REPORT

AN INVESTIGATION OF EXERCISE INTENSITY OF REPETITION TRAINING FOR JUNIOR ELITE SWIMMERS BY BLOOD LACTATE ANALYSIS

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In this paper we reported an investigation of exercise intensity and validity of method for athletes' training in case of some interval training based on an empirical for junior elite swimmers from point of blood lactate.

The subjects were ten junior swimmers designated to train by a local federation in Nigata. Six swimmers specialized in a short distance swimming and four swimmers specialized in 400 m individual medley.

All subjects were measured for their blood lactate and heart rate immediately after swimming, velocity and the necessary time of swimming.

The results of this experiment led us to conclude

1) In the case of this examination of repetition training of 100 m free style, it is thought that a buffering of blood lactate can not compensate for a producing of that, and because of oxygen debt for respiratory muscle, anaerobic metabolism may be participated.

2) In case of 400 m individral medley, it is thought that 400 m individual medley have been demanded aerobic work capacity in comparison with 100 m crawl stroke.

1. Introduction

Various studies[9 10 11] about the transition from aerobic to anaerobic metabolisum in a organ in represented of AT(anaerobic threshold), VT(ventilation threshold), LT(lactate threshold), OBLA(on set of blood lactate accumulation) were applied to various situations, for example, exercise therapy, rehabilitation of heart disease or diabetes or exercised training for an athlete.

Recently based on above-mentioned studies, some exercise training for athletes especially swimming or speed skate have been carried out using blood lactate as an estimate of aerobic and anaerobic work capacity, fatigue, or a standerd intensity of a training. Ogasawara et al. (1990)[2] investigated the validity of a step-test for an elite swimmer by analysis of blood lactate and described how blood lactate correlated closely with heart rate, and the validity of a step-test by estimating aerobic capacity. Wakayoshi et al (1990)[8] investigated the validity and a method to decide a critical speed of a swimmer and described how a critical speed had come into use as an estimate for aerobic capacity of swimmer.

But for examples training activities of swimming, an effective exercised intensity or its systematic method for training, had been mostly analized based on an empirical knowledge which a conductor had, especially at a local revel, because of no materal for blood lactate.

In this paper we investigate the validity of exercise intensity and its method by blood lactate analysis for two repetition training for junior elite swimmers based on an empirical knowledge, and of blood

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lactate as a measurment of exercise intensity, and the importance of easy measurment at a local revel, for example measuring heart rate[3] from an artery by palpation (examination by touch).

2. Methods

The subjects were ten junior elite swimmers designated to train by a local federation in Niigata. Six swimmers specialized in a short distance swimming (100 m crawl stroke), and four swimmers specialized in long distance swimming (400 m individual medley-as a comparative subjects for 100 m crawl stroke). First of all, all subjects were instructed completely about the purpose and importance of this experiment. In addition, they were told about the method and the danger of taking blood samples and measurement of blood lactate.

An experiment were carryed out in the middle of a special training week at a short length (25 m) swimmimg pool.

Shout-distance swimmers were instructed to swim 5 times 100 m crawl stroke. But they were given a time-limit of 6 minutes per 100 meters (1 time).

Then a rest time was deducted with 6 minutes of swimmiming. All subjects repeated this "6 minute" 5 times.

Long-distance swimmers were instructed that they had to swim an individual 400 m medley 5 time. And like shout-distance swimmers, they were given a time-limit of 6 minutes per 1 time.

The above-mentioned instruction was based on the actual training of swimmers.

In addition, all subjects were instructed that they had to make an effort of increment of a velocity of swimming step by step per 1 time.

Heart rate of all subjects were measured from an artery by palpation (examination by touch) as soon as they finished a swimming per 1 time.

Swimming time was measured with a stop-watch, and a velocity of swimming and the necessary time in each subject was calculated.

Blood samples were taken from the tip of the figer of all subjects as soon as they finished swimming per 1 time by a medical doctor. Blood lactate was measured by inserted blood samples (25 ul) using a syringepet into the automatic lactate analyzer(YSI). The calibration of the lactate analyzer was carryed out per blood sampling using two calibrated liquids already-known its density (44.5 mg/dl = 5.0 mmol/l and 133.5 mg/dl = 15.0 mmol/l). Blood samples were taken by Koutarou TACHIKAWA; measurment and calibration was done by Akira SHIONOYA.

From points of the above-mentioned three parameters "heart rate", "velocity of swimming", and "blood lactate", we investigated the exercised intensity for the above-mentioned training of swimming and the importance of easy measurment for example "heart rate" measured from an artery by palpation (examination by touch).

3. Results

Table-1 shows an averaged swimming velocity of each subjects for each 5 times of 100 m crowl stroke swimming (units are "m/sec", value in ( ) is %velocity in case of 1 st time of velocity is 100%).

Table-2 shows the heart rate of each subjects immediately after swimming each 100 m free 5 times (units are beats/10 sec, value in ( ) is calculated to beats/min).

Table-3 shows a blood lactate of each subjects immediately after swimming 100 m crowl stroke 5 times (units is mmo/l). Before swimming (but after warming up) the highest numerical value of blood lactate was that of subject "D", 2.49 mmol/l. The lowest numerical value of blood lactate was that of subject"E", 1.56 mmol/l, and average of that was 2.56 mmol/l (SD = 0.35).

Immediately after the 1 st timed swimming, an average of blood lactate was 5.97 mmol/l (SD = 0.14) 2 ed time, that was 8.77 mmol/l (SD = 0.89), the 3 rd time, was 9.20 mmol/l (SD = 1.31), the 4 th time, was 10.98 mmol/l (SD = 1.13), and the 5 th time, was 11.94 (SD = 0.90).

Table-4 shows the velocity of swimming of each subjects for each item of individual 400 m medley and total times for each 5 times (units is m/sec).

Table-5 shows a heart rate of each subjects immediately after each 5 times of swimming (units is beats/10 sec, but value in ( ) is culculated to beats/min).

Table-6 shows the blood lactate of each subject immediately after 5 times of 400 m individual medley (units is mmol/l). Before swimming(but after warming up), the highest numerical value of blood lactate was that of subject"G", 2.01 mmol/l, and the lowest numercal value of blood lactate was that of subjects"J", 1.25 mmol/l. And an averaga ofblood lactate was 1.50 mmol/l(SD=0.31).

Immediately after the 1 st time of swimming, the average of blood lactate was 3.18 mmol/l(SD=1.58), the 2 nd time, was 3.35 mmol/l(SD=1.58) the 3 rd time, was 4.15 mmol/l(SD=1.60), the 4 rh time, was 5.57 mmol/l(SD=1.47), and 5 th time, was 7.22 mmol/l(SD=0.41).

TABLE-1:Velocity of swimming of each subjects in each 5 time of short-distance swimming(units is "m/sec"and value in ( )%velocity in case velocity of swimming in 1st time is 100%.

SUB	Velocity1st	Velocity2nd	Velocity3rd	Velocity4th	velocity5th
A	1.35(100)	1.32(97.7)	1.34(99.2)	1.36(100.7)	1.37(101.4)
B	1.38(100)	1.35(97.8)	1.35(97.8)	1.33(96.3)	1.35(97.8)
C	1.40(100)	1.40(100)	1.42(101.4)	1.45(103.6)	1.45(103.6)
D	1.58(100)	1.61(101.9)	1.62(102.5)	1.63(106.7)	1.64(103.8)
E	1.68(100)	1.72(102.4)	1.72(102.4)	1.70(101.2)	1.65(98.2)
F	1.31(100)	1.29(98.5)	1.29(98.5)	1.29(98.5)	1.29(98.5)
%AVE	100	99.72	100.30	101.17	100.55
SD	—	1.89	1.88	3.36	2.51

TABLE-2 : Heart rate of each subjects immediately after swimming in each5 times of shout-distance swimming(units is "beats/10sec" but( )is "beat/min" calculated from "beats/min").

SUB	HR1	HR2	HR3	HR4	HR5
A	30(180)	27(162)	30(180)	29(174)	30(180)
B	26(156)	25(150)	29(174)	29(174)	30(180)
C	26(156)	27(162)	30(180)	28(168)	28(168)
D	29(174)	29(174)	32(192)	32(192)	33(198)
E	30(180)	32(192)	35(210)	34(204)	39(234)
F	32(192)	32(192)	33(198)	34(204)	35(210)
AVE	28.83	28.67	31.50	31.00	32.50
SD	2.19	2.62	2.06	2.44	3.69

TABLE-3 : Blood Lactate of each subjects before swimming and immediatelyafter in each time of shnort-distance swimming(units is "mmol/l, ----- shows"not estimate"as solidification of blood samplimg).

SUB	LA	LA1	LA2	LA3	LA4	LA5
A	2.13	5.92	9.07	6.40	9.29	10.37
B	1.65	5.93	7.76	9.87	10.62	12.76
C	2.49	6.20	7.76	9.57	11.12	11.80
D	1.70	5.82	8.38	9.40	11.23	12.88
E	1.56	—	10.21	9.43	10.52	—
F	—	—	9.43	10.53	13.07	11.88
AVE	2.56	5.97	8.77	9.20	10.98	11.94
S.D	.35	.14	.89	0.31	1.13	.90

TABLE-4 : %velocity of swimming of each subjects in each items and %tot-al time of 400m individual medley in each 5 times(units is % in case velocity and total time in 1st time is 100%. And in items "BC" shows back stroke, "BR" shows brest, "BT" shows butterfly, "CS" shows crowl stroke.

SUB	SET	%VELO-	%VELO-	%VELO-	%VELO-	%TOTAL TIME
G	1	100	100	100	100	100
	2	106.1	108.2	107.1	104.9	93.8
	3	102.1	102.9	100.7	102.1	98.5
	4	102.7	104.4	103.6	102.8	96.5
	5	104.1	106.6	103.6	104.2	95.7
H	1	100	100	100	100	100
	2	100	100.8	100	105.9	97.8
	3	100.7	103.2	101.7	104.4	97.3
	4	102.1	104.0	102.6	107.4	96.3
	5	100.7	102.4	104.3	102.1	95.8
I	1	100	100	100	100	100
	2	100	98.3	100.9	100.8	100.2
	3	100.8	100	100.9	100.8	100.2
	4	100	95.8	99.0	98.4	101.5
	5	99.2	99.2	101.9	100	99.9
J	1	100	100	100	100	100
	2	102.6	100.7	102.7	102.8	97.7
	3	105.3	104.1	101.4	106.9	97.9
	4	107.3	106.1	106.8	109.0	93.5
	5	109.9	106.8	105.5	109.7	92.6

TABLE-5 : Heart rate of each subjects immediately after in each 5 times of 400m inkividual medly(units is "beats/10sec" but value in ( )is " beats/min" calculated from "beats/10sec").

SUB	HR1	HR2	HR3	HR4	HR5
G	28(168)	30(180)	31(186)	32(192)	36(216)
H	25(150)	27(162)	30(180)	31(186)	32(192)
I	31(186)	29(174)	31(186)	31(186)	30(180)
J	29(174)	30(180)	32(192)	38(228)	40(240)
AVE	28.25	29.00	31.00	33.00	34.50
SD	2.17	1.22	0.71	2.92	3.84

TABLE-6:Blood Lactate of each subjects before and immediatly after in each 5 times of 400m inidividual medley(units is "mmol/l").

SUB	LA	LA1	LA2	LA3	LA4	LA5
G	2.01	2.73	2.66	3.33	6.31	7.17
H	1.49	3.58	3.63	4.17	—	7.27
I	1.26	5.39	5.79	6.70	7.48	7.22
J	1.25	1.00	1.31	2.39	3.91	—
AVE.	1.50	3.18	3.35	4.15	5.57	7.22
S.D	.31	1.58	1.68	1.60	1.47	—

4. Discussion

1) In the case of 100 m free style swimming

Fig-1 shows the average of blood lactate (○), heart rate (△), and % velocity of swimming (◇) of all subjects and these relationships for each 5 th time of 100 m crowl stroke swimming. Statistically these relationship show no significance, but in case of relationships in connection with blood lactate was $r=0.867$ (between blood lactate and heart rate) was $r=0.847$ (between blood lactate and % velocity), both of them are large in scale of the numerical value. Then because these relationships are based on the averaged value of all subjects for each 5 times, and as a number of subjects for which relationship had been derived a number of data was 5 (averaged value of 5 th times of swimming) and very few sampling, therefore it is thought that these relationships show no significance statistically. But above-mentioned, from points of scale of the numberical value of correlation coefficient was beyond 0.8 and large scale. Therefore it was thouget that an easy measurment of heart rate(by palpation) and swimming velocity was shown by blood lactate.

Fig-2 shows the relationship between blood lactate and % velocity of swimming in plotting all samplings. A correlation coefficient was $r=0.18$ and this relationship show no significance. And fig-3 shows the relationship between blood lactate and heart rate immediately after swimming in plotting all sampling. In this case, the correlation coefficient was $r=0.543$ and this relationship show very highly significance ($p<0.01$) statistically.

As aboved-mentioned in this experiment, all of the subjects had been instructed to make a effort of increment of a velocity of swimmimg step by step per 1 time (time by time). But in seeing table-1, this instruction was not necessarily performed. In three cases out of six subjects, veloicty of swimming inclines to be down in comparision between 1 st time and 5 th time.

Added to be above-mentioned, Wakayoshi et al. (1990)[8] described that a critical speed have come into use as an estimation for aerobic capacity of a swimmer. A critical speed have been defined the maximum in a speed meeted a qualitification which an organ could continue to exercise indefintely.

Moritani et al. (1981) pointed out that a critical speed correlated closely with an AT (anaerobic threshold). As is generally know, it has been thought that a mechanisum of AT, to some degree, has been related to a mechanisum of a producing and buffering a lactate, and an increse in H^+ originated in a lactate has brought about a decline of c-onstractial force of respiratory muscle.

Moreover AT has been defined the maximum work intensity in an intensity meeted a qualitification which an organ could continue to exercise without continuous increment of blood lactate; and, Yamamoto et al. (1989)[7] had called this threshold was Maximal Lactate Steady State or Maxless Lactate.

Mader et al. (1976)[1] pointed out maxless lactate was 4 mmpl/l empiriaclly, and from this numeriacl value of lactate (4 mmol/l), a participation of an anaerobic metabolisum on exercise could be explained. And Sjodin and Yacobs[4] defined that an exercised intensity proportionated to 4 mmol/l blood lactate was OBLA (on set of blood lactate accumulation). Yamamoto et al. (1989)[7] pointed out that a standerd point of 4 mmol/l blood lactate was based on an empirical knowledge and was based on a ground of physiology.

Stegmann and Kindermann (1982)[5] reported that on running of velocity proportionated to OBLA, in almost all subjects, maximum lactate steady state had not been observed, and almost all subjects came to all out at nearly 20 minutes from start of exercise. But in the case of training for athlete, OBLA had been utilized frequently and validly as an estimation of an aerobic capacity.

In this study, in the case of 100 m crowl stroke swimming. all subjects were already beyond 4 mmol/l blood lactate immediately after 1 st time of swimming and per 1 time to 5 th timr of swimming, blood lactate was continuously incrementing and at the last blood lactate came to 11.94 mmol/l (averaged), it is thought that this numerical value of 11. 94 mmol/l suggests nearly all out of subjects. Before in this type of repetition training for swimming, it was thought that a buffering of blood lactate could not compensate for a producing of blood lactate, and because of oxygen debt for rspiratory muscle, an anaerobic metabolisum may be participated. And it is thought that this repetition is valid to improve an anerobic capacity, and that it is adequate for training of 100 m free style swimming thought to be important in anaerobic especially anaerobic glycolysis metabolisum.

And in this training, the velocity of swimming and heart rates presented per 1 time as an information of organ, and averaged velocity per 1 time did not increase regulary from 1 st to 5 th time although instructed a continuous increment of velocity of swimming. But blood lactate increased regularly step by step per 1 time, and the relationship between blood lactate and % velocity was not significant statisically. But the relationship between heart rate and lactate was significant. Before, in training, it was thought that to get these information especially heart rate from organ was valid to see the state of a swimmer.

2) In the case of 400 m individual medley as a comparative subjects of 100 m crowl stroke—

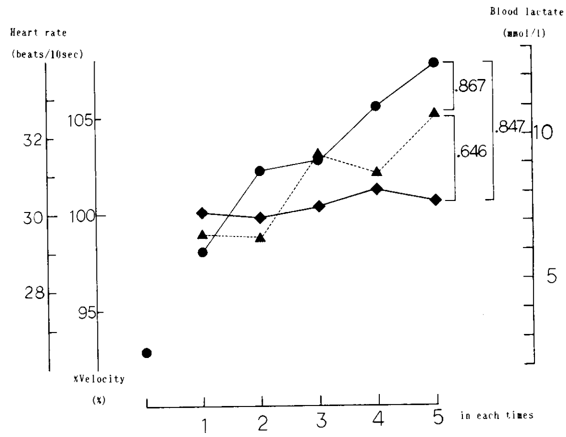

FIG-1 :Average of blood lactate (●), hearts rate (▲), and % velocity (◆) of all subjects and these relationships in each 5 th time of 100 m crawl stroke swimming.

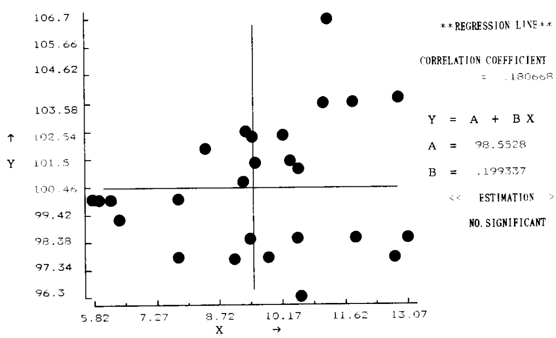

FIG-2 :Relationship between blood lactate (x-axis:units is mmol/l) and %velocity (y-axis:units %) of swimming in plottig of all samplings.

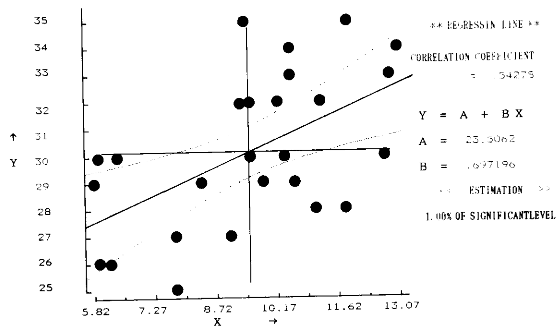

FIG-3 :Relationship between blood lactate (x-axis:units is mmol/l) and heart rate (y-axis:units is beats/10 sec) immediatly after 100 m crawl stroke swimming in plotting of all samplings.

Fig-4 shows an average of blood lactate (○), heart rate (△), and the necessary time of swimming (◇), and these relationship for each 5 th time of 400 m individual medley swimming.

The relationship between blood lactate and heart rate had the high significance statistically ($p < 0.01$) and the correlation coefficient was $r = 0.976$. And the correlation coefficient between heart tate and the necessary time was $r = 0.837$, between blook lactate and the necessary time was $r = 0.737$.

Fig-5 shows the relationship between blood lactate and the necessary time in the case of plotting of all data of the subjects. This correlation coefficeint was $r = 0.186$, and the relationship was not significant staistically.

Fig-6 shows relationship between blood lactate and heart rate. This correlation coeffidient was $r = 0.302$ and this relationship was not significant.

In Table-4 and 6, the blood lactate of subject "J" who made the best record in this experiment, was below 4 mmol/l until the 4 th time swimming, therefore it is thought that an aerobic metabolisum takes the initiative in a point of 4 th time of swimming (But in 5 th time of swimming as solidification of sampling blood, blood lactate was not estimated).

From this point, it was thought that subject "J" was superior to the other subject in aerobic work capacity or buffering capacity of blood lactate. Thinking about time table of 400 m individual medley in this experiment, becuase interval of 6 minutes was very short for 400 m individual medley. And it is thought that a metabolisum mobilized for this type of exercise is anaerobic (anaerocic glycolysis process) process. Therefore in case of subject "J" the latter was applied. And fig-7 shows a relationship between blood lactate and heart rate except for the data related to subjest "J". The correlation coefficient was $r = 0.589$, and this relationship was highly significant staistically.

It is thought that 400 m individual medley have been demanded an aerobic capacity in comparison with 100 m free style, because blood lactate in case of 400 m individual medley was lower than that in case of 100 m free style. And above-mentioned for subject "J", the buffering of blood lactate is above the producing of blood lactate so that blood lactate was not beyond 4 mmol/l until 4 th time of swimming. But in subject "I", the blood lactate was already over 4 mmol/l by the 2 nd time of swimming. Accordingly after the 2 nd time to the 5 th time of swimming,the necessary time of swimming has not made progress. Therefore in the case of subject "I, like this repetition training it is thought that a exercised intensity is too strong or the interval time for rest(time for buffering of blood lactate) is too short. And at result it is thoght that anaerobic metabolisum had been mobilizated and drain of glycolysis has been caused.

Moreover in the case of 400 m individual medley too, like 100 m free style, it is thought that an easy measurment of heart rate and velocity is a valid to estimate of the state or fatigue of a swimmer. But it is difficult for those who are conspicuous of capacity in comparision with the other swimmers, like subject "J" to estimate by heart rate or velocity of swimming. For example, the heart rate of subjects "J" were higher than those of the other subject for each times, but as mentioned above, the blood lactate of subject "J" was lower than that of the other subjects. Before there was a case that heart rate does not indicate the state of a swimmer or fatigre. These points, as Yamamoto et al.[7] pointed out, indcated that a numberical value of 4 mmol/l is based on an empirical knowledge, and in utilizing of

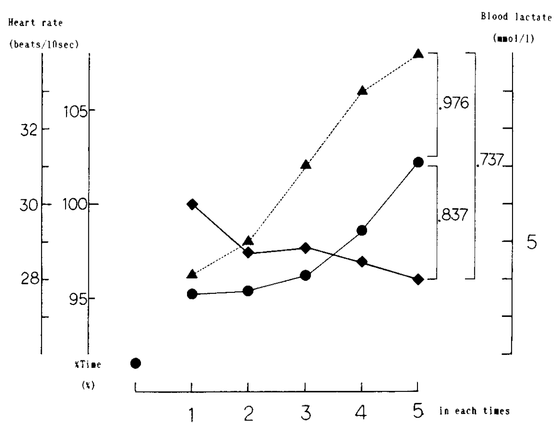

FIG-4 :Average of blood lactate (●), heart rate (▲), and % velocity (◆) of all subjects and these relationships in each 5 th time of 400 m individual medley.

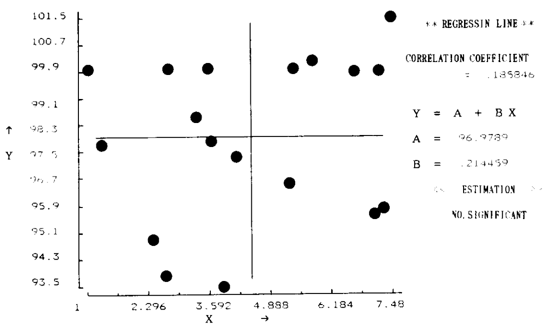

FIG-5 :Relationship between blood lactate (x-axis:units is mmol/l) and %time of swimming (y-axis:units is%) in plotting of all samplings in 400 m individual medley.

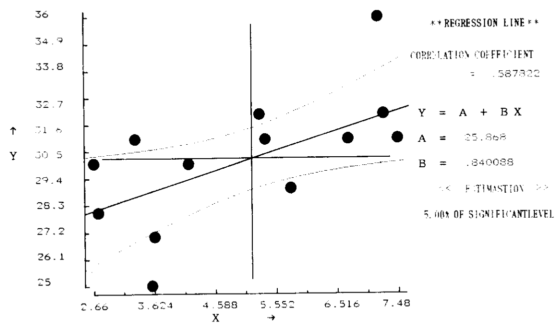

FIG-7 :Relationship between blood lactate (x-axis:units is mmol/l) and heart rate (y-axis:units is beats/10 sec) immediatly after 400 m individ-ual medley except the datas related with subjects "J" recorded the best time in this experiment.

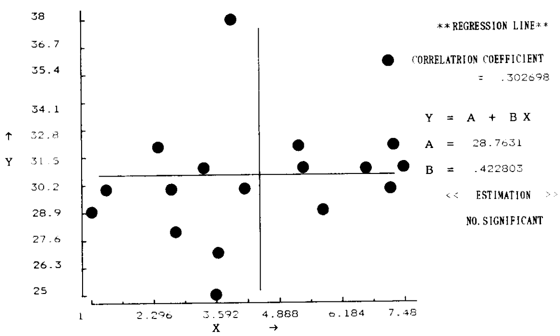

FIG-6 :Relationship between blood lactate (x-axis:units is mmol/l) and heart rate(y-axis:units is beats/10 sec) immediatly after 400 m individual medley in plotting of all samplings.

blood lactate or data related to blood lactate as an estimate in a activity engaged training are a subject (theme) for a future study.

5. References

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