Ventilatory Response to CO2 Rebreathing at Rest in the Ama

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Summary Ventilatory response to CO2 in the Ama (Kachido) was determined by the CO2 rebreathing method in the beginning (March) and during (September) harvest season. It was found that mean slopes of the ventilatory response curve in March and September were 0.76 and 0.73 liters/(min·m2·mmHg), respectively, this difference being insignificant.

IGARASHI (1969) observed in 8 active Amas that sensitivity of the respiratory system to carbon dioxide just after harvest season was significantly lower than that obtained 3 or 6 months later. Since the method of his study was not performed in accordance with the current concept (CHERNIAC et al., 1977), we intended to reinvestigate whether such acclimatization of CO2 response would have occurred in the Ama during harvest season.

The subjects were 5 active Amas, aged 41–65 years, with 24 to 27 years of diving career, at Izu peninsula in Shizuoka Prefecture, Japan. Their diving was performed without assistance, called the Kachido type. No general clinical examination was carried out, but all subjects were physically active female divers in good health. The subjects were studied in a Japanese inn near the seaside where they had been working for about 4 hr each day throughout the year except from December to February. The subjects were briefly informed about the experimental procedure, but not about the results of experiments until the study had been completed. The experiments were performed midmorning at least 1 hr after their breakfast.

Ventilatory response to CO2 was determined by the rebreathing method (READ, 1967). The rebreathing bag with a capacity of 10 liters was placed in an airtight
plastic box which was connected to a respirometer (Benedict type, 13.5 liters, Fukuda, Tokyo) to record ventilation. After the subject had rested in a sitting position on a comfortable chair for 30 min, the subject rebreathed 5 liters of gas mixture of about 7% CO₂ in O₂ for 4 min. A continuous record of alveolar $P_{CO_2}$ ($P_{A\ CO_2}$) during rebreathing was obtained by drawing a sample of gas from the mouthpiece through an infrared CO₂ analyzer (Capnograph, Godart, Holland). After passing through the CO₂ analyzer, the sample gas was returned to the rebreathing bag via a three-way stopcock to prevent changes in the bag volume. The CO₂ analyzer was calibrated by two gas mixtures of known CO₂ concentration that had been checked by the Scholander gas analyzer.

Minute ventilation ($\dot{V}_E$) was calculated for successive 30-sec intervals from a spirographic recording, and the gas volume was corrected to BTPS condition. From these $P_{A\ CO_2}$ and $\dot{V}_E$, we calculated the slope of the ventilatory response curve to CO₂ by the least-square method: $\dot{V}_E = S (P_{A\ CO_2} - B)$, where $S$ is the slope expressed as change in ventilation per unit change in $P_{A\ CO_2}$. In order to ascertain the reproducibility of the slope of ventilatory response curve for each subject, duplicate determinations were conducted for each subject on different days both in March and September, respectively. In these experiments the experimental conditions were kept as similar as possible, and they were carried out about the same period of time each day. All probability values were derived by applying the paired t test, and differences in $p<0.05$ were considered significant.

The Amas in the present study engage in diving work with breath-holding almost all the year round except the winter. It is conceivable that, being accustomed to such breath-holding, the Ama may have acquired tolerance to hypercapnia and/or hypoxia. As described above, IGARASHI (1969) has determined the ventilatory response to CO₂ in 8 active Amas, 34-42 years old, with 10–30
Table 1. Comparison of the ventilatory response to CO₂ in the Ama measured before (March) and near the end (September) of the harvest season.

<table>
<thead>
<tr>
<th>Subjects</th>
<th>March</th>
<th>September</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S₁</td>
<td>S₁₁</td>
</tr>
<tr>
<td>H. Y.</td>
<td>1.37</td>
<td>0.87</td>
</tr>
<tr>
<td>K. F.</td>
<td>1.17</td>
<td>0.67</td>
</tr>
<tr>
<td>A. Y.</td>
<td>0.80</td>
<td>0.52</td>
</tr>
<tr>
<td>M. Y.</td>
<td>1.37</td>
<td>0.86</td>
</tr>
<tr>
<td>M. F.</td>
<td>1.40</td>
<td>0.76</td>
</tr>
<tr>
<td>Mean</td>
<td>1.22</td>
<td>0.76</td>
</tr>
<tr>
<td>±SD</td>
<td>0.22</td>
<td>0.14</td>
</tr>
</tbody>
</table>

S₁, slope of the ventilatory response curve (liters/min·m²·mmHg); S₁₁, slope of the ventilatory response curve as ventilation was corrected to body surface area (liters/(min·mmHg)); B, extrapolated to intercept on PₐCO₂ (mmHg).

years of diving career. Their CO₂-ventilation response slope just after harvest season (0.48 liters/(min·m²·mmHg)) was found to be significantly lower than that 3 months (0.89 liters/(min·m²·mmHg)) or 6 months (0.91 liters/(min·m²·mmHg)) later (p<0.001). On the contrary, it was found in this study that mean values and standard deviation of the slope of ventilatory response curve were 1.22±0.22 liters/(min·mmHg) (0.76±0.14 liters/(min·m²·mmHg)) in the beginning (March) and 1.18±0.43 liters/(min·mmHg) (0.73±0.25 liters/(min·m²·mmHg)) near the end of the harvest season (September). These differences were statistically not significant (Table 1).

At present no definite explanations for the discrepancy in the results between Igarashi’s and our studies can be given with physiological reasons. Possible reasons so far considered are as follows.

1) Method of study: Igarashi (1969) estimated the CO₂ response slope from the ratio of change in ventilation (Vₑ) to change in alveolar PₐCO₂ (PₐCO₂) between room air breathing and at the end of 5% CO₂ inhalation for 15 min. Since the respiratory data in room air breathing are not recommended for inclusion in evaluation of CO₂ response slope due to large deviation from the response curve frequently encountered (Cherniak et al., 1977), physiological significance of Igarashi’s data must be evaluated with some reservation. On the other hand, we used the rebreathing method for the following reasons; (1) The so-called steady-state method is very time-consuming because at a given PₐCO₂ level 7–13 min were needed in order to obtain a steady ventilatory level, and ventilation and alveolar PₐCO₂ were recommended to determine at the 4 to 5 level of increasing PₐCO₂ (Miyamura et al., 1976). (2) The rebreathing method is simple, so that the response curve can be obtained within a single trial lasting only 4 min. (3) The slope of response curve at rest was reported to be the same both in the steady-state and rebreathing methods (Read, 1967; Clark, 1968; Linton et al., 1973). (4) There
was a high correlation between the first and second slopes when the slope of
the response curve was determined in duplicate (Ohkuwa et al., 1980).

2) Difference in the subjects: Although the Amas in both studies are un-
assisted breath-hold divers (Kachido) with comparable diving careers, the length
of diving period in the year is much shorter (May to October) in Igarashi’s than in
our subjects (March to November). A brief interruption in diving activities could
have been a cause of insufficient deacclimatization from adaptation to CO₂ stimu-
lation in our subjects, thus no difference in CO₂ response was seen between the
beginning and midharvest seasons. However, Masuda et al. (1981) found that
there were no significant differences in CO₂-ventilation response slope between
the same subjects in the present study and the control female group of comparable
age. Therefore, the present Amas may not have acclimatized at all to hypercapnic
drive by their professional diving activities.

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