Heart Rate and Lactate During Endurance Training Programs in Rowing and its Relation to the Duration of Exercise by Top Elite Rowers

Authors: U. Hartmann, A. Mader and W. Hollmann (GER)

Secher (29) states that in the course of the last 30 years races in rowing eights have become about 35 seconds faster. Because of the improvement of the performances and the closeness of the results achieved by world class rowers, scientific investigations on rowing have become more and more important. The objectives of these investigations are first the analysis and second the improvement of the physiological performance capacity of rowers (5, 6, 7, 8, 10, 21, 27, 28, 29, 30, 34).

Even a superficial look at the training practice of rowers reveals gaps in the knowledge of the physiological and, more precisely, the metabolic effects of rowing exercises (1, 17).

The aim of this study is therefore to analyse and classify the rowing-specific training loads on the water. During both the preparation and competition periods, several highly qualified (elite) West German rowers underwent lactate tests at different training loads on the water. The results of these tests make the determination of the real intensity of the training exercises possible.

Method

Between 1985 and 1988, about 40 male rowers (elite) were tested during training in camps and at home (at sea level). The height of the rowers varied between 194 and 197 cm (6'4" and 6'6"), their average weight was 90 to 95 kg (198-209 lbs.), and their average age was 23 years. They had trained for competition for at least five years.

Heart rate was measured by hand immediately after each exercise. In a number of cases, for reasons of comparison, heart rate was measured both by hand and by telemetry. The maximal individual differences between both methods amounted to four to six beats/minute.

Twenty microlitres of capillary blood were taken from the earlobe at the first and third minute after a submaximal exercise and additionally at the fifth, seventh and tenth minutes after a more intensive exercise (see Table 1)(11). The lactate concentrations were determined enzymatically (20). For every training exercise (see Table 1) the mean and the standard deviation of both the lactate concentrations (LA) and the heart rates (HR) were calculated.

Results and Discussion

Table l shows the relationship between lactate and heart rate during different rowing-specific training exercises on the water. As expected, the lowest heart rates were measured during the exercises with the lowest metabolic activities.

During extensive endurance training exercises (moderate long distance training - ModLDT), 1.47 +/- 0.65 millimol/litre (mmol/l) blood lactate and 146.5 +/-15.1 beats/minute heart rate were measured. During intensive endurance training (medium long distance training - MedLDT), 2.47 +/- 0.88 mmol/l blood lactate and 163.6 +/- 9.4 beats/minute were measured. As far as 4 to 7 minute workouts are concerned, lactate concentrations were found between 4.48 +/-1.73 mmol/l and 8.52 +/- 2.00 mmol/l and heart rates between 172.7 + 8.8 beats/minute and 183.8 + 12.9 beats/minute. During tempo training over different distances (500, 1000, 1500 and 2000m), lactate levels increased to 15.24 +/- 3.30 mmol/l. Heart rate was not measured during competition. However, various authors found a maximal heart rate of 190 beats/minute after maximal rowing exercises in the laboratory (7, 8, 30, 34). This heart rate can be considered as a competition value.

Table 1: Number, mean, and standard deviation of lactate [LA (mmol/l)] and heart rate [HR (min^{-1})] for different rowing specific intensities.

Training Program	Number of Sessions (n)	Lactate (mmol/l)	Heart Rate (per min)
Moderate Long Distance (ModLDT)	236	1.47 +/- 0.65	146.5 +/- 15.1
Medium Long Distance (MedLDT)	39	2.47 +/- 0.88	163.6 +/- 9.2
Long Distance Training with 15 strokes	12	3.04 +/- 0.76	163.1 +/- 9.4
Power (endurance) Training (PT) including 80-120 strokes	36	3.64 +/- 0.96	171.5 +/- 10.0
Intensive Long Distance Training (IntLDT; 15-20 min)	16	3.66 +/- 1.28	168.8 +/- 7.8
Intensive Long Distance Training (IntLDT; 10 min)	46	4.48 +/- 1.73	172.7 +/- 8.8
Pyramid (e.g., 30-40-50-60-50-40-30 strokes)	28	5.95 +/- 1.33	175.5 +/- 12.6
5 km in Short Time (with heart rate)	9	5.88 +/- 1.75	165.0 +/- 11.1
5 km in Short Time (without heart rate)	20	6.87 +/- 2.03	
10 km in Short Time	25	6.23 +/- 1.67	
Alternate Training, 3 x 7 min	32	6.84 +/- 1.49	184.1 +/- 10.6
Alternate Training, 3 x 4 min	26	8.52 +/- 2.00	183.8 +/- 12.9
Alternate Training, 3 x 7 and 3 x 4 min	48	7.59 +/- 1.92	184.0 +/- 11.6
Alternate Training, 2 or 3 x 2 min	10	10.74 +/- 1.17	
2000 m Temp Training, 6 strokes < race frequency	17	7.27 +/- 2.02	177.8 +/- 13.0
1500 m Tempo Training, 3 strokes ~ race frequency	16	10.57 +/- 2.48	178.8 +/- 7.6
500m Tempo Training	158	9.88 +/- 2.17	
1000m Tempo Training	83	12.48 +/- 2.61	
1500m Tempo Training	14	12.90 +/- 2.08	
Test Regatta - Duisburg	45	13.75 +/- 2.59	
International Regatta - Lucerne	38	15.24 +/- 3.30	

On the basis of the results mentioned above (see Table 1), we divided the different training exercises into four categories:

- category I = more than 8 mmol/l of blood lactate
- category II = 4 mmol/l to 8 mmol/l of blood lactate
- category III = 2 mmol/l to 4 mmol/l of blood lactate
- category IV = lactate at rest to 2 mmol/l of blood lactate

This division is not arbitrary, but can be justified as follows:

If after a submaximal exercise of 10 to 15 minute duration the lactate concentration is four mmol/l, the lactate concentration will not increase by more than 0.5 to 1.0 mmol/l when continuing this exercise at the same constant speed (intensity) (12, 22).

The maximal, but constant intensity for long-term exercises of more than 10 to 15 minute duration can be defined as the maximal lactate steady state (MaxLass) (13, 19). The mean lactic acid concentration at MaxLass is four mmol/l.

All sports medicine specialists consider four mmol/l a reference value (12, 13, 15, 16, 19, 22, 34).

In our study on the rowing ergometer, we found lactate concentrations between two and four mmol/l during long-term exercises (24 to 40 min) (8). However, an endurance training session of more than one hour duration at a lactate concentration close to MaxLass is not possible. We can therefore consider this range of intensities as the upper limit for MedLDT.

The division of training intensities into different values reaching from lactate at rest to a lactate concentration of two mmol/l is based on the high number of values measured in this range (n = 236) and on reasons in connection with metabolic energy supply (11).

During exercises at a higher, but still constant speed, we generally found a continuous increase in lactate concentration (16). Lactate concentrations of more than eight mmol/l can lead to exhaustion. Such high lactate concentrations can also be observed on the water.

A concentration of eight mmol/l blood lactate can be considered as the limit between exercises of moderate and high intensity. Specialists in the field of sport sciences, however, regard a concentration of eight mmol/l blood lactate as the transition between exercises of low and moderate intensity. They consider a lactate concentration of 12 mmol/l or more as a value indicating exhaustion (22).

It is not necessary to further subdivide the training intensities at higher lactate concentrations because of the low percentage of those exercises in training (see Table 2).

For training practice, it is important to know to what extent the load structures of different exercise categories (see above) are involved in the successive training phases.

Table 2: Percentage of the different training intensities related to the total amount of training and to the training phase. For further information, see discussion in the text.

Training Period	Categories (% of the total amount of training				
	IV	**III**	**IV + III**	**II**	**I**
Preparation period					
Autumn/winter	90-94	8-5	98-99	1	1-0
Winter/spring	86-88	9-5	95-93	4	1-3
Competition period	70-77	22-15	92-93	6	2

Table 2 is the presentation of the analysis of training data in accordance with the different intensity categories and depending on the active training time (32) in the course of one year.

It is remarkable that in both preparation phases the greatest part of training (90% and more) consists of exercises at an intensity lower than two mmol/l (cat. IV). About 7% of the training is done at an intensity between two and four mmol/l (cat. 111). In the training period before a competition, the percentage of exercises of category IV decreases to 73.5%, while the percentage of exercises of category III increases to 17.5%. Both categories (III and IV) make up 92% of training, which is a significant amount of aerobic work. This is not in accordance with modern training conceptions, advice and plans (1, 2, 3, 23, 24, 25). In the competition period, the amount of training between four and eight mmol/l (6%) is higher than in the preparation period. Training at moderate and maximal intensity amounts only to one to two percent and varies slightly depending on the respective season.

Heart rate seems to be the only meaningful parameter for controlling training intensity. During long distance rowing at about two mmol/l blood lactate, the heart rate corresponds to 87 to 88%, of the heart rate at a lactate concentration of four mmol/l. This is in accordance with results in athletics and swimming (4, 26).

Many authors claim that endurance training is only effective if it is done at a lactate concentration between 2.5 and 3.5 mmol/1 (18, 31, 33) or four mmol/l (1, 14). The results of most intensity checks done in the field show that coaches generally assume that long distance training should be done at a lactate concentration of about three mmol/l or just under four mmol/l. However, the results of our lactate measurements (Table 1) conflict with this assumption. The athletes examined by us seem to choose lower and more tolerable training intensities depending on their individual feelings. These intensities, which are chosen for purely subjective reasons, seem to be more effective for the improvement of the athletes' endurance than the intensities suggested by the coaches which are based on theoretical concepts. If necessary the athletes could sustain a load intensity corresponding to a lactate concentration of 3.5 mmol/l for 45 minutes, but they found it very hard. Higher intensities were felt as very exhausting. Despite its unscientific character, this observation is typical of the quality of their subjective load perception. Training at an intensity corresponding to a lactate concentration of four mmol/l in order to achieve a better effectiveness can no longer be justified physiologically.

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