Exercise Testing of Elite Rowers: Comparison of Methods and Protocols

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Abstract: The aim of the study was to search for appropriate, informative, accessible and reproducible method for testing of elite rowers. Six healthy elite rowers (5 male and 1 female) aged 24±7 underwent two types of exercise testing (ET). Exercise performance of rowers was evaluated by means of: i) standard maximal RAMP cycle test, which is considered to be the gold standard measurement in sports medicine; ii) ET specific for rowers with the use of Concept rowing machine. Both protocols of ET were designed according to International Guidelines for Exercise Testing and Prescription Tests were conducted with simultaneously HR monitoring (Garmin) and breath-by-breathe gas-exchange analysis with the use of desktop metabolic analyzer Fitmate PRO (Cosmed, Italy). A range of physiologic parameters were under consideration: VO_2, HR, attained power, minute ventilation and anaerobic threshold (AT). Undertaken comparative analysis demonstrated no significant differences in major analysed physiologic parameters during both tests. The obtained data enabled us to conclude that cycling ET with the use of maximal ramp incremental protocol is an informative, accessible, reproducible and appropriate method for testing of elite rowers. Conducting both exercise tests − cycling and rowing − may highlight the limiting factors of specific physical workability in rowers.

1 INTRODUCTION

Exercise testing (ET) in sport, especially in high performance sports, is an integral part of training process (Smith, 2003; Saw, 2016; Vilikus, 2012). The range of ET application is quite broad: from sports selection and search for potential future champions to evaluation of dynamics and progress in training.

Data obtained from ET provides with valuable information on various physiologic changes under exercise load condition (Maxzzani, 2017). It allows to assess the integrative exercise responses of cardiopulmonary, neuropsychological and skeletal muscle systems (Albouaini, 2007). Methods of ET depend much on a range of important factors. Among them: i) sports specifics; ii) athletes age, level and gender; iii) available laboratory equipment and many others. Currently, various types of protocols, load machines and measurement devices are used to assess aerobic performance in athletes (Foster, 2001). The preference of method selection is in close connection to the aim and information request. In particular, sometimes incremental step protocols are used, though, in many cases maximal RAMP protocols are more reliable. As for the choice of load device type much depends on the cost and laboratory space limit. Generally, it is recommended to test elite athletes specifically to get correct and reliable data. Meanwhile it is essential to always keep in mind the significant difference in biomechanics of movements in the real field and modeled laboratory environment (Nymark, 2005).

The proposed research was focused on search for informative, accessible, reproductible and appropriate method for testing of elite rowers.

2 ORGANIZATION AND METHODS

Subjects: Six healthy elite rowers (5 male and 1 fe-

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male) aged 24±7 were recruited for the study. All participants of the proposed research had more than 10 years of sports experience. Three of studied rowers were members of national team, winners of a number of international competitions. Each athlete gave a written consent to participate in the study with following data collection and further publication of the obtained results before the experimental study was undertaken. The work conforms to the principles of WHO Helsinki Declaration.

The proposed study was conducted in the sports research lab of Ural Federal University (Yekaterinburg, Russia).

2.1 Anthropometric Measurements

Anthropometric measurements are of high importance in elite sports. Such parameters as detailed body composition, height, lean muscle mass (absolute and relative values), body fat component and BMI are commonly used both in sports selection, as well as dynamics evaluation in training practice and research.

Weight and detailed segment body composition data were measured with the use of MC-980MA Plus Multi Frequency Segmental Body Composition Monitor (TANITA, Japan) based on the advanced Bioelectric Impedance Analysis (BIA) technology. The following parameters were analyzed: body mass (kg), body mass index (BMI, kg/m^2), muscle mass – absolute and relative values (kg; %), absolute and relative fat mass (kg; %), fat free mass (kg), differentiated muscle mass of the trunk, upper and lower extremities (kg).

2.2 Exercise Tests

Aerobic performance of rowers was evaluated by means of ET with the use of two different types of protocols and load devices. First, we conducted standard maximal RAMP cycling test, which is considered to be the gold standard measurement of integrated cardiopulmonary-muscle oxidative function (Poole, 2017). Then we applied ET specific for rowers with the use of Concept rowing machine. Protocols of ET were designed according to International Guidelines for Exercise Testing and Prescription (Pescatello, 2014; Gibbons, 2006; Wasserman, 2012). Tests were conducted with simultaneously HR monitoring (Garmin) and gas-exchange evaluation with the use of desktop metabolic analyzer Fitmate PRO (Cosmed, Italy).

Both tests were completed within a period of 1 week approximately at the same time of the day in a controlled laboratory environment (temperature – 20-22° C; 50%-60% relative air humidity). These conditions were kept to minimize the biological variations on the collected data. As both tests were performed at maximal protocol to exhaustion, athletes were recommended to have 24-36 hours of rest from trainings and competitive activity before the first test and 24-48 hours of rest between the tests. This implied sufficient time for recovery and obtaining accurate and precise data. Additionally, it was required to avoid any intake of alcohol or caffeine 24 hours before ET and to have meal uptake no later than 4 hours before the test to exclude unexpected hypoglycemia during ET.

Each tested subject was given comprehensive instructions on purpose of the experiment, methods used, registered parameters during ET and safety regulations before the tests. Athletes were encouraged to inform laboratory staff about appearance of any disturbance and such symptoms as acute weakness, shortness of breath, dizziness etc.

Breath-by-breath oxygen uptake (VO_2) data were analyzed throughout both conducted tests. Before each test started the metabolic analyzer had been accurately calibrated according to manufacturer's guidelines and instructions.

2.2.1 Cycling Exercise Test

Cycling ET (Fig.1) was performed with the use of cycle ergometer (Schiller, Switzerland) and desktop metabolograph Fitmate PRO (Cosmed, Italy). The cycle seat and handle height and position were adjusted in accordance with the each athlete's comfort (height and limbs length).

The following maximal ramp-incremental protocol was applied: the initial load (warm-up stage) was set at 0 W for 1 min with further linearly steady increase by 40 W per minute (approximately 1 W per each consecutive 1.5 second of the test). Athletes were instructed to keep the constant cadence of 80 rpm throughout the whole test, including the warm-up stage and the 1st min of recovery.

The test was carried out to exhaustion (inability to maintain the required cadence due to muscle fatigue despite verbal inciting) or the appearance of absolute medical restrictions to continuing exercise (abnormal HR response, shortness of breath, dizziness, signs of vegetative dysfunction etc.).

The following parameters were recorded starting with the first warm-up stage (1 min) and continuously during exercise testing: oxygen consumption (VO_2, ml/kg/min), heart rate (HR, bpm), stated exercise load (P, W), volume of ventilation (Ve, l/min), and respiration rate (Rf, 1/min). Current values of all measured parameters were displayed on the metabolic analyzer screen and saved in the device memory for ongoing analysis.

Figure 1: ET with the use of cycle ergometer.

2.2.2 Rowing Exercise Test

The proposed rowing ET (Fig. 2) was carried out with the use of Concept rowing machine (model E, Concept 2, USA) and desktop metabolograph Fitmate PRO (Cosmed, Italy). We designed step incremental ET protocol for rowers. The duration of each stage was 1 min. Initial load was set by the athlete himself at 100 W. After that it was suggested to increase the load by 50 W each subsequent minute of the test. Test proceeded up to attainment of refusal criteria and inability to keep on at the required power for the current ET stage.

As described in the previous section (cycling test), we analysed oxygen consumption (VO_2, ml/kg/min), heart rate (HR, bpm), power of exercise load (P, W), volume of ventilation (Ve, l/min), and respiration rate (Rf, 1/min).

After completion of both ET trials we recorded the following parameters: maximum oxygen consumption (VO_{2max}, ml/kg/min), maximum respiration rate (Rf_{max}, 1/min), maximum volume of ventilation per minute (Ve_{max}, l/min), resting heart rate (HR before the test, bpm), HR at 150 W of work load (HR_{150}, bpm), HR at 200 W of work load (HR_{200}, bpm), HR at 300 W of work load (HR_{300}, bpm), maximum HR at the end of the test (HR_{max}, bpm), HR at anaerobic threshold (HR_{AT}, bpm), HR at the 1st, 2nd and 3rd minutes of recovery ($HR_{recovery\ 1\ min}$, $HR_{recovery\ 2\ min}$, $HR_{recovery\ 3\ min}$, bpm), percentage of VO_2 at anaerobic threshold (% AT), maximum attained power (P_{max}, W) and relative maximum attained power (P_{max}/kg, W/kg).

Figure 2: ET with the use of Concept rowing machine.

2.3 Statistical Analysis

Statistical analysis was performed with the use of statistic software package "SPSS Statistics 23.0" (IBM). We used descriptive analysis of the obtained data in order to estimate basic functional status of athletes.

Normality of distribution was assessed by the Shapiro-Wilk test. Mean value (M), standard deviation (SD), minimum and maximal values of the measured parameters were calculated.

Paired T-test (Student criterion) was used to evaluate differences between the measured parameters in studied group. The level of significance was set at $P < 0.05$.

3 RESULTS AND DISCUSSIONS

The obtained anthropometric data of elite male rowers (Table 1) showed that studied subjects had adequate body composition in regards to specific athletic norms for rowers. Although, high mean values of lean mass and low values of fat component were found, these parameters varied within a certain range. These pointed at individual peculiarities of skeletal muscle compounds of rowers, thus it may have an impact on ET results.

Table 1: Anthropometric and body composition data of male rowers.

Parameters	M±SD	(min-max)
Height, cm	179.6±7.4	171-188
Weight, kg	72.36±5.2	60-74
Muscle mass, kg	63.86±2.85	59-66.5
Muscle mass, %	88.24±3.34	83.4-92.6
Fat, kg	5.2±2.3	2.2-8.4
Fat, %	7.2±3.24	3-11.8
BMI, kg/m^2	22.5±1.9	20.3-24.7

Assessment of exercise performance of studied athletes provided with comprehensive data on both aerobic performance and cardiopulmonary response to maximum load, as well as strength endurance of musculoskeletal system.

Generally, each athlete demonstrated high level of exercise performance and was well tolerated to aerobic work in both tests.

As was described above it was assumed that ET in specific test could have shown better results considering impact of motivation on performing very hard exercise work.

However, undertaken further comparative analysis (Table 2) demonstrated no significant differences in all analysed parameters from both tests.

Table 2: Comparative analysis of ET data in rowers.

Parameters	**Cycle test**	**Concept test**	**P**
VO_{2max}, ml/kg/min	59.5±11.03	64.8±7.1	0.17
Rf_{max}, 1/min	63.24±7.77	56.44±17.97	0.23
Ve_{max}, l/min	168.9±23.5	126.78±67.5	0.11
HR before the test, bpm	88.6±17.86	72.7±17.9	0.09
HR_{150}, bpm	135.7±17.1	130.83±15.84	0.31
HR_{200}, bpm	143±17.27	146±16.35	0.38
HR_{300}, bpm	165.2±10	168.3±10.9	0.32
HR_{max}, bpm	181.2±5.42	177.5±6.69	0.16
HR_{AT}, bpm	172±7.35	172.8±9.15	0.43
$HR_{recovery\ 1\ min}$, bpm	155.3±4.63	133.3±44.15	0.13
$HR_{recovery\ 2\ min}$, bpm	127.5±5.5	132.8±10.5	0.16
$HR_{recovery\ 3\ min}$, bpm	119.4±5.8	124.5±6.36	0.18
% AT	83±4.05	82.5±3.11	0.42
P_{max}, W	40.3±61.64	429.5±76.96	0.28
P_{max}/kg, W/kg	5.75±0.5	6.01±0.74	0.19

VO_{2max} – maximum oxygen uptake; HR – heart rate; AT – anaerobic threshold; P_{max} – maximum power.

Although the group of rowers was mixed –formed of male and female athletes, undertaken paired comparative analysis for statistics was appropriate and correct in this case.

Values of the majority of the most important functional indicators which are milestones in training design (HR_{AT}, % AT) were very close.

Further analysis of individual graphs (Fig. 1-6) of HR dynamics during stress test revealed no significant differences of heart response to exercise load irrespective to type of ergometer and protocol used.

Nevertheless, when analyzing individual HR-curves we should take into account the following issues:

1. In rowing ET the movement pattern is specific for the tested subjects, whereas cycling is not widely used in severe Urals weather conditions.
2. In cycling test the value of maximal attained P (P at VO_{2max}) in ET was determined as an indicator of strength of lower extremities. As each athlete was instructed to maintain the constant cadence of 80 rpm throughout the test whereas the external load was raised continuously, so the moment of volitional fatigue (when leg muscles were not able to maintain the required cadence) was considered as the maximal power (P-VO_{2max}). So P_{max} in cycling ET was limited by strength of lower extremities together with an oxidative potential of muscles.
3. Procedure of specific rowing ET implied the following: every step with demanding load was provided by internal strength and rowing rate. In case of limited strength the rower had an opportunity to increase the stroke frequency. These means that higher P_{max} in rowing ET could be provided by the rate of strokes rather than higher volume of working muscle mass.

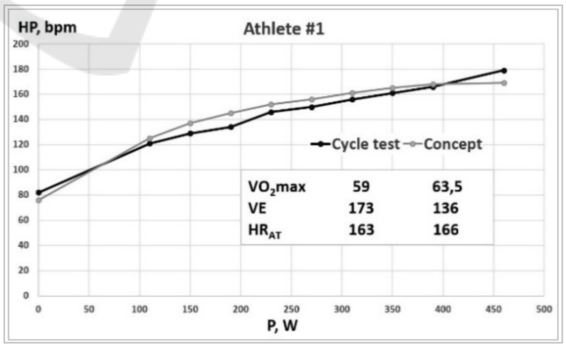

Figure 3: Heart rate response during ET of the 1st athlete.

Individual HR graph of the 1st athlete (Fig. 3) is a good example of similar heart response to exercise load irrespective of type of ergometer and protocol used. One can see that only respiratory system response (maximal minute ventilation) differed.

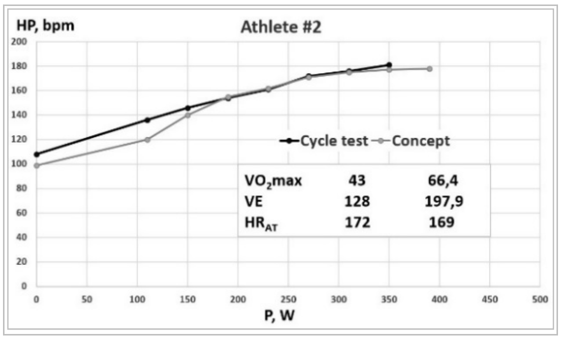

Figure 4: Heart rate response during ET of the 2nd athlete.

2nd rower (Fig. 4) started both tests at high HR ($HR_{resting}$ > 100 bpm), which points at lowered volume parameters of heart for endurance athletes and low aerobic abilities. High values of VO_{2max} (66.4 ml/kg/min) in rowing ET and low – in cycle ET (43 ml/kg/min) serve as a proof of essential further work for both increasing of strength and endurance of lower extremities muscles.

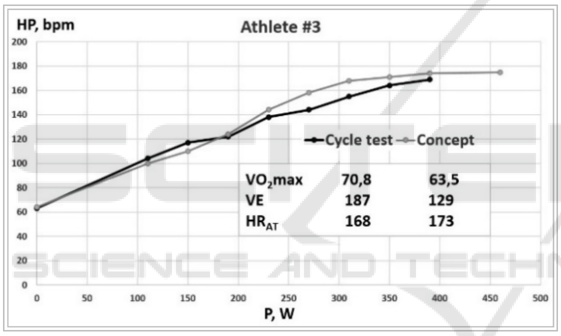

Figure 5: Heart rate response during ET of the 3rd athlete.

3rd athlete (Fig. 5) had low resting HR value in the beginning of both tests (60 bpm) and throughout the first minutes of ET due to important for successful rowers sufficient heart volume parameters. The observed data in cycling ET pointed at good condition of leg muscles. Meanwhile, difference in VO_{2max} value of 7.3 ml/kg/min in tests showed the importance of additional trainings of upper extremities and back muscles (increasing the rate of rowing with only arms and back without legs involvement). Additionally, the obtained difference in respiration (significant lower Ve in rowing ET) could have had an impact of insufficient breathing in rowing test on VO_{2max} results.

Data of the 4th rower (Fig.6) revealed a considerable difference in HR in aerobic exercise zone. Potentially, increased HR during cycling ET could be a result of agitation or incomplete recovery. After 100 W of load increase HR curves match, which does not enable to state insufficient training condition. Comparison of P_{max} in tests demonstrated higher level of P in cycling, than in rowing ET. The reasons could be: i) weak muscles of back and upper extremities; ii) issues with frequency increase in rowing test due to lowered speed abilities or inability to increase the rate of single motion (rowing); iii) rowing technique incompetence.

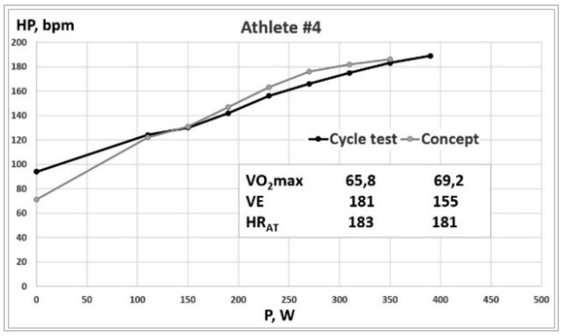

Figure 6: Heart rate response during ET of the 4th athlete.

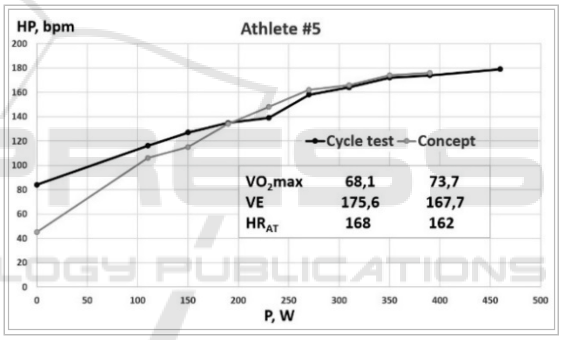

Figure 7: Heart rate response during ET of the 5th athlete.

The curves "load–HR" of the athlete 5 (Fig.7) in two tests are very similar to the 4th rower's graphs. This means that rowers 4 and 5 had identic problems in specific physical readiness. So their training must be focused on the same aspects (i-iii).

Rower #6 (female) demonstrated satisfactory levels of fitness competence in both tests and specific rowing ET was done efficiently. Comparison of two curves did not reveal problems although physiologic coping in both tests is lower than in male athletes.

Overall obtained results indicate, that although the attained load and absolute values of the measured parameters varied in tests, in most cases cardiovascular response to exercise load had no significant differences. This may serve as a proof that no matter what type of exercise activity, engaging more than 2/3 of skeletal muscle, is carried out, it does not impact significantly on cardiopulmonary physiologic reaction.

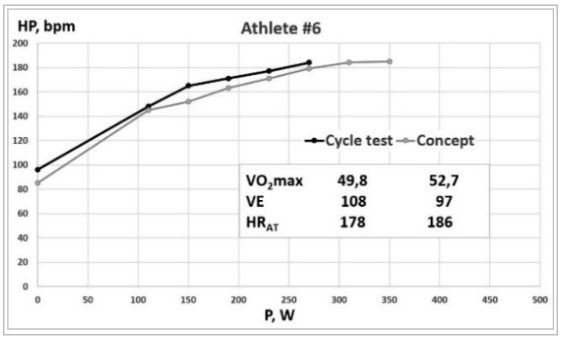

Figure 8: Heart rate response during ET of the 6th athlete.

4 CONCLUSIONS

Cycling ET with the use of maximal ramp incremental protocol is an informative, accessible, reproducible and appropriate method for testing of elite rowers. It is safe, cost-effective and has the same patterns of physiologic response as in specific rowing test.

Meanwhile conducting both exercise tests – cycling and rowing – provide the researchers with valuable information highlighting the limiting factors of specific physical workability in rowers.

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REFERENCES

Albouaini, K., Egred, M., Alahmar, A., Wright, D.J., 2007. Cardiopulmonary exercise testing and its application. *Postgrad Med J,* 83, 675-682.

Foster, C., Florhaug, J.A., Franklin, J., Gottschall, L., Hrovatin, L.A., Parker, S., Doleshal, P., Dodge, C., 2001. A new approach to monitoring exercise testing. *Journal of Strength & Conditioning Research*, 15, 109–115.

Gibbons, R.J. et al. 2006. ACC / AHA 2002 guideline update for exercise testing: summary article: a report of the American College of Cardiology / American Heart Association Task Force on Practice Guidelines. *Journal of American College of Cardiology*, 48(8), 1731 p.

Mazzani, A., 2017. Cardiopulmonary Exercise Testing: Basics of Methodology and Measurements. *Ann Am Thorac Soc*, 14(1), 3–11.

Nymark, J.R., Balmer, S.J., Melis, E.H., Lemaire, E.D., Millar, S., 2005. Electromyographic and kinematic nondisabled gait differences at extremely slow overground and treadmill walking speeds. *Journal of Rehabilitation Research and Development,* 42(4), 523-534.

Pescatello, L.S., Arena, R., Riebe, D., Thompson, P.D., Kluwer, W., 2014. ACSM's Guidelines for Exercise Testing and Prescription. 9th Ed. *Lippincott Williams & Wilkins, Philadelphia, PA*. 456.

Poole, D.C., Jones, A.M., 2017. Measurement of the maximum oxtgen uptake VO_{2max}:VO_{2peak} is no longer acceptable. *J Appl Physiol*, 122, 997-1002.

Saw, A.E., Main, L.C., Gastin, P.B., 2016. Monitoring the athlete training response: subjective self-reported measures trump commonly used objective measures: a systematic review. *Br J Sports Med*, 50(5), 281-91. DOI: 10.1136/bjsports-2015-094758.

Smith, D.J., 2003. A framework for understanding the training process leading to elite performance. *Sports Med*, 33(15), 1103-26.

Vilikus, Z., 2012. Functional Diagnostics. *College of Physical Education and Sport, Palestra*, 12-15.

Wasserman, K., Hansen, J.E., Sue, D.Y., Stringer, W.W., Whipp, B.J. 2012. Measurements during integrative cardiopulmonary exercise testing. *Principles of exercise testing and interpretation: including pathophysiology and clinical applications,* 5th ed. Philadelphia, PA: Lippincott Williams & Wilkins, 71–106.