Physiological and Biomechanical Aspects of Rowing
Implications for Training

Niels H. Secher
Department of Anaesthesia, Rigshospitalet, University of Copenhagen, Copenhagen, Denmark

Contents

Summary 25
1. Background 25
2. Biomechanics 26
   2.1 Boats and Oars 26
   2.2 Energy Expenditure 26
   2.3 The Rowing Stroke 27
   2.4 Race Split-Times 28
2. Metabolic Cost of Rowing 28
3. Metabolic Cost of Rowing 31
4. Ventilation 32
5. Circulation 33
6. Endocrine and Metabolic Responses 33
   6.1 Muscle Damage 33
   6.2 Lactate 33
   6.3 Hormones 33
   6.4 Diet 34
7. Oarsmen 34
   7.1 Strength 34
   7.2 Circulation 35
   7.3 Lungs 35
   7.4 Maximal Oxygen Uptake 36
   7.5 Anaerobic Threshold 36
8. Training 36
   8.1 Background 36
   8.2 Strength 37
   8.3 Endurance 37
   8.4 Altitude Training 37
   8.5 Psychology 38
9. Conclusion 38
The drag force on a racing shell increases with the square of velocity corresponding to a 3.2 power increase in energy expenditure. However, the metabolic cost increases with only an approximately 2.4 power function of shell velocity. During international races the metabolic cost corresponds to an oxygen uptake of 6.7 to 7.0 L/min over 6.5 min. The relative anaerobic contribution to 6.5 min of 'all-out' rowing has not been determined but is estimated to range from 21 to 30%. Because of the large muscle mass involved in rowing, blood variables reach extreme values: adrenaline 19 nmol/L; noradrenaline 74 nmol/L; pH 7.1; and bicarbonate 9.8 mmol/L. Because of the static component of the rowing stroke at the catch, blood pressure increases to near 200mm Hg, and the heart of oarsmen has adapted to this load by increasing wall thickness and internal diameters. The maximal oxygen uptake of oarsmen may reach 6.6 L/min and ventilation 243 L/min. Arterial oxygen tension decreases by 20mm Hg during 'all-out' rowing corresponding to a decrease in pulmonary diffusion capacity. A force of approximately 800 to 900N is developed on the oar. Force generation during rowing is relatively slow, 0.3 to 0.4 sec. Oarsmen are strongest in low velocity movement with 70 to 75% slow twitch fibres in skeletal muscle. Data indicate that rowing technique and training may improve explaining why results become approximately 0.7 sec faster per year.

The physiology of rowing has previously been reviewed (Åstrand & Rodahl 1986; Hagerman 1984; Korner & Schwanitz 1985; Secher 1983, 1990, 1991; Steinacker 1987; Thorner 1950; Zsidegh 1981). This review is an update of the training and practical aspects with discussion of the latest research on the physiology and biomechanics of rowing.

Rowing varies from other types of exercise most often studied. There are 3 main differences. First, in contrast to cycling and running, almost every muscle group takes an active part in rowing. Blood variables change to the extreme during 'all-out' rowing because of the workload of the arm, back and leg muscles. Secondly, while traditional exercise physiology distinguishes between static and dynamic exercise, circulatory aspects of rowing physiology are best understood by accepting that both types of exercise are important. Thus, in the catch phase of the rowing stroke the arms and back muscles perform static exercise while the legs are stretching. Later in the stroke the back and shoulders extend and the arms bend. Thirdly, during most types of human locomotion the legs are used in such a way that alternative force is applied on the right and left legs; however, during rowing the 2 legs are simultaneously used in the press against the footboard (the 'stretcher'). With a race duration of approximately 6 to 7 min for the 2000m course, rowing may be regarded as a sport model for one key exercise physiological variable: the maximal oxygen uptake (\(\dot{V}\text{O}_2\text{max}\)), i.e. the highest pulmonary uptake of oxygen that a person can attain during a given type of exercise. Thus, many early studies on rowers were conducted to report extraordinarily large \(\dot{V}\text{O}_2\text{max}\) values (Hagerman et al. 1978; Henderson & Haggard 1925; Mellerowicz & Hansen 1965; Nowacki et al. 1969; Secher et al. 1983).

1. Background

Despite early 'cultures' being dependent on rowing for transport they did not arrange rowing competitions (Secher 1990). For a discussion of ancient oared warships see Foley and Soedel (1981). The earliest type of competition may have involved a match between 2 'knights' in the rear end of 2 boats who were fighting with a stick in order to push the opponent in the water (Henningsen 1949). Such competitions are still arranged in Denmark and France where they are called 'joutes' (OK Magasinet 1989). The longest row by a single person in a traditional rowing boat may be that of O. Joensen from the Faroe Islands to Copenhagen (1670km) in 1986 (Mortensen et al. 1987).

Rowing, as a sport depending on the speed of the shell, was initiated in 1716 on the River Thames with the Doggett Coat and Badge race for profes-