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Basic Rowing Physiology

***Autor**: Thor S. Nilsen (NOR)*
***Editors**: Ted Daigneault (CAN), Matt Smith (USA)*

AUTHOR'S NOTE

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1.0 INTRODUCTION

Rowing is a sport which requires a well conditioned body to operate at a high performance level during periods of training and competition. During training and competition, the human body acts as the engine to propel the rowing boat across the water. As an engine, the body requires energy to enable it to operate. The source of the energy for muscle contraction is the breakdown of chemical bonds in the muscle cells. However, these chemical bonds must be replaced by the fuels of the body. The fuels of the body are carbo- hydrates and fats from the food we eat. They are stored in the body in the form of glycogen and fat and, when needed, are used to restore the chemical bonds in the muscle cells.

In order to improve the efficiency of the human body to utilize the fuels and produce energy, many adaptations take place within the body during exercise. In this course, the physiology of exercise will be presented in a way that will allow an understanding of some of these adaptations.

2.0 THE ROWING MOTION

It is necessary, in the beginning, to study the rowing motion to enhance the understanding of the physiology of rowing. The rowing motion is created by an athlete seated in a boat moving forward and backward on a sliding seat while pulling on an oar placed in the water. This will result in the boat being pried forward across the surface of the water. When the athlete is pulling on the oar, he creates a positive directional force on the boat and, when the oar is out of the water and the athlete is moving in the opposite direction of the boat, he creates a negative directional force.

The method or technique that the athlete uses must coordinate the proper use of the muscle groups and the movement of the boat to maximize the positive directional forces and minimize the negative directional forces. This will optimize the prying motion of each stroke and cause the greatest possible velocity to be achieved during a 2000 metre rowing race. During each stroke, the athlete applies the equivalent of a 40 to 45 kilogram load to the oarhandle in each of the 220 to 250 strokes that occur during the race.

3.0 THE ROWING RACE

Next, we will examine a rowing race. The 2000 metre rowing race consists of three parts or phases: the start phase, the middle or distance phase, and the finish or sprint phase.

During the start phase, the rowing boats generally start the race at a stroke rate that is higher than the stroke rate of the middle or distance phase and the velocity of the boat is higher than the average velocity achieved by the boat during the race. The energy used to achieve and maintain this increased velocity is obtained from the stored chemical bonds in the muscle cells and the breakdown of stored fuels. However, during this phase of the race, the muscle cells are operating without sufficient oxygen in the breakdown of these fuels. This process is termed anaerobic (or without oxygen) metabolism and results in the production of a waste product, lactic acid. The accumulation of lactic acid causes pain in the muscles of the athlete.

During the middle or distance phase, the athlete is using energy that is obtained by converting the stored fuels into energy using oxygen. The presence of sufficient oxygen in the system results in the more complete breakdown of these fuels and is termed aerobic (or with oxygen) metabolism. This phase will continue for about 4 to 6 minutes until the finish phase.

It should be noted that the aerobic process is about 18 times more productive than anaerobic metabolism and does not produce the debilitating waste product, lactic acid. However, anaerobic metabolism provides energy more quickly and can support high velocity muscle contraction.

As with the start phase, the crews will increase the stroke rate during the finish or sprint phase in an attempt to increase the velocity of the boat over the remaining one to two minutes of the race.

This increase in stroke rate, and resultant increase in boat velocity, will increase the energy requirements of the body to a level that will exceed the capacity of the aerobic metabolic process to provide sufficient energy. Therefore, the anaerobic metabolic process is called upon to contribute and the waste product, lactic acid, is produced in increasing amounts.

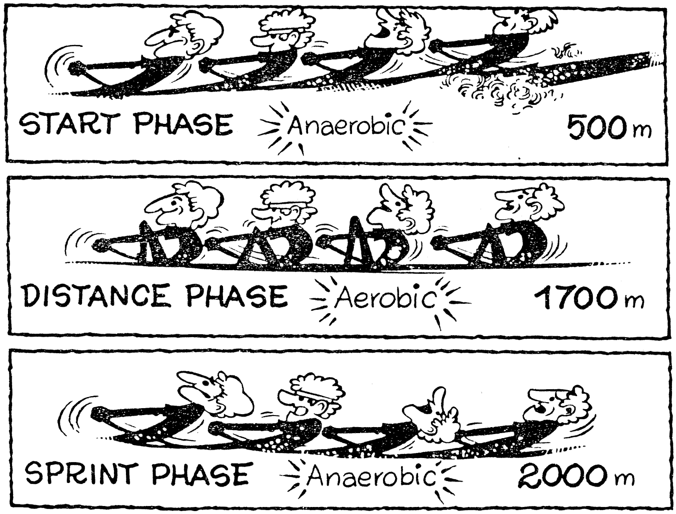


Figure 1 - The Phases of the Race

In order to improve the ability of the athlete to move the boat over the water, it is necessary to increase the athlete's capacity to produce energy and to improve the athlete's ability to endure the physical demands placed upon the body. This is called the athlete's endurance capacity. But what exactly is endurance capacity?

4.0 ENDURANCE CAPACITY

Endurance capacity is defined broadly as the ability to persist in the performance of physical activity. However, a more precise definition would be the ability of the athlete to perform at a given load over a period of time.

For the athlete to perform at a greater load (and, thereby, move the boat over the race course in a shorter period of time), it is necessary to increase the endurance capacity of the athlete by proper training.

As a coach of rowing, you have a responsibility to understand the effects of training on your athletes. This knowledge will assist you in the preparation of training programmes that will more effectively produce the desired physiological adaptations. Your goal will be to give the athlete an opportunity to obtain an increased performance level and, thereby, realize his or her potential.

5.0 AEROBIC METABOLISM

Proper training to increase the endurance capacity of the athlete must include training the aerobic metabolic process since this system contributes 75 to 80 percent of the energy used in a rowing race. Thus, the importance of oxygen transportation and utilization is very clear. However, this raises two important questions: How do we get oxygen from the air to the muscle cells? And, what happens to produce energy at the muscle cells? As the process which utilizes oxygen in the muscle cells to produce energy is complex, it will be discussed in Levels II and III of the FISA CDP.

5.1 The Oxygen Transportation System

There are three systems involved in the journey of oxygen from the air to the muscle cells. The first system, the respiratory system, takes air (containing oxygen) into the lungs by breathing. Approximately 21 percent of the air is composed of oxygen (O2).

After the lungs receive air, the oxygen diffuses from the air through the walls of the tiny air sacs (alveoli) of the lungs into the blood.

The second system, the circulatory system, carries the blood, now saturated with oxygen, from the lungs to the heart where it is pumped out through the arteries to the areas most in need of oxygenated blood, namely the exercising muscles. As the blood travels through the circulatory system, the arteries become smaller and branch off into thousands of small arteries called capillaries. The capillaries are small enough to surround the individual muscle fibres.

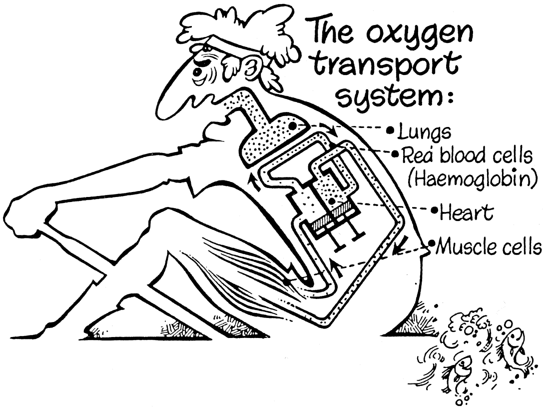


Figure 2 - The Oxygen Transportation System

In the third system, the muscular system, an important transfer or diffusion of oxygen occurs as oxygen is passed through the walls of the capillary to the muscle cells. In the muscle cells, the oxygen is taken to the mitochondria (power plants of the muscle cells) and used in the conversion of fuels to energy in the oxygen utilization process.

We have now seen that the oxygen utilizes three different systems while reaching the muscle cells where it is used to produce energy in the aerobic metabolic process: the respiratory system, the circulatory system and the muscular system.

The air that is inhaled into the lungs is the primary carrier of oxygen. From the lungs, the oxygen is then transferred to the blood.

The blood then becomes the second carrier of the oxygen. The oxygenated blood is carried to the heart, pumped out through the arteries and then to the capillaries.

When the capillaries carrying the blood reach the muscle fibres, the oxygen is then transferred to the muscle cells. Within the cells the oxygen is used in the process of producing energy. We shall now look more closely at the major components of these three systems and the possibility of increasing their effectiveness through training.

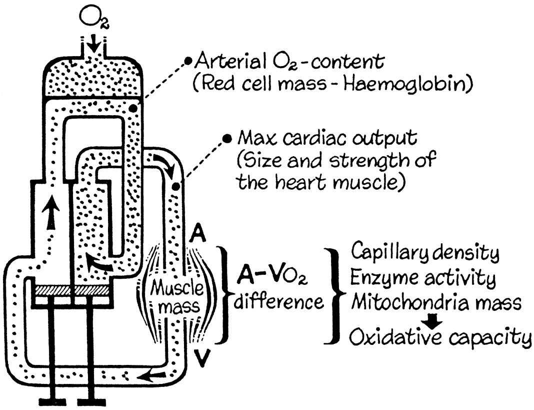


Figure 3 - The Transportation System Simplified

5.2 The Major Components of Oxygen Transportation

The first component is the lungs. The lungs can take in 120 to 180 litres of air per minute during exercise in normal people. Top rowing athletes have been observed with an intake of over 200 litres of air per minute.

Considering that the air we breathe contains approximately 21 percent of oxygen, this means that up to 42 litres of oxygen per minute can be inhaled by a heavyweight athlete during heavy exercise. This is considered enough oxygen for the metabolic demands of the body and does not change significantly with training.

The second component is the ability of the blood to carry the oxygen. This is dependent on the volume of blood and the number of red blood cells in the blood. The red blood cells carry haemoglo- bin which actually carries the oxygen within the blood. Trained athletes generally have more total blood volume and a greater number of red blood cells than untrained persons. It has been observed that endurance training can produce up to a 16 percent increase in resting blood volume. This change is caused by an increase in plasma volume and red blood cell volumes.

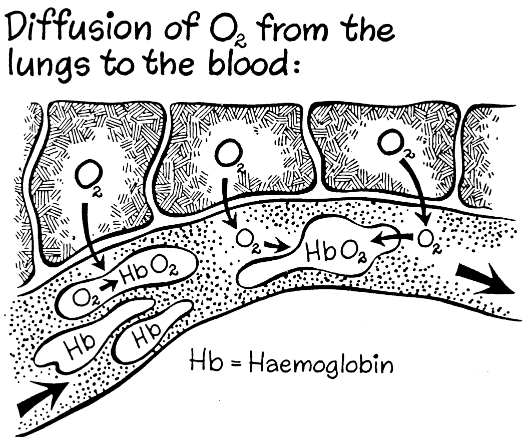


Figure 4 - Diffusion of O2 to the Blood

The third component is the heart. The cardiac output is the measure of the quantity of blood pumped by the heart through the circulatory system to the body in one minute. It is equal to the blood volume pumped in each beat (stroke volume) multiplied by the heart rate. The volume of blood pumped can be increased by training.

Cardiac output varies from 5 litres per minute at rest to over 40 litres per minute during strenuous exercise. Reductions in exercise heart rate and resting heart rate, that typically occur with training, are indicators that stroke volume has increased.

Illustration: Considering that a normal male can pump approximately 110 millilitres of blood per heart beat during exercise and assuming a heart rate of 200 beats per minute, the result is 22 litres per minute of blood being pumped. In athletes, stroke volumes of 160 ml (lightweight men) and up to 200 ml (heavyweight men) can produce 32 and up to 40 litres per minute of blood pumped at maximum exercise. Therefore, blood, having a haemoglobin level of 15 g per 100 ml blood and carrying 200 ml of oxygen per litre, can deliver up to 8 liters per minute of oxygen to the muscular system.

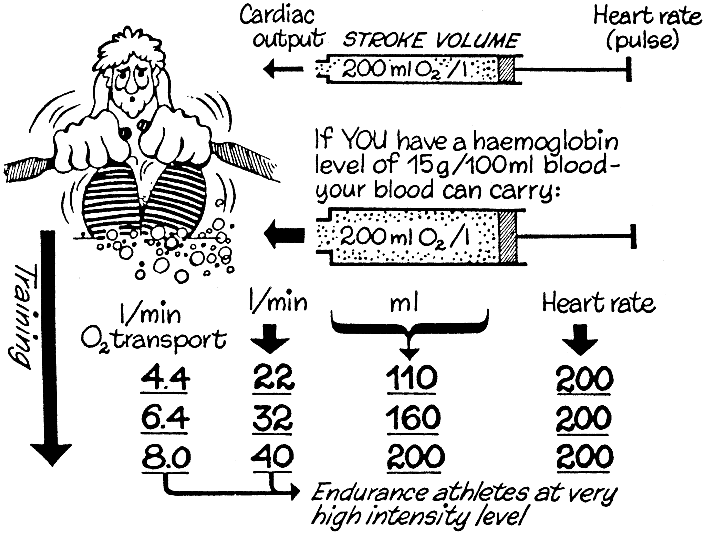


Figure 5 - Cardiac Output

The fourth component is capillary density. Each muscle fibre is surrounded by capillaries which are the extensions of the arteries. An increase in the number of capillaries surrounding a particular muscle fibre will deliver more blood to the area and, therefore, deliver more oxygen to the muscle.

It has been shown that training probably increases the total number of functional capillaries surrounding muscle fibres and, thereby, allows more oxygen to be available to the muscles.

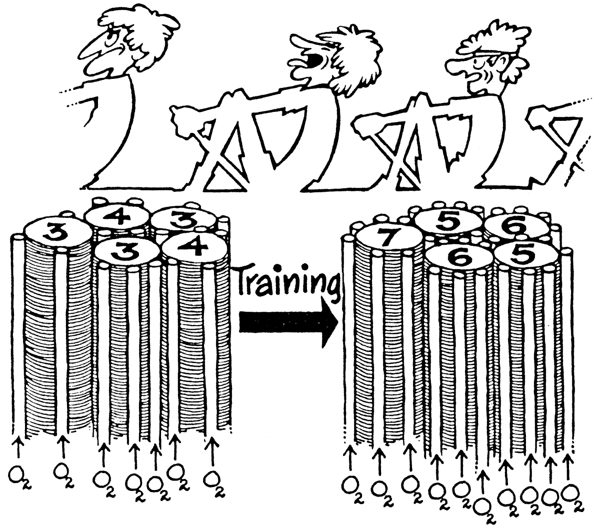


Figure 6 - Capillary Adaptation

Another component of oxygen transportation is the flow of blood to the working muscles. During exercise, the flow of blood to the working muscles does increase because arteries carrying blood to inactive areas tend to constrict while arteries carrying blood to areas that are requiring greater amounts of oxygen tend to dilate. Research indicates that training will increase the blood flow to working muscles.

Many adaptations also take place in the muscle cells themselves to increase the consumption of oxygen. Endurance training has been shown to increase the effectiveness of the machinery within the muscle cells to produce energy.

Again, the adaptations that improve oxygen utilization will be discussed in Levels II and III of the FISA CDP.

5.3 Limitations

The major components involved in the transportation of oxygen have been discussed. They are, however, not equally important in a discussion of the limitations in the transportation process. The respiratory system delivers more oxygen to the circulatory system than can be transported in the blood. Thus, the lungs are not considered a limitation to a rowing athlete's performance.

However, the circulatory system can be improved with training and can have a strong influence on the physiological capacity of the athlete. To produce a training effect in the circulatory system, any type of exercise that loads the heart can produce improvement in oxygen transportation and, therefore, oxygen uptake.

In the muscles, the oxygen is taken up and utilized in the conversion of fuels to energy. These two processes have also been shown to improve significantly with training and, therefore, contribute to improved physiological capacity. Manyexercise physiologists consider the muscular system to have the greatest potential for improving aerobic metabolism. To produce a training effect which will influence the utilization of oxygen by the muscle cells, training should remain specific to the sport by loading the muscles which are principally used in the motion specific to the sport at a medium training load for a long duration. Later, we will relate specific types of training to the systems involved.

As stated, aerobic metabolism is not capable of supplying all the energy needs of the body during work periods at a high load. We will now look at the other system that provides energy to the body in the absence of oxygen.

6.0 ANAEROBIC METABOLISM

We have now completed our discussion of the aerobic metabolism process. However, there is another source of energy that contributes 20 to 25 percent of the energy used in a rowing race. We call this anaerobic metabolism.

Anaerobic metabolism is utilized primarily in the start and finish phases of the rowing race. It should be noted that, during the initial seconds of the race, energy is provided by the chemical bonds stored in the muscle cells. After this initial period, the body must rely on the anaerobic breakdown of glycogen to provide the remaining energy requirement of the start phase. The intensity experienced during the start and finish phases of the race necessitate the use of the anaerobic metabolic system to support the high velocity muscle contraction and provide sufficient energy to meet the high energy demands on the body.

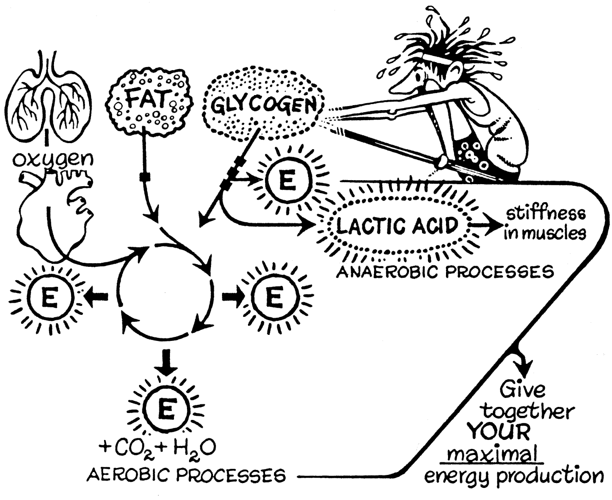


Figure 7 - Energy Production

The use of the anaerobic metabolic system for the breakdown of the fuels produces the waste product known as lactic acid. The accumulation of lactic acid causes fatigue and reduces the ability of the muscles to contract.

Training improves the athlete's ability to tolerate the accumulation of lactic acid and improves the mechanism for its removal. However, because the aerobic metabolic system is more efficient and contributes a greater proportion of the energy requirements of the rowing race, this course will emphasize aerobic metabolism. Further information will be provided on both of these metabolic systems in Levels II and III of the FISA CDP.

7.0 MEASUREMENT

How does one measure the ability of athletes to work efficiently with their bodies? By using laboratory instruments, exercise physiologists can evaluate the athletes' maximal oxygen uptake or VO2 Max. VO2 Max represents the body's maximal total aerobic metabolic rate. This is an important measurement because of the relative importance of the aerobic metabolism to rowing. The difference between the oxygen content of the inhaled air and the oxygen content of the exhaled air is measured (we know that the air inhaled from the atmosphere is 20.9 percent oxygen). This difference is multiplied by the amount of air exhaled (ventilation) to arrive at the absolute maximal oxygen consumption of the athlete. This value is expressed as litres per minute of oxygen.

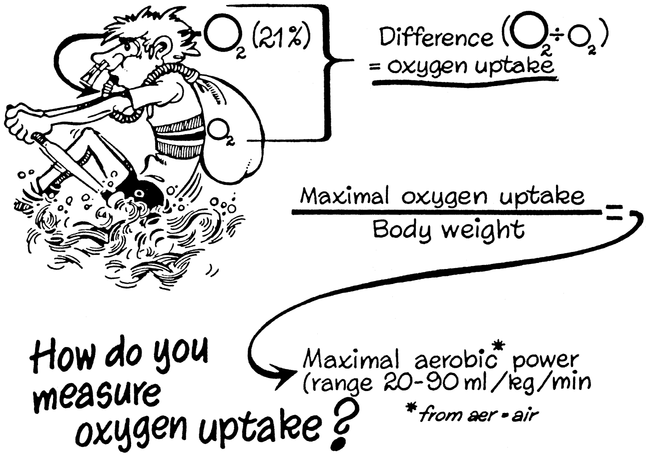


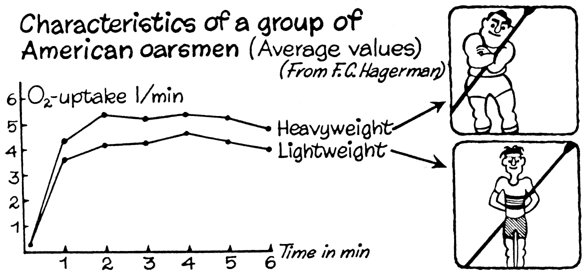
Figure 8 - Maximal Oxygen Uptake

The following average VO2 Max values have been observed for international athletes in rowing:

Heavyweight Men:	6.2 litres per minute
Lightweight and Junior Men:	5.3 litres per minute
Heavyweight Women:	4.4 litres per minute
Lightweight and Junior Women:	3.9 litres per minute

VO2 Max can also be expressed as the relative oxygen consumption of the athlete by dividing VO2 Max by the athlete's body weight in kilograms. For example, using the relative VO2 we have observed average consumptions of 68 ml/kg-min for heavyweights and 71 ml/kg-min for lightweights.

Although the measurement of oxygen uptake requires the use of expensive equipment and the assistance of an experienced exercise physiologist, this information is not necessary to produce world class rowers.



Number invest.	Time (min)	Watt	l/min	ml/kg/min	Category
503	6	374	6,1	68,9	Heavyweight
120	6	358	5,1	71,1	Lightweight

Figure 9 - Characteristic Statistics

Further measurement systems for aerobic and anaerobic metabolism will be discussed in Level II and III of the FISA CDP. It is now important to look at the training methods that will improve the aerobic metabolic system.

8.0 TRAINING METHODS

To relate the information presented to practical training methods, we will focus on training methods which will affect the principal systems of aerobic metabolism. The three systems are represented by the lungs, the heart, and the muscles.

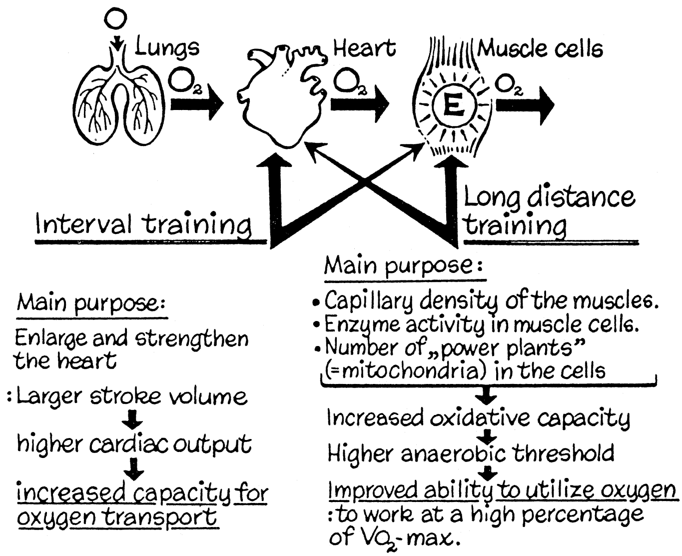


Figure 10 - Training the Body Systems

8.1 The Lungs

The respiratory system cannot be significantly improved to increase the efficiency of the entire system. Although the lungs adapt to the load imposed by the increased breathing that occurs with training, the respiratory system is not considered to be a limitation to physiological improvement.

8.2 The Heart

The circulatory system can be improved with training. The most effective type of training places a demand on the heart that causes it to enlarge and strengthen itself. The best type of training to produce this effect is interval training. Interval training is a systematic prodecure that utilizes short periods of work at a high training load alternating with periods of recovery. This type of training will result in a higher cardiac output to the body and, therefore, an increased capacity for oxygen transport.

8.3 The Muscles

The muscular system can also be improved with training. The most effective type of training places a demand on the muscle fibres to utilize oxygen. The best type of training is long distance training. Long distance training is a systematic training procedure that utilizes long periods of work at a medium training load which may or may not alternate with periods of rest. This type of training increases the number of functional capillaries around the muscle fibres and increases the activity and mechanisms in the muscle cells to utilize oxygen.

This is a very brief description of the types of training that will increase the performance level of the athlete. Other courses in Levels I and II of the FISA Coaching Development Programme will provide further information.

9.0 SUMMARY

You should now have acquired a basic understanding of the physiological requirements of the sport of rowing. With this information you will be able to assist your athletes in their understanding of the body systems that are important to rowing and how to improve these systems.