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B.2. Reaction of the Heart Frequency and the Lactate Level on the Bicycle-ergometer at Different Speeds

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The measurement of the blood lactate level has achieved a big importance in sport medicine, because it is used as well in the diagnosis of performance as in the dosage of the training. One condition is the standardization of the ergometric examination. According to Hollmann, persons, equipments, and climatic conditions are factors that influence the performance on the bicycle-ergometer. Factors that depend on the equipment are: The height and length of the crank, the height of the saddle, and the pedal rate (number of revolutions). Different authors have shown that there seems to be a higher physical stress if one gets a higher speed. It is the purpose of this paper to analyze whether the number of revolutions has a significant influence on the heart frequency and on the lactate reaction.

B.2.1. Material and methods

20 male and healthy sport students, whose anthropometric data are shown in Table 1, were undergoing a sitting test on the bicycle-ergometer. One time the number of revolution amounted to 70/min, another time it amounted to 90/min. The examinations were made within one week. The

test subjects were randomized in order to avoid an influence of training on the examination. The bicycle-ergometric examination was carried out step by step, starting with 50 watts, and increasing by 50 watts after every two minutes until the Vita-max criteria were reached. The heart frequency was determined by means of an Electrocardiogram (firm: Hellige), as well after the end of each step of load and at the end of the 3rd and the 6th minute after the test; at the same time 20µl of blood were withdrawn from the earlobe in order to determine the lactate (firm: Boehringer, fully enzymatically). For the examination we used a bicycle-ergometer that works with electric brakes (firm: Jaeger).

The aerobic-anaerobic threshold (AAT) was determined by means of interpolation between two lactate data, below and above 4 mmol/l (3,7). The average data and the standard deviations of the random samples were calculated (Fig.1). The significances were guaranteed by means of a T-test for connected random samples according to Student. The symbols used are:

(n.s) not significant for $p > 0.05$
(+) for $p \leq 0.05$
(++) for $p \leq 0.01$
(+++) for $p \leq 0.001$

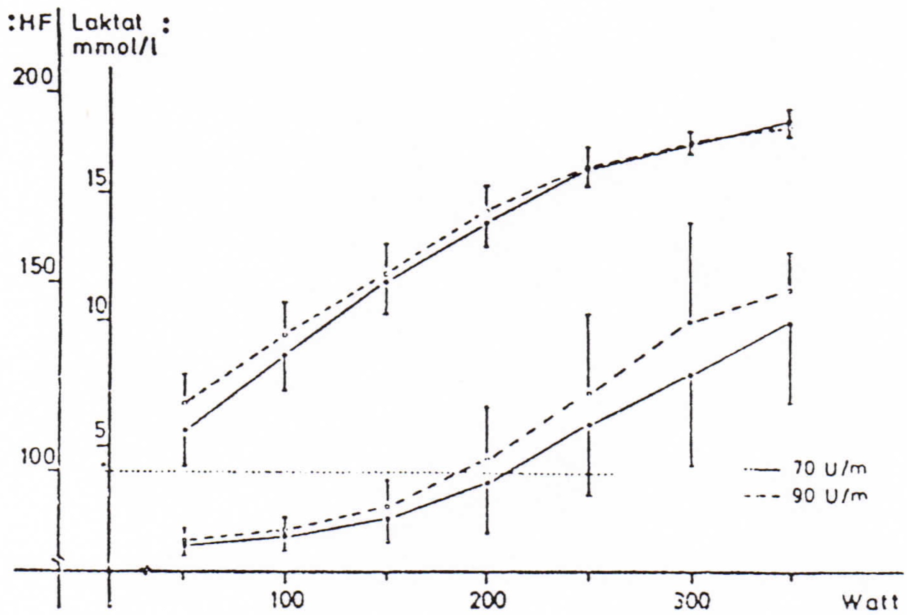

Fig. 1: The reaction of the average data of the heart frequency and of the lactate level at 70 and at 90 revolutions/min on the bicycle-ergometer; the load was average data and standard deviations.

Table 1. Anthropometric data

Age		23,8	Jears
	±	1,7	
Height		184,3	cm
	±	7,6	
Weight		74,6	kg
	±	7,3	
n		20	

B.2.2. Results

From Table 2 we can see that with 5,6 beats/min the difference of the average data of the heart frequencies is highest at the beginning of the load, and that it gets smaller with an increasing load. One can find significant differences in the steps 100, 150, and 250 watts. The data of the test subjects who performed 350 watts are not representative of the collective because there was only a small number of them (n=4).

Table 2. Reaction of the heart frequency at 70 and 90 revolutions/min during the sitting test on the bicycle-ergometer; the load was increased by 50 watt at intervals of 2 minutes average data, standard deviations differences, number of test subjects and significances.

Watt	0	50	100	150	200	250	300	350
70 U/min	85,1	111,2	130,9	149,2	166,5	179,1	185,5	191,5
s±	18,7	18,3	20,4	18,7	15,8	10,7	7,9	7,4
90 U/min	81,9	117,2	136,5	153,3	168,9	181,7	186,8	189,5
s±	18,2	18,9	17,4	16,6	14,9	10,0	7,7	8,2
$\bar{d}$	3,2	6,0	5,6	4,1	2,4	2,6	1,3	2,0
n	20	20	20	20	20	19	12	4
Significance	NS	NS	+	+	NS	+	NS	NS

From Table 3 we can see that the average difference of the lactate data grows with an increasing load until it reaches a maximum average difference of 2.2 mmol/l. Here, as well, the small difference of the lactate data at 350 watts is not representative of the collective because of the small number (n=4) of test subjects.

Table 3. Reaction of the lactate level in mmol/1, analogous with table 2.

Watt	0	50	100	150	200	250	300	350
70 U/min	0,9	1,1	1,4	2,2	3,7	6,0	7,8	9,8
s±	0,3	0,3	0,5	1,0	2,0	3,0	3,6	3,2
90 U/min	0,9	1,3	1,8	2,7	4,5	7,0	10,0	11,2
s±	0,4	0,5	0,6	1,0	2,1	3,2	3,8	1,4
$\bar{d}$	0,0	0,2	0,4	0,5	0,8	1,0	2,2	1,4
n	20	20	19	20	20	18	11	4
Significance	NS	NS	+	++	++	+	++	NS

In order to get a better review of the individual results, the test subjects were divided into 3 groups (A, B and C) (Table 4).

Table 4. Number of the test subjects of the groups A, B and C; classification according to performance at different numbers of revolution on the bicycle-ergometer.

Group A	n = 4	higher amount of watt and/or longer load duration	at 90 r/pm
Group B	n = 6	higher amount of watt and/or longer load duration	at 70 r/pm
Group C	n = 10	same amount of watt and load duration	at 70 and 90 r/pm

The test subjects of group A achieved a better performance at 90 revolutions/min. 2 of the 4 test subjects achieved a higher watt load and 2 achieved a higher duration of load during the same maximum watt load.

The test subjects of group B achieved a better performance at 70 revolutions/min. 5 of the 6 test subjects achieved a higher watt load and 1 a higher duration of load during the same maximum watt load.

At 70 and 90 revolutions/min, the test subjects of group C achieved the same performances during the same maximum watt load and during the same duration of load.

In the comparison of the heart frequencies of both loads the individual data of every test subject show no significant differences in 9 cases

(Table 5). Nine of the remaining 11 test subjects had a higher heart frequency at 90 revolutions/min (2 test subjects of group A, 2 test subjects of group B, and 5 test subjects of group C). 2 had a higher heart frequency at 70 revolutions/min (1 test subject of group B, 1 test subject of group C).

Table 5. Classification of the test subjects of group A, B and C after the comparison of the heart frequencies during different numbers of revolution. A minimum difference of 5 beats/min. ($\Delta HF \geq 5$) was counted as significant.

	$\Delta HF \geq 5$ HF90 > HF70	$\Delta HF \geq 5$ HF70 > HF90	$\Delta HF < 5$ HF70 ≈ HF90
Group A	2	0	2
Group B	2	1	3
Group C	5	1	4
Total n=20	9	2	9

Table 6 shows that in the calculation of the AAT the test subjects show higher absolute and relative (watt/kg) watt loads at 70 revolutions/min. The average difference amounts to 18.5 watt or 0.26 watt/kg and is highly significant. The reaction of the heart frequency in the range of the AAT is different; here, we do not find a significant difference.

Table 6. Absolute and relative performance (watt, watt/kg) and heart frequency in the range of aerobic-anaerobic threshold (lactate 4 mmol/l) analogous with table 2.

	lactate 4 mmol/l		
	Watt	w/kg	HF
70 U/min	212,0	2,88	170,8
$s^{\pm}$	45,3	0,54	12,1
90 U/min	193,5	2,62	168,4
$s^{\pm}$	40,8	0,51	12,3
$\bar{d}$	18,5	0,26	2,4
n	18	18	18
Significance	++	++	NS

In Table 7 the results are classified according to their group affiliation. Throughout a tolerance of 10 watts and 70 revolutions/min. 11 of the 18 test subjects achieved a higher watt load in the range of the AAT. 7 of them belonged to group C. In 5 cases the difference of the watt load was in the field of tolerance. A higher AAT was calculated for 2 test subjects at 90 revolutions/min.

From the same table we can see that the same heart frequency in the field of the AAT was calculated for 13 of the 18 test subjects, with a tolerance of 5 beats/min. 6 of them belonged to group C. 3 test subjects show a higher heart frequency at 70 revolutions/min, 2 at 90 revolutions /min.

Table 7. Classification of the test subjects of the group A, B and C according to watt load (W) and heart frequency (HF) in the field of the aerobic-anaerobic threshold by a comparison of the results at 70 and at 90 revolutions/min.
range of tolerance (△): 10 watt, or 5 beats/min.

	W90 > W70	W70 > W90	W70 ≈ W90	HF90 > HF70	HF70 > HF90	HF70 ≈ HF90
Group A	1	2	-	1	-	2
Group B	1	2	3	-	1	5
Group C	-	7	2	1	2	6
Total n=18	2	11	5	2	3	13
	△ Watt ≥ 10	△ Watt ≥ 10	△ Watt < 10	△ HF ≥ 5	△ HF ≥ 5	△ HF < 5

Discussion

12 test subjects achieved higher lactate data at 90 revolutions/min (3 of group A, 1 of group B, 8 of group C). That corresponds with the observations of the other authors (Israel, 1967, 1976, Schürch, 1976). A higher number of revolutions means a higher physical load.

One of the 5 test subjects who showed a higher maximum lactate at 70 revolutions/min belonged to group A, 4 belonged to group B. One of the remaining test subjects, whose maximum lactate data differed by less than 1 mmol/l, belonged to group B and one belonged to group C. The consequence of both examinations is a small difference of 0.4 mmol/l, which is not significant (Table 8).

Table 8. The reaction of the maximum lactate level and the maximum heart frequency of 19 test subjects and of all test subjects of group C (n=10) analogous with table 2.

	max. lactate		max. HF
70 U/min	12,0	12,0	188,8
$s^{\pm}$	3,0	3,0	7,6
90 U/min	12,4	13,4	189,1
$s^{\pm}$	2,2	2,4	6,2
$\bar{d}$	0,4	1,4	0,3
n	19	10	10
Significance	NS	++	NS

The difference amounts to 1.4 mmol/l and is highly significant if we consider only those test subjects who produced the same performance in both load examinations.

In both load examinations the average maximum heart frequencies of group C are not significantly different from each other.

Our results show that the number of revolutions is an important factor in bicycle-ergometry that leads to a wrong interpretation if it is not taken into consideration. In the calculation of the aerobic-anaerobic threshold this leads to a significantly lower watt load-an average of 18.5 watts-if one has a higher number of revolutions. It is recommendable to use the heart frequency for the dosage of the training because the average difference only amounted to 2.4 beats/min in the calculation of the heart frequencies in the threshold-reach and it was not significant.

By means of our test results we can not really judge if a higher maximum performance can be achieved at a higher number of revolutions; 50% of our test subjects achieved the same maximum watt load during the same duration of load in both tests (group C). Just 4 test subjects achieved a better performance at 90 revolutions/min (group A) and 6 test subjects did better at 70 revolutions (group B).

Most times the aerobic-anaerobic threshold is being determined to give a better judgment of the development of the fitness of competitive athletes. We recommend a standardization of the number of revolutions in bicycle-ergometry, so that an individual comparison and a group comparison can be made possible. In opposition to the suggestions of the ICSPE 1981 (Smodlaka, Mellerowicz, Horak), we recommend to keep the number of revolutions constant during the examination because the heart frequency can be higher in the range of the AAT than in the range of the maximum capacity (as it is defined by Smodlaka, Mellerowicz, Horak: heart frequency $\geq$ 2s of HF max.).

Pulsfrequenz und Blutlaktatspiegel bei Fahrradergometrie mit 70 und 90 U/min.

Wir beobachteten männliche Studenten im Alter von 22 bis 26 Jahren ($\bar{x}$ = 23,75) während Fahrradergometerbelastungen (Vita-maxima-Tests) 70 und 90 U/min. Die Belastungsintensität wurde stufenweise um 50 W jede dritte Minute gesteigert. Die Pulsfrequenzen bei unterschiedlichen Umdrehungen zeigten während der 50- und 200-Watt-Belastung keine signifikanten Unterschiede. Im submaximalen Bereich waren die Pulsfrequenzen bei 90 U/min signifikant höher als bei 70 U/min. Im maximalen Bereich waren die Pulsfrequenzen fast identisch. Die Laktatkonzentrationen waren signifikant höher bei 90 U/min als bei 70 U/min, mit Ausnahme der 50 W-Stufe. Die gleiche Tendenz konnte während der Erholungsperiode beobachtet werden. Die Watt-Leistung an der aerob-anaeroben Schwelle lag bei 70 signifikant höher als bei 90 U/min. Die Pulsfrequenzen zeigten keine signifikanten Differenzen im Bereich der aerob-anaeroben Schwelle. Da die Umdrehungszahl einen gewissen Einfluß auf Pulsfrequenz und Laktatspiegel hat, sollte die Umdrehungszahl beim Vergleich von Fahrradergometerdaten berücksichtigt werden.

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B.3. Central Hemodynamics And Pedal Rate In Ergometry

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B.3.1. Introduction

Experimental studies on pedal rate have been performed since ergometry was introduced into physiological and clinical investigation. We reported results on pedal rate and perceived exertion at the last but one World Congress on Sports Medicine in Melbourne 1974 (3). Since then, a number of papers have contributed to the problem of pedal rate in ergometry. However, no data are yet available on central hemodynamics and intracardiac pressures during bicycle exercise at varying pedal rates.

It is well-established that varying the pedal rate at identical power output influences physiological variables such as heart rate (2,4,5), ventilation (1,2), and oxygen uptake. Similarly, cardiac output should be influenced by pedal rate also.

The purpose of the present study was to analyze the influence of pedal speed in bicycle ergometry on central hemodynamics and pressures in the left and right heart, and to investigate eventually if there is a different stress response with regard to pedal speed in normals and patients suffering from cardiac disease.