

Applied Rowing Ergometer Testing

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Introduction

A number of fitness tests have been developed to measure the aerobic and anaerobic capacities of elite athletes and determine the effects of specific training regimens. Initially these tests utilized the indirect measurement of gas volumes and fractions to determine oxygen consumption during and following maximal exertion (3, 8, 11, 16, 17, 18, 19, 24, 27, 28, 29, 30). Pulse rates were then matched with VO_2 and when correlated with power output were then used to predict fitness (1, 2, 5, 7, 9, 10, 14, 15, 31, 32). Some tests have utilized pulse rate responses either during an incremental exercise load or a standardized exercise to estimate aerobic fitness or physical working capacity (2, 5, 10, 14, 15). A test designed by Conconi (6) and the standardized blood lactate procedure devised by Mader and Heck (23) have been used extensively by a variety of sports to assess fitness and plot training responses. Anaerobic fitness has also been estimated with tests designed by Koutedakis (22), Margaria (24), and Bar-Or (3).

It is generally agreed among rowing trainers (coaches) that most training for rowing should be devoted to improving oxygen utilization and transport. With the exception of measuring VO_2 during and following actual rowing or rowing ergometry (16, 17, 18, 20, 21, 29) or applying the Conconi test (12, 13) or lactate analysis (23), most of the current fitness tests are not specific enough to adequately measure rowing fitness. We have already demonstrated that the aerobic and anaerobic components of rowing could be estimated using rowing ergometer testing (17). However, the measurement of exercise and recovery VO_2 is costly, requires special equipment, and is very time consuming. In addition any VO_2 test by itself, whether steady-state incremental, or a simulated 2000 m, cannot determine the specific effects of utilization or transport training. With this in mind we wanted to design a test that: 1) would permit team testing over a one or two day period (effective use of time available during elite athlete test weekend); 2) would assess maximal work capacity, sub-anaerobic threshold, and anaerobic threshold responses; 3) would provide useful information to coaches and athletes concerning the relative development of utilization and transport systems and determine effects of training; and 4) would offer a simple, easily administered test procedure that could be carried out and reproduced in any boathouse.

Methods

Maximal Test

Each athlete being tested will initially perform a maximal 2000 m effort on a rowing ergometer followed by 3 successive submaximal efforts at 60%, 70%, and 80% of either the athlete's own maximal power output or the average team power output; most coaches prefer to use the latter. At least 24 hours must elapse

between the end of maximal testing and the beginning of submaximal testing for each subject to permit adequate physiological recovery.

The exercise test procedure begins with a maximum ergometer effort for 2000 m using a Concept II rowing ergometer fitted with the special low resistance sealing ring (speed ring) with the air vents completely closed and the chain engaged on the small sprocket of the flywheel. Immediately before this test the athlete is fitted with a telemeter pulse monitor unit (Polar CIC, Inc., USA) consisting of a transmitter attached to an elastic band worn around the upper back and chest and adjusted so that the transmitter is positioned just left of center on the chest at mid-sternal level. The pulse signal is transmitted to a pulse rate watch either worn on the athlete's wrist or, as used more often, hand-held by someone recording pulse rate data. Exercise pulse rate is recorded at each 500 m segment. In addition to pulse rate data the recorder notes total accumulated time and stroke rating and observes average time for each successive 500 m segment of the 2000 m exercise. The digital display on the Concept II ergometer can be set for continuous monitoring of 500 m split times or average power output in watts; in most cases athletes prefer 500 m split times. A 5 minute recovery period follows exercise with the rower in a seated position. At 5 minutes of recovery a microliter capillary blood sample is taken using a finger or ear lobe prick and the sample is then analyzed on a YSI lactic acid analyzer (models 23L or Sport 1500; Yellow Springs Instruments, Inc., USA). Pulse rate is recorded at the end of each minute of recovery in order to determine cardiovascular recuperative ability. Each athlete is encouraged to take a normal warm up before the maximal effort but warm down is not permitted as it may affect recovery lactate values. We have selected a 5 minute recovery period for sampling because lactate values seem to consistently peak at this time following maximal rowing efforts and the athlete sits quietly because a low intensity warm down exercise tends to increase lactic acid clearance from the muscle and blood and its subsequent resynthesis.

This 2000 m maximal effort should be performed no less than 24 hours before the successive submaximal 60%, 70%, and 80% of max efforts.

Submaximal Tests

At least a 24 hours period should separate the maximal test and the beginning of the submaximal testing. The submaximal testing requires the athlete to row at 60%, 70% and 80% of their own previously recorded maximal power output, the average team maximal power output, or if the coach desires, a series of predetermined 60%, 70%, and 80% submaximal efforts. Each of the 3 successive submaximal efforts are 5 minutes in duration and pulse rate is recorded at the end of every minute for each of the efforts. A microliter blood sample is taken by finger or ear lobe prick immediately following completion of the 60% and 70% of max efforts while a 5 minute recovery follows the 80% of max effort; pulse rate is recorded at the end of each recovery minute and a microliter blood sample is taken at 5 minute recovery via a finger or ear lobe prick. A recorder is assigned to each athlete being tested and will serve to assist the rower in maintaining the prescribed steady-state power intensity and note exercise time, heart rate, and stroke rating. No warm up is necessary prior to the 3 submaximal exercise bouts since the first exercise test (60% of max power) serves as an optimal warm up. The test subjects have had no problems maintaining the prescribed power outputs as there is a constant display of average watts or 250 m split times depending on the athlete's preference for pacing assistance.

We have successfully utilized the following predetermined work intensities for U.S. National Team testing:

Table 1

Group	60%		70%		80%	
	500m split	Stroke rate	500m split	Stroke rate	500m split	Stroke rate
Male Heavy	1:47	18-20	1:42	20-22	1:37	22-24
Female Heavy	2:03	18-20	1:58	20-22	1:53	22-24
Male Light	1:55	18-20	1:50	20-22	1:45	22-24
Female Light	2:11	18-20	2:06	20-22	2:01	22-24

These times and stroke ratings can be adjusted according to the quality of athletes being tested. If the athlete's own maximal power output is used then the submaximal test protocol simply involves using 60%, 70%, and 80% of the maximal values and although 500 m split times can be used it is often better to use watts as the power indicator; e.g., athlete's max power output is 350 watts, therefore 60% would equal 210 W, 70% would equal 245 W, and 80% would equal 280 W. These same calculations can be applied to the team maximal power output. We prefer to use the team average maximal power output to calculate the appropriate submaximal work intensities and in doing so believe that a standardized exercise intensity for all team members provides more useful comparative data.

Although submaximal testing can be conducted as many times as the coach desires we recommend the following schedule for National and Olympic Teams: maximal test conducted in late November or early December followed as closely as possible by first series of submaximal tests and then followed by submaximal testing in late February or early March, late May or early June, and finally in late July or early August. This test schedule can be adjusted accordingly for the usually shorter college and club seasons.

This schedule also allows for frequent testing but not so much that it will be disruptive to normal training. It will also permit adequate time to make the necessary training adjustments if results demonstrate that expected training goals are not being achieved. Because most club, college, and developing rowing programs may not have access to blood lactic acid analysis but can continuously measure pulse rates, it is possible to monitor and determine effects of training based on pulse rate data only.

Results

Maximal Test

Maximal power output, heart rate, and blood lactate data are used to determine maximal aerobic and anaerobic capacity. These data are more appropriately defined as peak data because the testing procedure does not follow the recommended increasing intensity of traditional maximal tests. However we believe a simulated 2000 m all-out ergometer effort provides more applied information to the coach and athlete and can provide excellent selection data and help to reveal talent and determine fitness for exhaustive exercise. The following

peak power output, heart rate, and lactate values for National and Olympic Team candidates have recently been reported:

Table 2: Range of Peak Values

Group	Power Stroke (Watts)	Heart Rate (beats/min)	Lactate (mmol/L)
Male Heavy	420-520	175-200	10-20
Female Heavy	260-360	175-200	8-18
Male Light	350-400	175-200	10-20
Female Light	220-320	175-200	8-18

Submaximal Tests

The major purpose of these tests is to determine the effects of specific training programs, especially the balance between utilization and transport training. Because the emphasis is on utilization training during the out-of-competition period and it also represents a major proportion of training during the competitive period, test results are indicative of how closely the athletes have followed the prescribed training program.

Based on submaximal data observed for recent National and Olympic Teams the submaximal tests should yield the following results:

Table 3: Submax Test

Percentage of maximum	HR (beats/minute)	LA (mmol)
60%	120-140	1-2
70%	140-160	2-4
80%	160-180	4-6

It is important to note that these values are ideal and athletes should expect to achieve them only when they have followed prescribed training and have reached a high level of physical fitness. There are, of course, exceptions and some athletes, because of heredity factors or other influences, may demonstrate different than expected results.

Discussion

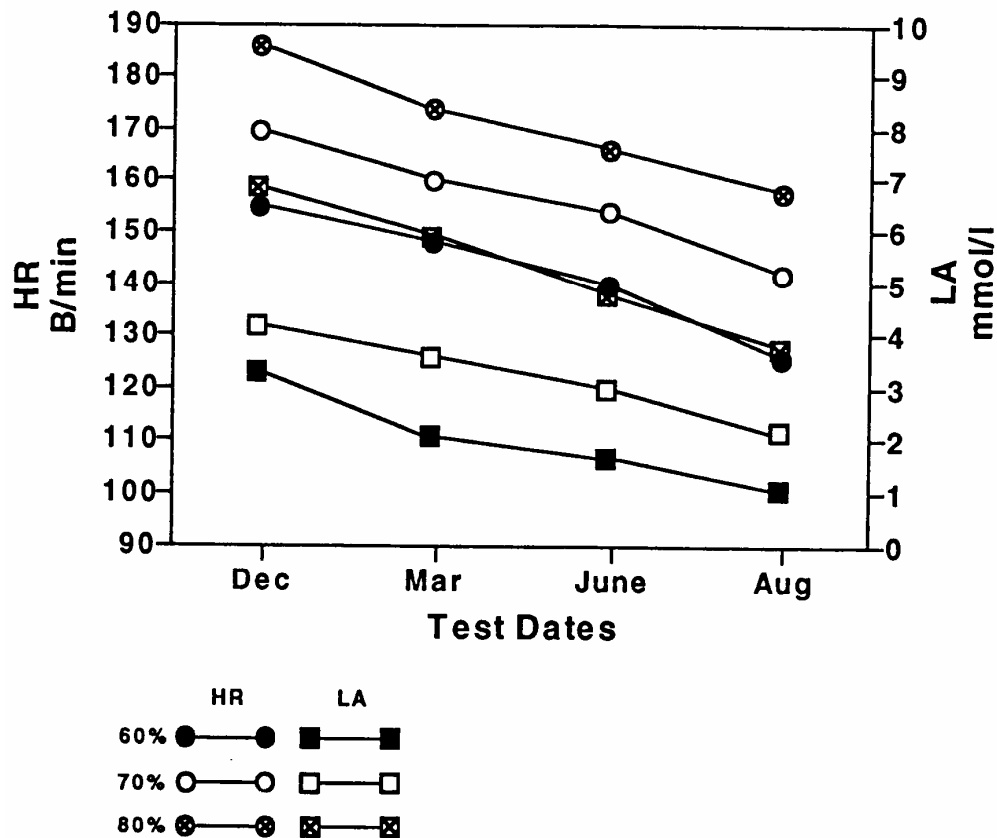
There are several advantages to this testing program: it requires very little time to administer and because the submaximal test results are based on the initial maximal test there is no need of repeating the maximal 2000 m ergometer test again unless additional maximal or peak data are needed. However, if it is desired to chart training effects accurately then all subsequent submaximal test results should be compared based on the initial maximal power output.

The submaximal data have proven valuable in charting training effects and thus have allowed time to modify or change training programs if necessary, discovered athletes who have not adhered to prescribed training, revealed overtrained and fatigued athletes, and have afforded important individual data for training diaries and schedules. This testing program has also provided a valuable learning experience for everyone. The optimal heart rate and lactate values of the upper end

of the 70% of maximal power test and lower end of the 80% of maximal power test approximate anaerobic threshold (AT), Lactate Takes Hold (LAT), or Onset of Blood Lactate (OBLA) for elite rowers. Our previous data have shown that elite rowers achieve an AT of about 85% of maximal working capacity when they are highly trained (26), and using Mader's standard AT value of 4 mmol/L seems to confirm that in most cases our recommended heart rate and lactate values for the 80% test are very near AT, LAT, or OBLA.

Results of the submaximal testing can be displayed in tables or plotted graphically. It may be more useful for displaying individual data to graph subsequent HR and LA data. In this way the athlete may be provided a clearer picture of his/her progress during training. A typical and expected graphic portrayal is presented and indicates significant training effects as both the submaximal heart rate and lactate curves shift to the right following extensive prescribed training. (see Fig. 1)

Figure 1: Typical submaximal heart rate and lactic acid responses during sequential submaximal ergometer testing.



There have been several examples recently where these series of periodic submaximal test data have been used to modify or change the training program. In one instance two athletes who were training without close supervision were tested early in their training program (March - Test 2) and were found to have excessively high submaximal pulse rates and lactates. It was discovered that both believed the prescribed utilization training was of too low an intensity and that there was not enough anaerobic work included. Therefore, they decided to perform their

utilization training at a higher intensity and also add significant amounts of anaerobic work to their training. It can be noted in their following data that heart rate and lactate data are not compatible with expected results for the second test but after convinced to follow the prescribed training, data for the third series of tests demonstrated each was back on proper physiological track. These submaximal tests are thus especially crucial in the early states of training.

Table 4

Rower		December		March		June	
		HR (b/min)	LA (mmol/L)	HR (b/min)	LA (mmol/L)	HR (b/min)	LA (mmol/L)
A	60%	148	3.3	161	4.9	141	2.9
	70%	165	5.2	171	6.6	153	4.2
	80%	185	6.4	190	9.1	166	5.9
B	60%	153	3.6	175	5.4	148	3.0
	70%	171	5.9	180	8.1	167	6.0
	80%	192	6.6	198	10.4	183	6.6

In another instance several National Team athletes, 4 weeks prior to the World Championships, complained of being over tired and fatigued and showed signs of overtraining as shown in Table 5. A comparison of average submaximal heart rate and lactate data for the U.S. Men's and Women's National Team reveals that indeed those values recorded at this juncture of training far exceeded those expected. As a result, training intensity and volume were reduced and although time did not permit further submaximal testing, competitive efforts 4 weeks later reflected that all National Team rowers were prepared to compete successfully.

Table 5

	Test 1 (Dec.)			Test 2 (Mar.)			Test 3 (June)			Test 4 (Aug.)		
	60	70	80	60	70	80	60	70	80	60	70	80
Men												
HR (b/min)	155	166	186	145	160	180	138	147	169	150	161	179
LA (mmol/L)	3.1	4.5	6.5	2.5	4.3	6.1	1.8	3.2	5.0	2.9	3.9	6.4
Women												
HR (b/min)	159	169	189	150	161	182	141	150	174	156	166	185
LA (mmol/L)	3.5	5.6	6.9	3.2	5.1	6.2	2.1	3.9	5.4	3.3	4.8	7.1

Finally, in our last example of test application, the second of four submaximal test sessions of Olympic team candidates revealed that heart rate values were excessively high for each test in December and as a result additional transportation training was added to the prescribed training program; results of the next testing conducted in March showed how successful this decision was (see Table 6). Consult Table 3 for desirable or target values.

Table 6: 1992 U.S. Olympic Candidates

MEN	DEC % max			MAR % max			JUNE % max		
	60	70	80	60	70	80	60	70	80
HR (b/min)	160	173	182	146	156	170	135	152	165
LA (mmol/L)	1.3	2.2	3.4	1.6	2.5	3.6	1.4	2.3	3.6

In summary, we are pleased with this rather rapid and accurate method of estimating rowing fitness. The use of periodic and successive submaximal testing following the initial maximal and submaximal tests can provide excellent predictive data of physiological potential and capacity and indicate training effects.

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