# Time, Month, and Year-related Variations of Electrocardiographic Responses Provoked by Apneic Facial Immersion.

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**Abstract**

This study examined the time, month, and year-related variations of electrocardiographic responses provoked by apneic facial immersion (AFI). First, there were no significant differences among three minimum heart rates (HRmin) obtained at 9:30, 12:00, and 17:30. Neither were there significant differences in the three relative values to resting heart rates (%HRmin). Correlation coefficients among three HRmin's were significant at r=0.845 ～ 0.953, and those among three %HRmin's were also significant at r=0.845～0.930. Furthermore good correspondence was observed in the incidence of arrhythmias by AFI. Second, in regard to month-related variations, although bradycardiac responses by AFI didn't seem to reveal seasonal variations, the incidence of arrhythmias corresponded fairly well. Third, with regard to year-related variations, the attenuated bradycardiac responses were observed in two subjects who were over 34.4 y.o. and over 38.9 y.o. respectively.

From these results, the following three points were suggested: 1) Good electrocardiographic correspondence can be expected from 9:30 to 17:30 except at times immediately after meals ; 2) Month-related reproducibility of the incidence of arrhythmias were fairly well ; 3) It is probable that bradycardiac responses start to attenuate on or after the mid thirties with large differences depending the individual.

**key words : apneic facial immersion, bradycardiac responses, arrhythmias**

## I .Introduction

Apneic facial immersion (AFI) test is believed to be necessary for medical check-up for swimming [1] since the diving bradycardia or diving arrhythmia is probably related to the cause of drowning [2～6].

We indicated the good correspondence between the electrocardiographic changes during AFI, various types of water immersion, and swimming [1]. However, the check method and test criterion is not established yet. Furthermore, time-related and month-related variations of electrocardiographic responses are not sufficiently elucidated yet, and the variation through over ten years have never been examined.

The purpose of this study is to gain the basic information in applying the AFI test to medical check-up for swimming.

## Ⅱ.Subjects and Methods

### 1. Time-related variations

Healthy Japanese subjects of both genders (n=12, 22～38 y.o.) participated in the experiment. Their daily time of sleep was from 23:30 to 6:30. They immersed their face in the 5℃ cold water for 45 seconds sitting on the chair following the 5 minutes sitting rest. Their respiratory stage of immersion was inhalatory one. The experiments time was at 9:30 (about 2 hours after the breakfast), at 12:00 (before lunch), and at 17:30 (before supper) . The room temperature in the experiment was from 24℃ to 26℃.

### 2. Month-related variations

Healthy Japanese subjects of both genders (n=4, 25～35 y.o.) participated in the experiment. Three subjects had exercise habit and one subject had no exercise habit. The method of AFI test was the same as that in time-related experiment. This experiment was carried out once a month throughout 13 months during at 14:00 and 16:00. The average room temperature of 4 subjects was from 23.9℃ to 26.5℃.

### 3. Year-related variations

Healthy Japanese male subjects (n=2) participated in this experiment. The method of AFI test was the same as that in time-related variations experiment, but breath-holding duration was the time as long as they could tolerate except at 36.3 y.o. of subject TOM (breath-holding time was 45 seconds). Subject TOM underwent this experiment 7 times from 26.6 to 37.5 y.o. while subject RYS did this one 6 times from 31.0 to 42.0 y.o. Their interval between the experiments was from several months to several years. Time of these experiments was from 14:00 to 16:00, and the room temperature was from 24℃ to 26℃. Their physical training contents were almost the same for their experiment period (Subject TOM took exercise from 2 to 3 times a week for 30 minutes in a day, and subject RYS did from 5 to 6 times a week for 40 minutes in a day). Besides, subject RYS underwent the experiments of 15℃ and 30℃ water at inhalatory and exhalatory stage as well as that of 5℃ water at exhalatory stage.

The electrocardiogram was recorded during rest, load and recovery (1 minute) in each experiment {Bipolar chest lead $CM_5$, using the electrocardiography Life Scope11/Four or instantaneous heart beat unit AC-611G (made by Nihon Kohden Inc.)}. The arrhythmias were detected, resting heart rate was calculated from the mean value of 10 consecutive R-R intervals, and the minimum heart rates (HRmin) was calculated from the longest R-R interval during load in the electrocradiographic records. Moreover, the relative value of HRmin to the resting heart rate (%HRmin) was also evaluated.

The comparison of mean values was made by paired t-test, and the correlation coefficient was evaluated using Pearson's product moment correlation coefficient. A significant level was set at $p<0.05$ in each case.

## Ⅲ.Results

### 1. Time-related variations

HRmin at 9:30, 12:00, and 17:30 was 43.9±9.7 b/min, 43.2±11.7 b/min, and 44.0±10.7 b/min respectively, and there was no significant difference among 3 values.Furthermore,%HRmin was 61.9±12.0 %, 61.0±15.0 %, and 63.2±13.7 % in the same order (described before) respectively, and also there was no significant difference among 3 values. The correlation coefficient of HRmin at each time was at r=0.851～0.953 ($p<0.01$), and that of %HRmin at each time was at r=0.845～0.930 ($p<0.01$).

The latent period of HRmin in the AFI (HRmin latent time) was 30.9±10.7 sec, 35.3±9.8 sec, and 31.2±12.2 sec in the same order respectively. There was no significant difference among 3 values, and the correlation coefficient at each time was r=0.649～0.699 ($p<0.05$).

The incidental arrhythmias of each subject during and after AFI at each time were revealed in **Table 1** and some electrocardiographic records were shown in **Fig.1**. The arrhythmias were atrioventricular junctional escaped beat (AVJEB), atrioventricular junctional rhythm (AVJR), atrioventricular dissociation (AVD), first degree atrioventricular block (1° AVB), second degree atrioventricular block Wenckebach type {2° AVB(W)}, second degree atrioventricular block MobitzⅡ type {2° AVB(M)}, idioventricular rhythm (IVR),and ventricular premature contraction (VPC). Although there was not complete accordance on the kinds of arrhythmias (× symbol indicates the disaccord), 11 out of 12 subjects showed the accordance in regard to the incidence of arrhythmias during AFI, and 10 subjects did so in regard to the incidence of arrhythmias after AFI. Furthermore, almost all of the arrhythmias were bradycardiac type, but subject MOR revealed the tachycardiac and lethal arrhythmia, VPC RonT type in her bradycardiac arrhythmias during AFI (Fig. 1).

**Table 1.** The incidental arrhythmias at each time.

| | 9:30 | | 12:00 | | 17:30 | |
|---|---|---|---|---|---|---|
| Subject | During AFI | After AFI | During AFI | After AFI | After AFI | After AFI |
| MIT | none | none | none | none | none | none |
| NAK | none | none | none | none | none | none |
| OKA | none | none | none | none | none | none |
| ARI | AVJEB, AVD, AVJR | AVJR | AVD, AVJR, IVR | IVR, AVD, AVJEB | AVJR | AVJR, AVD |
| NIS | AVJR | AVJR | AVJR | AVJR | AVJR | VPC |
| KOM | none | none | none | none | none | none |
| MOR | 2° AVB(W), AVD<br>VPC(RonT) | AVJR | 2° AVB(W), 2° AVB(M)<br>AVD, AVJEB | none × | 2° AVB(W), 2° AVB(M)<br>AVD, AVJR | AVJR |
| MIN | none | none | none | none | none | none |
| KAW | AVJR, AVJEB<br>1° AVB | none | AVJEB | AVJEB × | AVJEB | none |
| AOK | none | none | none | none | none | none |
| HIR | AVD | none | AVJEB, AVD | none | none × | none |
| KAI | none | none | none | none | none | none |

AFI : Apneic facial immersion
AVJEB : Atrioventricular junctional escaped beat
AVJR : Atrioventricular junctional rhythm
AVD : Atrioventricular dissociation
IVR : Idioventricular rhythm
VPC : Ventricular premature contraction
VPC(RonT) : Ventricular premature contraction RonT type
1° AVB : First degree atrioventricular block
2° AVB(W) : Second degree atrioventricular block Wenckebach type
2° AVB(M) : Second degree atrioventricular block Mobitz II type

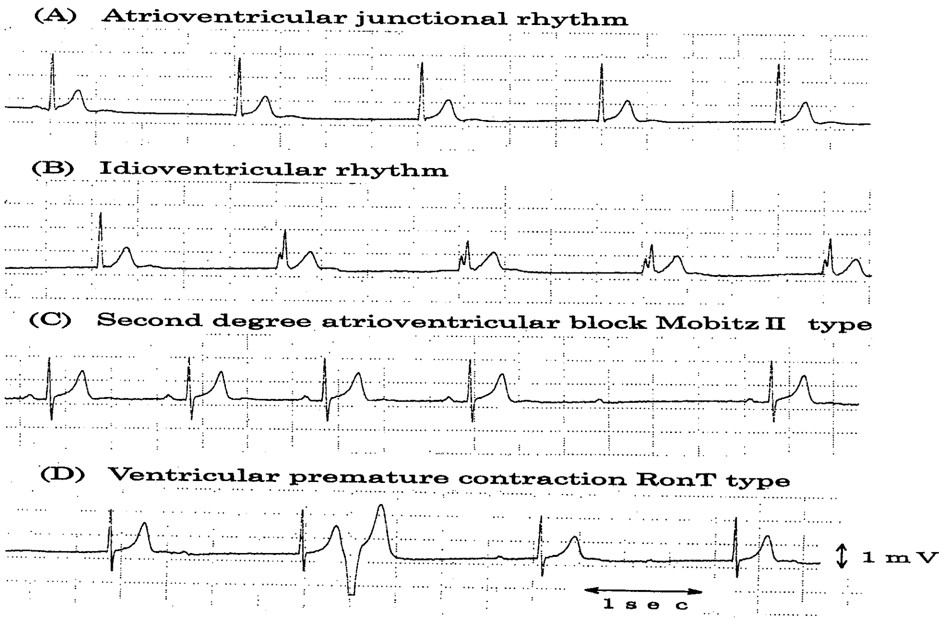


**Fig.1.** The samples of electrocardiographic records showing the various arrhythmias.

## 2. Month-related variations

HRmin and %HRmin of each subject throughout 13 months were indicated in **Table 2** (○ symbol indicates minimum value, ◎ symbol indicates maximum value in the table). There was no clear and regular variation of HRmin and %HRmin in accordance with the seasonal variation. On the contrary, subject SYO and TOK had no arrhythmia while subject HIY and NOR had arrhythmias constantly throughout 13 months during AFI. In addition, former 2 subjects had no arrhythmia constantly throughout 13 months even after AFI. Subject HIY had only one disaccord (October) and subject NOR had only two disaccord (May and June) in the incidence of arrhythmias (**Table 3**). Furthermore, the kinds of arrhythmias induced in two subjects were bradycardiac arrhythmias including AVJEB, AVJR, AVD, 1° AVB, 2° AVB(W), 2° AVB(M), and sinus arrest or sino atrio block (SA or SAB) and intraventricular abberant conduction (IAC).

The coefficients of variation of HRmin through 13 months in the latter two subjects were much greater than those in the former two subjects. In addition, the coefficient of variation of %HRmin in subject NOR was also much greater than that in the former two subjects.

**Table 2.** HRmin and %Hrmin at each month.

| | HRmin(bpm) | | | | | %HRmin(%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | SYO | TOK | HIY | NOR | Mean | SYO | TOK | HIY | NOR | Mean | RT |
| April | 61.3 | 62.5 ◎ | 41.2 | 22.5 ○ | 46.9 | 78.7 | 65.0 | 54.6 | 31.7 ○ | 57.5 | 24.3 |
| May | 66.8 | 53.0 | 45.4 | 32.3 | 49.4 | 77.6 | 61.5 | 55.0 | 44.0 | 59.5 | 23.9 |
| June | 56.0 | 53.4 | 46.1 | 33.3 | 47.2 | 74.3 | 62.5 | 53.2 | 44.5 | 58.6 | 25.5 |
| July | 62.1 | 47.1 | 45.6 | 34.4 | 47.3 | 77.3 | 65.1 | 52.3 | 55.4 ◎ | 62.5 | 26.5 |
| August | 58.0 | 50.6 | 47.3 ◎ | 31.9 | 47.0 | 80.9 | 68.9 | 51.1 | 42.7 | 60.9 | 26.0 |
| September | 59.2 | 48.5 ○ | 31.1 | 27.9 | 41.7 | 79.9 | 64.1 ○ | 46.6 | 35.1 | 56.4 | 24.9 |
| October | 59.5 | 54.0 | 29.4 ○ | 36.3 ◎ | 44.8 | 77.4 | 70.3 | 45.2 | 41.9 | 58.7 | 25.1 |
| November | 52.3 ○ | 56.9 | 41.8 | 36.0 | 46.8 | 63.5 ○ | 64.4 | 56.4 ◎ | 49.0 | 58.3 | 24.5 |
| December | 64.1 | 56.1 | 42.2 | 35.4 | 49.5 | 77.0 | 73.1 | 55.1 | 47.3 | 63.1 | 24.3 |
| January | 61.3 | 60.4 | 35.5 | 36.3 ◎ | 48.4 | 76.1 | 74.7 | 51.5 | 52.9 | 63.8 | 25.4 |
| February | 60.4 | 58.8 | 30.7 | 31.1 | 45.3 | 76.3 | 73.1 | 44.4 ○ | 43.6 | 59.4 | 25.3 |
| March | 64.8 | 57.9 | 40.5 | 29.2 | 48.1 | 85.0 ◎ | 66.3 | 48.6 | 40.7 | 60.1 | 24.5 |
| April | 67.3 ◎ | 56.2 | 39.2 | 34.6 | 49.3 | 72.8 | 76.6 ◎ | 53.2 | 48.3 | 62.7 | 24.5 |
| Mean | 61.0 | 55.0 | 39.7 | 32.4 | 47.0 | 76.7 | 68.1 | 51.3 | 44.4 | 60.1 | |
| SD | 4.2 | 4.5 | 6.2 | 4.0 | 2.2 | 5.0 | 5.0 | 4.0 | 6.5 | 2.3 | |
| CV | 6.9 | 8.2 | 15.6 | 12.4 | 4.6 | 6.5 | 7.3 | 7.7 | 14.7 | 3.9 | |

CV: Coefficient of Variation
RT: Room Temperature

**Table 3.** The incidental arrhythmias at each month

| | SYO | | TOK | | HIY | | NOR | |
|---|---|---|---|---|---|---|---|---|
| | During AFI | After AFI | During AFI | After AFI | During AFI | After AFI | During AFI | After AFI |
| April | none | none | none | none | AVJEB,AVJR | AVJR | 2° AVB(M),2° AVB(W)<br>1° AVB,AVD,AVJR<br>IAC,SAorSAB | none |
| May | none | none | none | none | AVJR | AVD,AVJEB,AVJR | 2° AVB(M),2° AVB(W)<br>AVJR,AVD | AVJR,AVD |
| June | none | none | none | none | AVD,AVJR | AVJR | 2° AVB(W),AVJR<br>AVD | AVJR |
| July | none | none | none | none | AVD,AVJR | AVJEB,AVJR | 2° AVB(W),1° AVB<br>AVD,AVJEB,AVJR | none |
| August | none | none | none | none | AVD,AVJEB,AVJR | AVJEB,AVJR | 2° AVB(M),2° AVB(W)<br>AVD,AVJEB,AVJR | none |
| September | none | none | none | none | AVJR | AVJR | 2° AVB(W),1° AVB<br>AVD,AVJEB | none |
| October | none | none | none | none | SAorSAB,AVJEB,AVJR | none | 2° AVB(W) | none |
| November | none | none | none | none | AVD,AVJR | AVJEB,AVJR | 2° AVB(W),AVD<br>AVJEB,AVJR | none |
| December | none | none | none | none | AVJEB | AVD | 2° AVB(W),AVJEB<br>AVD | none |
| January | none | none | none | none | AVD,AVJEB,AVJR | AVJR | 2° AVB(M),2° AVB(W)<br>AVD,AVJEB | none |
| February | none | none | none | none | AVD,AVJEB,AVJR | AVD,AVJR | 2° AVB(W),AVD | none |
| March | none | none | none | none | AVD,AVJEB,AVJR | AVD | 2° AVB(M),2° AVB(W)<br>AVD,AVJEB | none |
| April | none | none | none | none | AVJR | AVJR | 2° AVB(M),2° AVB(W)<br>1° AVB,AVD,AVJEB | none |

AFI: Apneic facial immersion
AVJEB: Atrioventricular junctional escaped beat
AVJR: Atrioventricular junctional rhythm
AVD: Atrioventricular dissociation
SAorSAB: Sinus arrest or sino atrio block
IAC: Intraventricular abberant conduction
1° AVB: First degree atrioventricular block
2° AVB(W): Second degree atrioventricular block Wenckebach type
2° AVB(M): Second degree atrioventricular block Mobitz II type

### 3. Year-related variations

Year-related variation of HRmin and %HRmin in two subjects were shown in **Fig.2 and Fig.3.** HRmin of subject TOK increased temporarily at 28.4 y.o. and then at around 34.4 y.o. it again began to increase gradually ( That meant the attenuation of bradycardiac response) accompanied by his %HRmin. HRmin and %HRmin of subject RYS tended to increase over 38.9 y.o.

HRmin and %HRmin of subject RYS under 6 conditions both at 31.0 and 42.0 y.o. were shown in **Table 4**. They all increased at 42.0 y.o. compared with them at 31.0 y.o. In addition, no arrthythmia was observed at 42.0 y.o. under every conditions while supraventricular premature contraction were observed at 31.0 under the conditions of 5℃ AFI of exhalatory stage and 15℃ AFI of inhalatory stage.

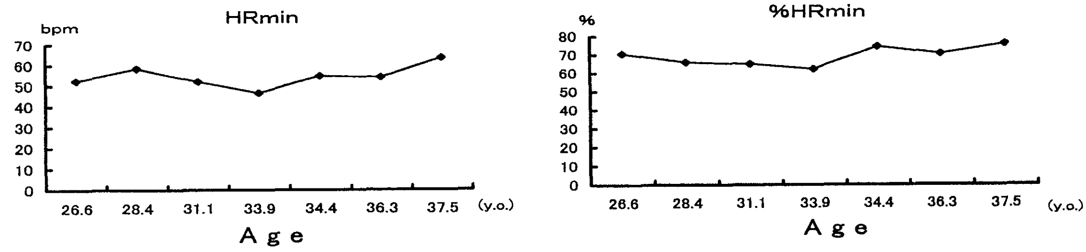


**Fig.2.** Year-related variation of HRmin and %HRmin of subject TOM.

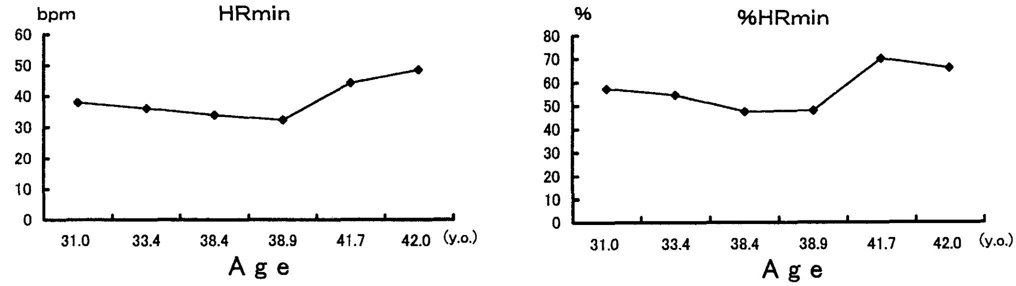


**Fig.3.** Year-related variation of HRmin and %HRmin of subject RYS.

**Table 4.** Comparison of HRmin and %HRmin at 31.0 and 42.0 y.o under each condition.

| | 31.0 y.o. | 42.0 y.o. |
|---|---|---|
| ○Inhalatory stage | | |
| <5°C-AFI> | | |
| HRmin (bpm) | 38.0 | 48.5 |
| %HRmin (%) | 57.2 | 66.2 |
| <15°C-AFI> | | |
| HRmin (bpm) | 42.4 | 56.0 |
| %HRmin (%) | 62.6 | 75.7 |
| <30°C-AFI> | | |
| HRmin (bpm) | 49.6 | 60.0 |
| %HRmin (%) | 81.0 | 87.6 |
| ○Exhalatory stage | | |
| <5°C-AFI> | | |
| HRmin (bpm) | 31.7 | 52.0 |
| %HRmin (%) | 47.7 | 70.9 |
| <15°C-AFI> | | |
| HRmin (bpm) | 42.1 | 59.1 |
| %HRmin (%) | 62.2 | 79.9 |
| <30°C-AFI> | | |
| HRmin (bpm) | 50.4 | 61.0 |
| %HRmin (%) | 82.4 | 89.1 |

AFI:Apneic facial immersion

## Ⅳ.Discussion

The reproducibility of HRmin and %HRmin was very good since there was little difference in HRmin's and %HRmin's measured at various times and each correlation coefficient of them was significant. Likewise, since the HRmin latent time revealed the results which was similar to those of HRmin and %HRmin, the period till the vagus nerve activity which intervened the diving reflex [7～10] became maximum was supposed not to be altered by the time.

Moreover, although there was not complete correspondence as to the kinds of arrhythmias, the reproducibility of incidence of arrhythmias was fairly well both in the load and recovery of AFI.

According to the study [11] in which the more extensive measurement time was set, there was significant difference between HRmin's at 15:00 and 7:00 and between HRmin's at 11:00 and 19:00, which indicated the diurnal rhythm of HRmin by AFI. However, this results seemed to be gained from the special group since the sleep time of this group was from around 2:00 to 10:00. If the more extensive and subdivided measurement times had been set in this study, regular diurnal rhythms of HRmin and %HRmin by AFI would have been observed. But at least the results of this study indicated the possibility of good reproducibility in electrocardiographic response on AFI in the time from 9:30 to 17:30 except at times immediately after meals.

Based on the results of month-related variation, electrocardiographic response by AFI showed no regular variation throughout 13 months. In general, sympathetic nerve activity was suppressed by the heat and was accelerated by the cold. In accordance with this fact, it was expected that HRmin and %HRmin by AFI decreased in summer and increased in winter, but actually the minimum values of them were not always limited to from June to September and maximum values of them were not always limited to from January to March. The reason for it was that the temperature of experimental room was kept constant by the heating and cooling apparatus, which did not induce the seasonal variation of HRmin and %HRmin.

The fear against cold water immediately before AFI, which had the possibility to enhance the bradycardiac response by AFI [4], and the other psychological situation like expected agony fluctuated month by month, which magnitude was more than day by day fluctuation. Consequently, the month by month fluctuation of these emotion were the main cause of random fluctuation in HRmin and %HRmin. From the paradoxical point of view, if we tried to let HRmin and %HRmin not be influenced by the seasons, we would have to keep the experimental room temperature constant. And the strict reproducibility of HRmin and %HRmin in the month unit could not be expected, since the psychological situation and susceptibility to the pain induced by the cold water were not unified over several months.

The coefficients of variation through 13 months in HRmin, like the study results of Okano et al [12], were more in the subjects with arrhythmias than in those without arrhythmias. This results indicated that the maximum suppression action via vagus nerve to the sinus node within the given time was variable, but the physiological meaning of this phenomenon was still unknown.

With regard to the incidence of arrhythmias, good reproducibility was observed during and after AFI, which indicated that the incidence of arrhythmias by AFI was irrelevant to the seasons. The reason for the usual incidence of arrhythmias despite the large fluctuation of HRmin was that the suppression action to the sinus node by AFI was usually over the threshold value which triggered the inducement of arrhythmias. But the further study in which the age of subjects was teens or over 40 will be indicated.

Based on the results of year-related variations, one subject showed an attenuation of diving bradycardia over 34.4 y.o. and another subject did so over 38.9 y.o. It was reported that the physical training enhanced the bradycardiac response by AFI [13], but the two subjects' cardiac attenuation responses were strongly influenced by the aging since the physical training contents of two subjects were unchanged for 11 years. In addition, it was expected that if the physical training had not been continued, the attenuation of bradycardiac response would have been further firmed. In the literature [14～17] which investigated the cross-sectional relationship between bradycardiac response by AFI and the aging, bradycardiac response was reported to be attenuated with the aging. Likewise, Okano [18] reported using the cross-sectional data that HRmin and %HRmin revealed the quadratic regression variation with the large difference depending on the individual and decreased in from 20 to 39 y.o.

The results of this longitudinal research, though the number of subjects was very few, supported the results of the cross-sectional research. In addition, it was reconfirmed that there was individual difference in the opening age of bradycardiac response attenuation. This attenuation suggested the weakening of vagus nerve susceptibility with the aging. However, Okano et al [19] reported the gradual increase of serum catecholamine during AFI of 5℃ water and the suppression of sympathetic nerve responsiveness was reported over 35 y.o. by Hayano [20], and over thirties by Tamura et al [21]. Consequently, further study concerning the age-related variation of sympathetic nerve activity should be indicated.

Furthermore, based on the comparison of HRmin's and %HRmin's in subject RYS under 6 conditions separated for 11 years, it was suggested that the bradycardiac response attenuation was irrelevant to the water temperature or respiratory stage. However, it was very significant as the effects of age that the latter age of subject RYS in the experiment was over 40 y.o., so further study containing more subjects should be indicated. Moreover, the fact that the number of arrhythmias in subject RYS tended to decrease after 11 years was in accordance with the result reported by Okano [18] that the incidence rate of arrhythmias by AFI in the group aged from 40 to 67 y.o. was lower than that in the group aged from 20 to 39 y.o.

Taking that AFI is a maneuver to arrest the paroxysmal supraventricular tachycardia (PSVT) into consideration [10,22], it is suggested that the suppression effect of AFI on PSVT is expected firmly from 9:30 to 17:30 except at times immediately after meals and is possibly attenuated with the aging based on this study results.

## V. Conclusion

This study examined the time, month, and year-related variations of electrocardiographic response provoked by AFI.

There was no time-related variation on bradycardiac response and was good correspondence in the incidence of arrhythmias, which indicated that there was good reproducibility in the electrocardiographic response by AFI at 9:30, 12:00, and 17:30 except at times immediately after meals.

There was no regular and seasonal variation of bradycardiac response throughout 13 months, which was to some extent related to the fact that the level of room temperature was kept constant in the experiment and the difference of the subject's psychological situation. However, good reproducibility was observed in the incidence of arrhythmias.

Although the number of subjects was very few, longitudinal study over 11years showed the attenuation of bradycardiac response by AFI after the mid thirties, which was in accordance with the results of cross-sectional study.

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