The human energy capacity consists of two main parts, aerobic and anaerobic, according to the nature of the energy yielding biochemical processes which take place in the cell. Characteristics of physical activity depend on the volume and rate of energy release necessary for physical activity and differ significantly in various forms and shapes of activity. The volume of the energy capacity and the level of its exploitation are significantly different among individuals. This is of particular importance for achieving top sports results. Energy capacity can be accurately measured in many ways.

The assessment of the anaerobic capacity can be conducted in several ways. The most common are the motor tests [1–3], determination of the maximum oxygen debt [4], and maximum oxygen deficit [5] and muscle biopsy [6]. The most commonly used test today is the Wingate anaerobic test. The Wingate test (WAnT) is widely used test for the comparison of anaerobic capacity between different sexes [7,8], age groups [9] and athletes [10,11]. The validity of the WAnT for measuring anaerobic capacity was proved many times in the past and remains on the higher level till the end of the test on the rowing ergometer. By correlating the anaerobic parameters of the classic Wingate test and a modified Wingate test on the rowing ergometer a significant positive correlation was detected in the peak power (r=0.63, p<0.05) as well as in the mean power (r=0.65, p<0.05). The results show that the rowers achieved better results of the anaerobic parameters on the rowing ergometer compared to the cycling ergometer due to a better mechanical efficiency. It is concluded that the modified Wingate test on the rowing ergometer can be used in rowers for testing their anaerobic capacity as a sport specific test ergometer since it provides more precise results.

Key words: Anaerobic Threshold; Exercise Test; Ergometry; Athletic Performance; Muscle Strength + physiology; Physical Endurance + physiology

Introduction

A cycle ergometer, as a tool for conducting WAnT, provides valuable information for measuring anaerobic capacity; however, there is still a question whether it depicts the real situation in various sport disciplines. For this reason, there is a need to assess anaerobic capacity on the principle of the Wingate test, performed on other more sport – specific devices.

The aim of this study was to determine the difference between the Wingate test on a cycle ergometer and a modified Wingate test on a rowing ergometer in rowers.

Material and methods

Subjects

The study involved 20 male rowers from the rowing club Danubius, Novi Sad, who volunteered to participate in the study. All subjects were healthy, as confirmed by the medical examination, and able to participate in the planned study. The anthropometric parameters (age, body weight - BW and body height - BH) were measured and data on the length of the sports experience were collected.

Experimental procedure

Cycling ergometer

WAnT is 30 seconds „all-out” test on a cycling ergometer. The maximum load is achieved by turning the motor. The maximum load is achieved by turning the motor. The aim of this study was to establish differences in measuring anaerobic capacity between the classic Wingate test on a cycling ergometer and the modified Wingate test on a rowing ergometer in rowers. A group of 20 rowers was tested by both the cycle and rowing ergometers during 30s of maximum power to test anaerobic capacity and to make correlation between these tests. The parameters measured were the peak power and mean power. The peak power on the cycling ergometer was 475±75.1W and 522.4±81W (p<0.05) on the rowing ergometer. The mean power on the cycling ergometer and the rowing ergometer was 344.4±51.1W and 473.7W±67.2, (p<0.05) respectively. The maximum values were achieved at the same time on both ergometers, but remained on the higher level till the end of the test on the rowing ergometer.

The study involved 20 male rowers from the rowing club Danubius, Novi Sad, who volunteered to participate in the study. All subjects were healthy, as confirmed by the medical examination, and able to participate in the planned study. The anthropometric parameters (age, body weight - BW and body height - BH) were measured and data on the length of the sports experience were collected.

Experimental procedure

Cycling ergometer

WAnT is 30 seconds „all-out” test on a cycling ergometer. The maximum load is achieved by tur-
**Results**

Table 1 shows the group analysis of the basic characteristics of rowers. The results indicate the homogeneity of the measured parameters.

The testing of anaerobic capacity of rowers was carried out on the cycle ergometer and the rowing ergometer. The test results are shown in Tables 2 and 3.

**Table 2. Parameters klasičnog testa Wingate na bicikl ergometru**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean Value</th>
<th>Standard Deviation</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Power (W)</td>
<td>475</td>
<td>75.1</td>
<td>16</td>
</tr>
<tr>
<td>Peak power/Body weight</td>
<td>6.69</td>
<td>0.86</td>
<td>13</td>
</tr>
<tr>
<td>Prirast (W/s)/Explosive power</td>
<td>67.5</td>
<td>14.2</td>
<td>21</td>
</tr>
<tr>
<td>Prirast/telesna masa</td>
<td>0.95</td>
<td>0.19</td>
<td>20</td>
</tr>
<tr>
<td>Explosive power/Body weight</td>
<td>344.4</td>
<td>51.1</td>
<td>15</td>
</tr>
<tr>
<td>Mean Power/Body weight</td>
<td>4.85</td>
<td>0.72</td>
<td>14.85</td>
</tr>
</tbody>
</table>

**Table 3. Parameters of modified Wingate test on rowing ergometer**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean Value</th>
<th>Standard Deviation</th>
<th>Coefficient of Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Power (W)</td>
<td>522.4</td>
<td>81</td>
<td>15.5</td>
</tr>
<tr>
<td>Peak power/Body weight (W/kg)</td>
<td>7.36</td>
<td>0.96</td>
<td>13</td>
</tr>
<tr>
<td>Mean Power (W)</td>
<td>473.7</td>
<td>67.2</td>
<td>14.2</td>
</tr>
<tr>
<td>Mean Power/Body weight (W/kg)</td>
<td>6.67</td>
<td>0.79</td>
<td>11.85</td>
</tr>
</tbody>
</table>

The comparison of parameters of anaerobic capacity on the cycle ergometer and rowing ergometer is shown in Graph 1, according to which the rowers achieved significantly better results on the rowing ergometer. Statistically significant differences in favor of the rowing ergometer were obtained in parameters of maximum power (peak power - PP) and mean power (mean power - MP). The parameter PP on the cycle ergometer was 475±75.1W, while on the rowing ergometer it was 522.4±81W (P<0.05). The parameter MP was also significantly higher on the rowing ergometer (344.4W - 473.7±51.1 to 67.2W, P<0.05). Dynamics of the load shows that the subjects reached the maximum value at the same time interval on both ergometers (2.75 of 5sec interval on the cycle ergometer and 2.8 of 5sec interval on the rowing ergometer, p<0.05). However, a higher drop in power during the test was recorded on the cycle ergometer, as shown in Graph 2.

By correlating the parameters of anaerobic capacity on the rowing and cycle ergometer a statistically significant positive correlation was found for the parameters of maximum power (r=0.63, p<0.05) and mean power (r=0.65, p<0.05).

**Abbreviations**

WANT – Wingate test  
WANTv – Wingate test on a rowing ergometer  
PP – Peak Power  
MP – Mean Power

RING the wheel with integrated paddles against the resistance of air flow. The test was conducted on a cycle ergometer under identical experimental and microclimatic conditions.

The load was recorded directly through the module of the computer, set to measure the number of revolutions of the flywheel of the cycle ergometer. The software support provided storing and analysis of data. This method enabled the direct monitoring of testing the parameters of anaerobic capacity, maximum power (Peak Power, Peak Power/weight), medium power (Mean Power Mean Power/weight) and fatigue index [15]. The subjects were familiar with the way of performing the test. Prior to the test all subjects performed warm up procedure lasting 10 minutes. The aim of warm up was to achieve adaptation of physiological parameters to the higher level, which provided the maximum result of the test. The test started on the audio signal from the computer, after which the subjects pedaled at the maximum speed for 30s.

**Rowing ergometer**

The modified Wingate rowing ergometer test (WANTR) was performed on the Concept II rowing machine (Vermont, USA). The faster the subjects got the wheel spinning, the more resistance was generated. The WANTR test was performed for 30 seconds and the results were processed in the software system of the device. The average power of contraction was measured by finding the mean value of individual contractions in each interval of 5 seconds. Six values were obtained within the interval of 30 seconds.

The subjects were familiar with the way of performing the test and before the main test they had done a trial testing on the rowing ergometer. The trial test lasted for 10 minutes and, as in the previous test on the cycle ergometer, its goal was to warm up the subjects and make the subjects familiar with the test procedure.

The test started on the voice sign, after which the subjects performed their first contraction. After the first contraction the subjects were „rowing“ for 30 seconds with the maximal strength. The movements on the rowing ergometer are the most similar to those performed in a rowing boat by rowers during a race.

**Table 1. Osnovne karakteristike grupe veslača (n=20)**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Mean Value</th>
<th>Standard Deviation</th>
<th>Coefficient of variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>TV Height (cm)</td>
<td>181.75</td>
<td>5.08</td>
<td>2.8</td>
</tr>
<tr>
<td>TM Weight (kg)</td>
<td>71</td>
<td>7.44</td>
<td>10.48</td>
</tr>
<tr>
<td>Starost/Age</td>
<td>15.25</td>
<td>0.72</td>
<td>4.64</td>
</tr>
</tbody>
</table>

**Graph 1,** according to which the rowers achieved significantly better results on the rowing ergometer. Statistically significant differences in favor of the rowing ergometer were obtained in parameters of maximum power (peak power - PP) and mean power (mean power - MP). The parameter PP on the cycle ergometer was 475±75.1W, while on the rowing ergometer it was 522.4±81W (P<0.05). The parameter MP was also significantly higher on the rowing ergometer (344.4W - 473.7±51.1 to 67.2W, P<0.05). Dynamics of the load shows that the subjects reached the maximum value at the same time interval on both ergometers (2.75 of 5sec interval on the cycle ergometer and 2.8 of 5sec interval on the rowing ergometer, p<0.05). However, a higher drop in power during the test was recorded on the cycle ergometer, as shown in **Graph 2.**

By correlating the parameters of anaerobic capacity on the rowing and cycle ergometer a statistically significant positive correlation was found for the parameters of maximum power (r=0.63, p<0.05) and mean power (r=0.65, p<0.05).
Discussion

The success of athletes in each sport depends on the technical, tactical, physiological and psychological characteristics of the athletes. A sports score is determined by their mutual interaction and quality of these interactions. The share of individual components varies in different sports. That is why every sport must be considered separately. Hence, it is necessary to analyze the impact of individual components in a particular sport before the monitoring of training process begins.

Physiological abilities, such as aerobic and anaerobic capacity can be measured by various tests. The important thing in choosing the test is the selection of a relevant test for the activity of the individual, such as riding a bike for the cyclist or intermittently running test for the basketball players. It should also be known that laboratory tests provide general information about the physical fitness level of athletes, but rarely provide accurate data on the success of athletes on the sports field. To achieve a more accurate measurement of a performance it is better to use some of the field tests.

There are several tests that have been specifically designed to measure anaerobic capacity of rowers [16]. However, the unilateral movements of the lower or upper extremities do not correspond well with the coordinated bilateral movements of the upper and lower extremities in rowing. The fact that anaerobic capacity is very important for rowers [17] highlights even more the need to use sport-specific ergometric tests to assess anaerobic capacity in rowers.

The technique itself plays a great role in every sport competition as well as in testing with the rowing ergometer. The technique is in fact a dynamic stereotype. In this study we used the rowing ergometer along with the classic cycle ergometer to find out whether there is a correlation between these tests and to determine the impact of training process for specific muscles on the results of tests in rowers.

Dynamic stereotype is a complex mechanical action that takes place in the precisely defined sequence and timing and it is learned during life. The proper synchronization and execution of the movements of all extremities increase mechanical efficiency and enable better results. Uncoordinated movements lead to dissipation of energy. Therefore, a good training process is very important, especially in early childhood when people start with physical activity in different sports, since the dynamic stereotype is established at that early time.

A great influence on the test result of the well-established dynamic stereotype is also shown by this study in rowers. Rowers have increased not only the muscle strength during many years of training, but also the mechanical efficiency when using their muscles for the movements specific for their sport. Therefore, the results on the rowing ergometer are significantly better than the results of tests on the cycle ergometer.

Our results on the rowing ergometer match with those obtained by Mandic and associates in their research [18] where the value of PP in rowers on the Concept II rowing ergometer was 590.1±60.7W. Also, the results achieved on a cycle ergometer match the results of other authors [19,20] and belong to the group of good test results published by Inbar et al. [21].

A significant positive correlation was obtained by comparing the parameters of anaerobic capacity between the two ergometers. This increases the utility value of the rowing ergometer as a sport-specific ergometer in testing the rowers.

Conclusion

There is a significant correlation between the conventional Wingate test on the cycle ergometer and a modified Wingate test on the rowing ergometer. Rowers achieve better results of anaerobic capacity parameters on the rowing ergometer than on the cycle ergometer due to increased mechanical efficiency during their use of specific muscles in rowing motions. The rowing ergometer is recommended to be used as a sport-specific ergometer for testing rowers as it provides more accurate results.

Literatura

Wingate test je trideset-sekundni "all-out" test koji se koristi kod sportista svih sportskih specijalnosti za merenje anaerobnog kapaciteta tokom vožnje bicikl ergometra. Anaerobni kapacitet je odgovoran za kratke i intezivne aktivnosti. Cilj rada je bio da se utvrdi razlika između Wingate testa na bicikl ergometru i simulacije Wingate testa na veslačkom ergometru kod veslača.

Materijal i metode
Ispitivano je 20 veslača kod kojih su mereni parametri anaerobne sposobnosti na bicikl ergometru i veslačkom ergometru, specifičnim za dati sport. Vršena je i korelacija između ova dva testa. Mereni su parametri maksimalne snage (Peak power) i srednje snage (Mean power).

Rezultati
Parametar maksimalne snage na bicikl ergometru je bio 475±75 W, dok je na veslačkom ergometru bio 522,4±81 W (p<0,05). Parametar srednje snage se takođe značajno razlikuje (344,4±31,1 W prema 473,7±67,2 W, p<0,05). Maksimalne vrednosti opterećenja su postignute u istom vremenskom periodu, ali su vrednosti zadržane na višem nivou na veslačkom u odnosu na bicikl ergometar. Korelacijom između dva ergometra dobijena je visoka statistička značajnost u parametrima maksimalne snage (r=0,63, p<0,05) i srednje snage (r=0,65, p<0,05).

Diskusija
Dobijeni rezultati pokazuju da su veslači postigli značajno bolje parametre anaerobne sposobnosti na veslačkom ergometru u odnosu na bicikl ergometar. Korišćenje dva ergometra dobijena je visoka statistička značajnost u parametrima maksimalne snage (r=0,63, p<0,05) i srednje snage (r=0,65, p<0,05).

Zaključak
Veslački ergometar se može preporučiti za testiranje veslača kao sport specifični ergometar jer daje preciznije rezultate.