Journal of Sports Medicine & Doping Studies

Lavelle et al., J Sports Med Doping Stud 2018, 8:4
DOI: 10.4172/2161-0673.1000209

Research Article Open Access

A Rowing Ergometer Test to Assess the Arm Contribution in Force Production during the Rowing Stroke

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Received date: September 11, 2018; **Accepted date:** October 08, 2018; **Published date:** October 15, 2018

Abstract

Introduction: Rib stress fractures result from a nutcracker action on the ribs as the load on the blade is counteracted by the posterior scapular muscles. One of many factors is the proportion of force production from the arms in relation to the legs. If the arms give more the load on the ribs is greater.

Methods: This study sought to find a simple rowing ergometer test which is functional but accurately reflects the ratio of force contribution between the arms and the rest of the body. The new test was used to establish normative data for the protocol and a re-test study was conducted to investigate the reliability of the test protocol.

Results: The results were gender specific with men having a higher arm contribution percentage than women. Both groups were tested at two ratings 18 strokes/min and 26 strokes/min (s/m). Both groups had a lower arm contribution at the faster rating. At 18 strokes per min, the women averaged 21.85% of their power from their arms compared with 27.8% in the men. At 26s/m the women averaged 18.35% and the men 23.2%. However, these figures are contrasted with an average from the cohort of normal (no history of rib issues) elite rowers who produced only 10% of their power from their arms at 18 s/m and 7.47% at the higher rating of 26 s/m. Test re-test validity showed the test is reliable to 1.8%.

Conclusion: This test could be used as a training aid to modify technique and a screen to look for subjects at risk. The recommendation of the co-author and experienced coach, Rob Baker, is that using results from this test at 18 s/m; the arm contribution of non-elite rowers should aim not to exceed 20% in women and 25% in men. Elite rowers should aim for 10%.

Keywords: Ergometer test; Arm: Leg power ratio; Rib stress fracture

Introduction

It has long been recognised that efficient rowing technique seeks to produce the force primarily from the leg drive. In 2006 Vinther et al. [1], reported that the ratio of elbow flexor to quadriceps power was significantly higher in his sample of rowers who had sustained a rib stress fracture compared with a cross matched sample who had not (measured by isokinetic dynamometry). The suggestion being that if greater force is created from the arms then there is greater compressive pressure exerted through the rib cage. It would also be reasonable to postulate that over use of the arms might contribute to neck and shoulder pain.

Reybrouck et al. [2] sought to investigate are versus leg work contribution. They used a Douglas bag set up to measure VO2 max combined with heart rate monitors to compare exertion between different parts of the stroke - legs only, arms only and the full stroke but this, like isokinetic dynamometry, is an expensive method of investigating effort output.

This paper proposes a cheap easy reliable method using a Concept II ergometer. One of many possible displays on a Concept II is to view the rower's power in Watts. All rowing clubs have ergometers, the most common being the Concept II. Inter ergometer reliability has already been established. Vogler et al. [3] looked at physiological responses to exercise on different models of the concept II rowing ergometer and concluded that results from ergometers '*is nearly identical, and testing can therefore be carried out on either ergometer and the results directly compared*'. This confidence enabled direct comparison of data from the same subject on different Concept II ergometers.

The main objective of this study was to establish the spectrum of normality in club rowers; however the comparison with a small sample (9 subjects) of elite rowers was very interesting. The normative data collected enabled the authors to suggest guidance as to as to the maximum desirable percentage of arm power production for male and female non-elite rowers. A subset was tested twice to look at test: re-test variability in the same person.

Methodology

Methodology rationale

Pilot studies directed the final protocol. Reliability was increased by requiring the athlete to produce a peak torque twice in the same rating. If the rower raced the slide it was possible to cheat the rate meter before the rating on the machine caught up. This was solved by recording only the maximum wattage achieved twice. This method was also preferred because in isokinetic dynamometry the most reliable data is repetitions of peak torque (Croce et al.) [4]. For this test therefore the peak maximum moment of power the athlete was able to

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produce more than once within a 40 second time frame at two different ratings 18 and 26 s/m was the data to be recorded.

This 40 second time slot was the result of a pilot study which showed that the subject had done his best work within 40 seconds and that there was no point in going on longer. However strictness over the rating was absolute so 40 seconds enabled the subjects' time to produce a genuine result in the correct rating. This short burst meant that the recovery period necessary was also short.

A pilot looked at arms only rowing, then legs only and finally the whole stroke. However the arms and legs did not add up to the figures for the whole stroke. It was not possible to control the lean back so more consistent data was obtained by allowing the rowers to produce their maximum power at they wished. With arms straight rowing the power of the elbow flexors and shoulder extensors was eliminated thus subtracting the arms eliminated results from the whole stroke results from gave the arm contribution to the stroke.

Inclusion criteria

A diverse normative sample group was sought. A cohort of 48 normal subjects was used (24 male and 24 female), all club and University rowers with no injury or history of stress fracture. The age range was 17-64 years. All were asymptomatic with no history of rib problems. They were all experienced rowers with more than two years familiarity using an ergometer.

Nine elite female rowers volunteered from Cambridge University Boat Club of whom two had had occult rib stress fractures which were healed and back in full training (Table 1).

Methodology for arm: leg ratio erg test

Set the drag factor on the concept two ergometer to 130

- Set the display to watts.
- Collect the age, weight, height, years rowing, training session/ week data from the subject.
- Explain the test method to the subject.
- Do a comfortable warm up for 5 minutes any rating

Test 1

- Establish a rating of 18 strokes per min light pressure using the subjects' normal stroke.
- Once in a steady rating using a normal stroke pattern the subject has 40 seconds to produce the maximum wattage figure they can twice (it only counts if the rating is at 18 s/min). The maximum output they can achieve twice is what is recorded.
- Record this figure.
- Allow the subject to recover
- Explain legs only rowing. The subject does their normal stroke with lean back except that, at all times the arms are locked straight. Practice for as long as it takes to master this technique.
- Establish legs only rowing at 18s/min, once in a rhythm; the subject has 40 seconds to score the greatest wattage they can twice. Record this on the sheet.
- Allow the subject to recover.
- Subtract the second score from the first to establish the arm contribution.

Test 2

- Establish a normal rowing stroke at 26s/min.
- Subject then has 40 seconds to attain their highest wattage score twice in the rating.
- Record the result.
- Let the subject recover.
- Establish the rating at 26 with legs only rowing as in test 1.
- Subject then has 40 seconds to attain their highest wattage score twice in the rating of 26 s/min
- Record the result.
- Subtract test the second score from the first to establish the arm contribution.

End of test

A sample data set

	Pippa
Subject	1
Age	19
Height	179
Years Rowing	2
Training Session	11
Weight	74
Test 1	18 s/min
Full stroke	213
Legs only	172
Difference	41
% arms	19.2
Test 2	26 s/min
Full stroke	279
Legs only	2236
Difference	43
% arms	15.4

Table 1: Sample data set.

The tests were conducted in different locations at different times over a three month period. All data sets were collected by the author. Twelve subjects were randomly selected and asked to do the test a second time. Eight of the original sample were able to comply a further four volunteers were called for out of the original sample. The re-tests were as varied as possible. They were conducted at different- times of day, climatic conditions, levels of fatigue, times between tests and in some cases in different locations.

Results

The subject age, height, weight, years of rowing experience and number of training sessions a week were all recorded. Gender differences are discussed along with the influence of rowing experience and age (Supplementary file).

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Discussion

47 out of 48 data sets showed a reduced percentage of arm power production when rowing at the higher rating of 26s/m compared with 18s/m. The non-elite men's results (Table 2) showed that there was a large range (19-40%) of arm contribution but the average value was 27.8% when rowing at 18s/m. This dropped to 23.2% at the faster rating of 26 s/m, there is a suggestion that older rowers rely more on their arms for force production.

		%
At 18 stokes / min	Range	19-40
	Average	27.8
	Median	30.75
Men under 39	Average	26.7
Men over 50	Average	29.11
At 26 stokes/min		
	Range	16.9-32.9
	Average	23.2
	Median	23.95
Men under 39	Average	22.35
Men over 50	Average	24.33

Table 2: Result summary for non-elite men.

The eight men who were club rowers but training more than five time a week at 18 s/m averaged 26.23% arm contribution whereas the more recreational male rowers averaged 28.67%. The differences are small but may support the idea that better rowers have better technique.

The non-elite women (Tables 3-6) had a range of 15.7%-31.2% with an average of 21.85% at the slower rating of 18s/m. At 26s/m the average arm contribution was 18.35% of the power of a full stroke. In the women's cohort the eight women training five or more times a week averaged 21.48% of their power from their arms whereas the recreational rowers averaged 22.03% so no significant difference. The suggestion that older rowers recruit their arms more is seen again in the women's group. It may be that leg power diminishes with age.

		%
At 18 stokes/min	Range	15.7-31.2
	Average	21.85
	Median	23.45
Women under 39	Average	21.4
Women over 50	Average	23.4
At 26 stokes/min		
	Range	11.3-28.6
	Average	18.35
	Median	19.95
Women under 39	Average	19.02
Women over 50	Average	19.54

Table 3: Result summary for non-elite women.

The eight keen female rowers, training five or more times a week, averaged 21.4% arm contribution compared with 22.03% in the recreational group at 18s/m and 16.24% compared with 19.37% at the higher rating of 26s/m. The trend matches that of the men that better rowers may use leg drive better but the margins are quite small.

A clear gender gap exists with men relying more on their arms for power production. This is in line with expectation (Verbal communication, Baker 2018) [5].

Intra test validity

Twelve subjects repeated the test, six men and six women. W or M (indicates woman or man) followed by the number identifies the subject in the raw data listed in supplementary file.

Subject	**Test 1**	**Test 2**		**Test 1**	**Test 2**	
	18s/m 1	**18 s/m 2**	**Change**	**26 s/m 1**	**26 s/m 2**	**Change**
W 3	24.4	21.9	**2.5**	22.4	19.1	**3.3**
W 9	23.2	22.3	**0.9**	14.2	15.9	**1.7**
W 1	18.9	18	**0.9**	17.6	16	**1.6**
W12	21.5	19.1	**2.4**	18.7	17.1	**1.6**
W11	22.1	24.3	**2.2**	17.6	19.7	**2.1**
W10	20.6	22.5	**1.9**	16.7	15.9	**0.8**
M 19	35.8	34	**1.8**	32.9	33	**0.01**
M 23	16.2	14	**2.2**	15	12.7	**2.3**
M 3	31	31.8	**1.8**	26.5	27.1	**1.4**
M 4	21.8	20.1	**1.7**	16.9	14.9	**2**
M 6	35	34.2	**0.8**	22.2	19.4	**2.9**
M 17	21.8	21.7	**0.1**	19.7	17.8	**1.9**
		Total	**19.2**		**Total**	**21.61**
		Average	**1.6**		**Average**	**1.8**

Table 4: Intra test validation result.

Some of the changes were positive and some negative. The greatest range was 3.3% but over all this data suggests that a coach or clinician could safely regard the outcome of this test as being accurate to 2%. Thus a rower scoring 24% might at most be 26% on testing and 22% on another but a rower showing a shift from 24% to 20% with a stable total watt production would be exhibiting technique change. The huge meta-analysis of test-re-test data done by Hopkins et al. [6] found that the average coefficient of variance between the first test and the second was 1.2% but that his dropped dramatically to 0.02% upon subsequent tests. This may well be the case with this erg test as the subjects gain familiarity with the test.

Subject	1	2	3	4	5	6	7	
Age	19	23	23	28	22	23	23	
Height	179	185	183	180	181	178	171	
Years rowing	2	9	8	15	4	5	9	
Training session	11	10	10	11	11	12	11	
Weight	69	84	80	78	82	69	75	
Test 1	18 s/m							
Full Stroke	213	265	268	279	230	232	242	
Legs only	172	239	234	262	208	219	223	
Difference	41	26	34	17	22	13	19	Average
Arms %	19.2	9.8	12.6	6	9.5	5.6	7.8	10%
Test 2	26 s/m							
Full stroke	279	334	370	372	315	326	324	
Legs only	236	312	332	360	288	303	309	
Difference	43	22	38	12	27	23	15	
								Average
Arms %	15.4	6.5	10.2	3.2	8.5	6.1	4.6	7.47%

Table 5: Results in 7 elite women subjects without history of rib issues.

Subject	1	2
Age	23	24
Height	173	170
Years rowing	5	6
Training session	11	10
Weight	74	79
Test 1		
Full stroke	217	247
Legs only	177	214
Difference	40	33
Arms %	18.4	13.3
Test 2		
Full stroke	296	318
Legs only	249	277
Difference	47	41
Arms %	15.9	12.9

Table 6: Two asymptomatic subjects with previous rib stress fracture.

The elite women sample only contains nine subjects so clearly repeating the test with a larger cohort is necessary but the results are striking. The seven athletes with no history of rib stress fracture averaged just 10% of their maximum power with their arms at 18 s/m. This is in contrast with the non-elite women (21.85%). The gap between the two groups widens at 26 s/m with the elite athletes producing just 7.47 % and the non-elite group 18.35%. The two rowers who have already had a rib stress fracture (now healed) stand out from their peers producing 18.4% and 13.3% respectively of their power from their arms at 18s/m compared with an average of 10% in the non-injured group. At 26s/m their figures of 15.9% and 12.9% are in stark contrast with the group average of only 7.47% of the power coming from their arms.

One rower in the non-injured elite cohort-subject 1 produced far more of her power (19.2%) from her arms than the rest of her group. Interestingly this girl is a tall lighter weight elite athlete who has only been rowing for two years. She produced the least power, she is the least technically advanced rower of the cohort and this test has highlighted that she could be at a higher risk of rib stress fracture.

Conclusion

This ergometer test provides a quick, easy, cheap method to assess the arm contribution to the production of power during a rowing stroke. It is reliable to plus or minus 2%. It could be used to help screen rowers at risk of developing a rib stress fracture especially amongst elite rowers. Arm strength contribution is just one factor in the development of a stress fracture but it is one over which the rower has some control. The fact that the elite rowers overall produced so much more of their power from their legs in relation to their arms and yet it is elite rowers who predominantly suffer from rib stress fracture points to two factors. Firstly the power output from the elite rowers was vastly greater than the non-elite group so even though their technique was better the loading on the ribs is still huge and secondly the quantity of repetition of load is probably the greatest causation of rib stress fracture.

It is not surprising that men are stronger in their arms and produce more power than women. The finding that the arm contribution is consistently lower at higher ratings means that if a rower needs protecting from load accumulation, just keeping the rating higher will be helpful. There is a trend within the data that keen amateur rowers are creating more leg drive than their recreational counterparts. The dramatic difference however with the elite rowers shows that their training is focused on leg drive.

The recommendation of the authors is that using results from this test at 18 s/m the arm power contribution of non-elite rowers should not to exceed 20% in women and 25% in men. Elite rowers should aim for 10%.

Conflict of Interest

None declared.

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