The Effects of Physical Training on Electrocardiographic Response Provoked by Apneic Facial Immersion.

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Abstract

The effects of physical training on electrocardiographic response provoked by apneic facial immersion in 15℃ water were examined cross-sectionally and longitudinally. Several male athletes and non-athletes participated in this study.

It is suggested that firstly, physical training focused on endurance exercise accelerates the bradycardiac response by apneic facial immersion, and secondly, the bradycardiac response by apneic facial immersion as well as the resting heart rate is available as the assessment of the physical training effects on the autonomic nervous system. Lastly, the judgement criterion of the diving reflex test for athletes needs to be established since the notably increased R-R interval of 4.47 seconds during apneic facial immersion was observed in one athlete.

Key words : physical training, apneic facial immersion, bradycardiac response, diving reflex test

I .Introduction

The diving reflex test is necessary for medical check-up for swimming [1]. We confirmed that the correspondence of electrocardiographic change during apneic facial immersion (AFI) with that during the various types of swimming was good [1]. In addition, we reported that bradycardiac response including arrythmias during AFI was reproducible to some extent [2], and had no gender difference but was modified by aging [3]. However, the effects of physical training on electrocardiographic response during AFI was not elucidated sufficiently. Furthermore, the effects were not examined longitudinally.

The purpose of the present study is to examine the effects of physical training on electrocardiographic response during AFI cross-sectionally and longitudinally, and to acquire basic information in relation to the judgement criterion of the diving reflex test.

Ⅱ.Methods

There were two groups in the subjects. The first group (T1 group) had 5 male athletes (36.0± 4.0 y.o.,mean±SD). All were triathletes. Their training programs contained running, cycling, weight training and the others, which were performed 6～7 times per week and total exercise time in a day amounted to 2～3 hours. One athlete of T1 group was examined longitudinally. The control group had 7 males (38.0±3.0 y.o.), who did not routinely participate in regular execises.

The second group had 4 high school male long-distance cyclists (15～16 y.o.) who were examined twice in an interval of 12～15 months. During this interval, they carried out the training programs every day including high power training using a bicycle ergometer, cross country cycling, weight training and circuit training, in which the exercise time amounted to 3 hours in a day.

The subjects immersed their faces in 15℃ water without breathing sitting on a chair as long as possible after the 5 minutes sitting rest. Two trials were done, one breath holding style in the immersion was at the inhalatory stage and the other was at the exhalatory stage.

Electrocardiogram (ECG, bipolar chest lead) was recorded during rest (1 minute), load, and recovery (1 minute). This experiment was done before and after the training session, and simultaneously, the isometric leg extensor strength, the maximal oxygen intake (using a bicycle ergometer), and the maximal anaerobic power output (using a bicycle ergometer) were measured.

Resting heart rate (HRrest) which was calculated from the mean value of 10 consecutive R-R intervals during rest, the minimal heart rate (HRmin) which was calculated from the most prolonged R-R interval during AFI, and its relative value to the Hrrest (%HRmin) were evaluated in the present study.

Statisical analysis

A comparison of the mean values was made by using an unpaired t-test, and the significant level was set at $p<0.05$.

Ⅲ.Results

1.T1 group

The mean value of T1 group HRrests was not significantly different from that of the control group Hrrests. However, the means of T1 group HRmins and %HRmins at inhalatory stage and those of T1 group HRmins at exhalatory stage were significantly lower than those of the control group, and the mean value of T1 group %HRmins at exhalatory stage tended to be lower than that of the control group (**Table 1**).

One athlete of T1 group (38 y.o.) was induced second degree atrioventricular (2° AV) block Mobitz II type with 4.47 seconds of R-R interval (HRmin : 13.4 bpm) in his ECG record during AFI (**Fig. 1**).

In addition, his ECG records at 43 y.o. and 45 y.o. were revealed in **Table 2** and **Fig. 2**. He ran about 8km 5~6 times per week at 43 y.o. which was the same as at 38 y.o. He ran about 10km 5~6 times, cycled about 10km 3 times, and did weight training for ten minutes per week at 45 y.o., which was more than at 38 or 43 y.o.

There was no significant difference among 3 Hrrests. However, HRmin and %HRmin at inhalatory stage tended to decrease further. HRmin and %HRmin at exhalatory stage tended to increase a little but remained very low like the values at 38 y.o. Besides these matters, he showed atrial fibrillation even in his resting ECG at 43 and 45 y.o.

Table 1. HRrest, HRmin, and %HRmin in control and T1 group.

	Control (n=7)	T1 (n=5)
HRrest(bpm)	69.5±9.9	65.9±14.5
<Inhalatory stage>		
HRmin(bpm)	51.4±8.2	35.9±5.3 **
%HRmin(%)	74.7±13.7	55.9±12.4 *
<Exhalatory stage>		
HRmin(bpm)	49.8±10.5	33.3±12.1 *
%HRmin(%)	72.0±14.5	51.3±12.9

*:p<0.05,**:p<0.01

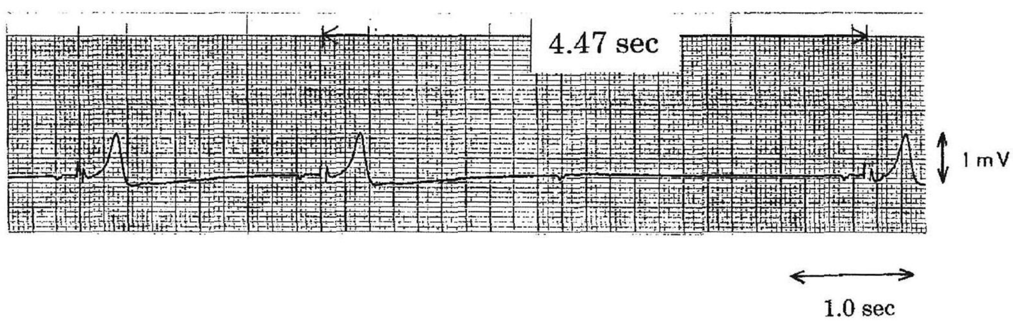

Fig. 1. An electrocardiographic sample of one athlete showing the R-R interval of 4.47 seconds during apneic facial immersion.

Table 2. Change of HRrest, HRmin, and %HRmin over seven years in one athlete.

		<Inhalatory stage>		<Exhalatory stage>	
Age(y.o.)	HRrest(bpm)	HRmin(bpm)	%HRmin(%)	HRmin(bpm)	%HRmin(%)
38	59.6	27.5	46.1	13.4	22.5
43	56.0	24.9	41.3	13.7	24.4
45	55.6	18.8	33.8	14.0	25.1

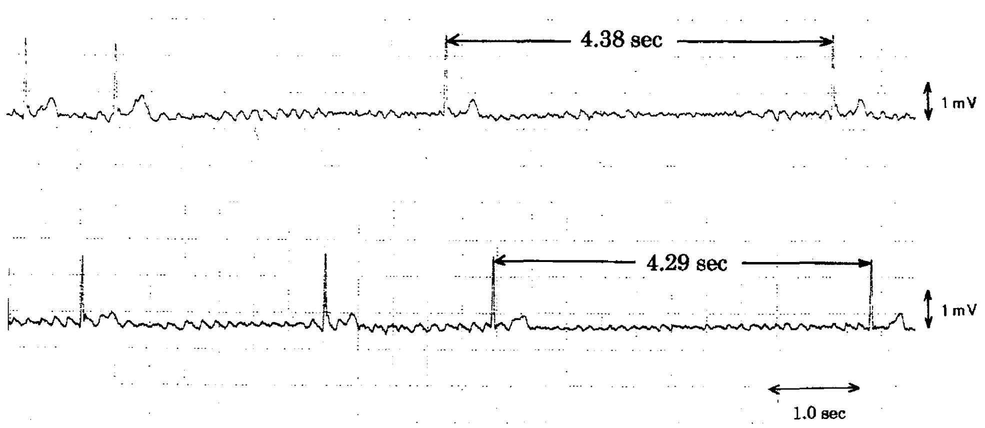

Fig. 2. Electrocardiographic samples at 43 y.o. (upper) and 45 y.o. (lower) of one athlete during apneic facial immersion.

2.T2 group

Each extensor muscle strength of 4 subjects improved from the mean value of 66.3 kg in the first AFI experiment to that of 76.6 kg in the second AFI experiment. Likewise, maximal oxygen intake improved from 62.5ml/kg/min to 69.0 ml/kg/min and maximal anaerobic power output improved from 924.1 watt to 1070.1 watt.

HRrest decreased in 3 subjects as the result of strenuous training. HRmin at both breath holding stages decreased in all subjects. %HRmin at inhalatory stage decreased in 3 subjects but increased in one subject while %HRmin at exhalatory stage decreased in all subjects (**Table 3**).

Table 3. HRrest, HRmin, and %HRmin of each subject in T2 group during apneic facial immersion.

Subject			1st	2nd
OND		HRrest(bpm)	79.6	88.1
	<Inhalatory stage>			
		HRmin(bpm)	47.2	38.8
		%HRmin(%)	59.3	44.0
	<Exhalatory stage>			
		HRmin(bpm)	36.6	35.5
		%HRmin(%)	46.0	40.3
SHI		HRrest(bpm)	74.4	72.0
	<Inhalatory stage>			
		HRmin(bpm)	50.9	46.4
		%HRmin(%)	68.4	64.4
	<Exhalatory stage>			
		HRmin(bpm)	55.7	47.1
		%HRmin(%)	74.9	65.4
YOK		HRrest(bpm)	84.4	75.3
	<Inhalatory stage>			
		HRmin(bpm)	64.8	60.5
		%HRmin(%)	76.8	80.4
	<Exhalatory stage>			
		HRmin(bpm)	54.8	36.7
		%HRmin(%)	64.9	48.7
MIN		HRrest(bpm)	71.0	63.0
	<Inhalatory stage>			
		HRmin(bpm)	47.3	34.9
		%HRmin(%)	66.6	55.4
	<Exhalatory stage>			
		HRmin(bpm)	45.8	34.9
		%HRmin(%)	64.5	55.4

IV. Discussion

There was no significant correlationship between the bradycardiac response induced by AFI and maximal oxygen intake, which indicated no correlationship of the bradycardiac response by AFI with physical fitness [4,5]. On the other hand, Bove et al [6] reported that the bradycardiac response by AFI was reinforced by physical training. Hong et al [5] showed that the bradycardiac response of the divers whose diving career was 6.5 years within a given AFI time was greater that of divers who had no diving career. In addition, Bonneau et al [7] showed that the longer the diving career was, the more distinguished the bradycardiac response was. The present study also supported that endurance training enhanced the bradycardiac response by AFI. The enhancement of the bradycardiac response by AFI was accompanied by the improvement of muscle strength, endurance and anaerobic muscle power output by physical training. From these results, it is suggested that the vagal activity by AFI will be accelerated by the physical trainig. However, it is commonly reported that the vagal activity is related to the diving reflex [8~10] in opposition to the fact that the mechanism of the diving reflex is not fully made clear yet.

It is generally believed that the combined effects including the depression of sympathetic nerve activity, the acceleration of vagus nerve activity, the increased stroke volume caused by the enlargement of heart volume, and the decreased intrinsic heart rate following the endurance training, induce the bradycardia at rest [11]. On the contrary, it is reported that endurance training did not produce the resting bradycardia and gave any effects on the cardiac sympathetic and vagal indices by spectral analysis of heart rate variability [12]. In the present study, there was little alteration on the HRrest in each experiment. But it may be suggested that for the certification of the endurance training effects on the autonomic nervous system, not only the observation of the HRrest but also the enforcement of the diving reflex test is necessary since the present study indicates the increased rates of heart rate decrease during AFI following the physical training.

Moreover, further study need be indicated because the bradycardiac response by AFI is possibly different according to the type of sport, training intensity, and training duration.

One athlete showed 2° AV block Mobitz II type which was thought to be malign in the cardiac patients, in which the longest R-R interval was 4.47 seconds.

It is still unknown whether such an arrythmias is induced as the result of endurance training. Therefore, the need for further study is indicated just as the criterion of the diving reflex test for endurance athletes should be considered (The normal range of R-R interval in the normal non-athlete is thought to be within 2.0 seconds). Furthermore, his notably decreased HRmin by AFI at exhalatory stage remained even at 43 and 45 y.o. with the incidence of atrial fibrillation, and his HRmin and %HRmin at inhalatory stage decreased further.

Much literature [5,13~16] had insisted that the bradycardiac response by AFI was attenuated with aging in spite of opposing literature [17]. We reported that HRmin and %HRmin by AFI increased gradually following the peak decrease between 20 and 39 y.o.[3]. Based on this evidence, the possibility is inferred that the notable bradycardia response by AFI in the present subject is maintained or enforced by long-term strenuous training.

However, the present subject at 43 and 45 y.o. was supposed to be abnormal because of the incidence of atrial fibrillation which mechanism induced by the training was still unknown and was seldom, if ever, observed in the athletes [18]. Therefore, the degree how the malign character of atrial fibrillation related to the bradycardia response by AFI should be further elucidated.

V.Conclusion

Based on the results of this study, it is suggested that firstly, physical training focused on endurance exercise accelerates the bradycardiac response by apneic facial immersion and secondly, the bradycardiac response by apneic facial immersion as well as the resting heart rate is available as the assessment of the physical training effects on the autonomic nervous system. Lastly, the judgement criterion of the diving reflex test for the athletes need to be established since the notably increased R-R interval of 4.47 seconds during apneic facial immersion was observed in one athlete.

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