediction equation requires that the individual is familiar with the Borg

Rating of Perceived Exertion Scale, is able to determine their own functional classification number, and can measure the distance covered in the 5 minutes of wheeling. Both the use of the Borg Scale and the determination of ones functional level is easily learned though an instructional pamphlet. For example, the IWBF provides generic abilities for each of the four classes, this could easily be modified into a simple questionnaire that would allow the individual to determine their own functional classification for the purposes of this fitness (10, 11).

Given that the 80 pushes/min cadence protocol provided somewhat better reliabilty values we would recommend that well trained wheelchair basketball athletes use this cadenced for both repeated testing and the prediction of VO_2 peak. However, with a larger variation of skill level, fitness level, and functional abilities the documented reliability of this sub-maximal test should improve regardless of the cadence. Further studies should be completed in order to make appropriate cadence recommendations for those who are less fit and for those who use other styles of sport specific wheelchairs.

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