Nagoya J. Health, Physical Fitness, Sports Vol. 8, No. 1 (March 1985)

Short Communication

Ventilatory Responses to Hypercapnia and Hypoxia after Intermittent Hypoxic Exposure

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The present study was designed to examine in the 6 male students whether or not ventilatory responses to hypercapnia and hypoxia at sea level increase after intermittent hypoxic exposure once a day (about 1 hour) for 6 days by means of decompression chamber (simulated altitude 4,500 m). It was found in this study that at sea level ventilatory responses to hypercapnia at rest and to hypoxia during submaximal exercise did not alter by intermittent hypoxic exposure as applied here.

In 1971 Forster et al. have reported that the ventilatory response to hypoxia and to increased CO_2 was elevated in lowlanders 75–100% throughout their altitude at 3,100 m, and that forty-five days after return to sea level, none of individuals had returned completely to their prealtitude status. Recently, we determined pulmonary ventilation breathing of room air and low oxygen gas mixture during submaximal exercise at sea level before and after ascent of Mt. Huascaran (6,768 m) or Mt. Tent Peak (5,760 m). It was suggested that raised ventilatory response to hypoxia during submaximal exercise was still maintain for at least 1 or 2 weeks after returning to sea level, but not hypercapnia at rest (Miyamura et al., 1984). These results obtained from lowlanders who had sojourned continuously at high altitude for 1–2 months. However, there are no avairable data regarding the hypoxic and hypercapnic ventilatory response after intermittent hypoxic exposure.

The present study, therefore, was designed to examine whether or not ventilatory response to hypoxia during submaximal exercise at sea level increase after intermittent exposure to hypoxic condition by means of decompression chamber, and to compare hypercapnic ventilatory response at rest before and after intermittent hypoxic exposure.

Six male students of our University 18–19 years of age participated in this study as subjects. All subjects had been born and lived in a city at sea level. Fig. 1 shows an outline of experimental procedures. The subject performed a preliminary test on bicycle ergometer to accustom themselves to the procedure at both sea level and an altitude chamber (simulated altitude 4,500 m). Successive experiments on each subject were conducted separate days on July 12, 1982 and July 18, 1982. The decompression chamber was used to intermittent hypoxic exposure to a barometric pressure of 462 mmHg, corresponding to 4,500 m. Each subject was entered into the decompression chamber once a day for six days and sojourned at 4,500 m for about one hour. During experimental periods, they performed submaximal exercise on the bicycle ergometer with work load of 1.5 kp for

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7 min both at sea level and altitude chamber after 20 min rest. In the decompression chamber, particularly, the submaximal exercise started after the lapse of 15 min from point of arrive at 4,500 m.

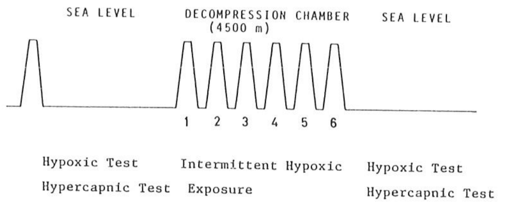

Fig. 1. Schematic diagram of experimental procedures.

The following measurements were made at sea level before and after intermittent hypoxic exposure. Experiments were always conducted in the afternoon starting not less than 2 hours after a light meal. First, the ventilatory response to carbon dioxide at rest was determined in the sitting position by Read's rebreathing method (Read, 1967). The experimental set-up was similar to that described previously (Miyamura et al., 1976). A rubber bag with a capacity of about 10 liters was placed in an-airtight plastic box which was connected at one end to a respirometer for recording ventilation. The bag was filled with 6 liters of a gas mixture about 7% CO_2 in O_2. Rebreathing started at the end of a maximal expiration and continued for 4 min. Gas from mouthpiece was continuously sampled through infrared CO_2 analyzer (Capnograph, Godart). Tidal volume and breathing frequency were obtained kymographically from the respirometer, and were converted to minute ventilation ($\dot{V}_E$). Ventilation / alveolar P_{CO_2} (P_{ACO_2}) response lines were determined by fitting a straight line by the method of least squares to 30 sec data points during the 4 min of rebreathing (the first 30 sec point was included) : $\dot{V}_E = S(P_{ACO_2} - B)$, where S is the slope expressed as change in ventilation per unit change in P_{ACO_2} and B is the extrapolated intercept in the abscissa. Moreover, the breathing pattern was analyzed in terms of the slope and intercept (M and k) of the linear regression of ventilation on tidal volume as proposed by Hey et al. (1966) : $\dot{V}_E = M(V_T - K)$.

To measure the hypoxic ventilatory drive during submaximal exercise, we chose to measure an index of hypoxic ventilatory drive during exercise at sea level by comparing minute ventilation breathing of air ($\dot{V}_{E(nor)}$) and breathing of about 10% O_2 ($\dot{V}_{E(hypo)}$) before and after the intermittent hypoxic exposure. The subject performed exercised on a bicycle ergometer for 8 min with work load of 1.5 kp. The pedaring rate was kept constant at 60 rpm and timed with metronome. The subject inhaled air through a face-mask from the start of exercise to 5 min and low O_2 from 5 min 15 sec to 7 min. Expired gas during exercise was collected into the Douglas bag two times from 3–5 min and from 5.5–7 min, respectively. The collected gas volume was measured with a wet-gasometer, and mean minute ventilation of breathing air ($\dot{V}_{E(nor)}$) and a low oxygen gas mixture ($\dot{V}_{E(hypo)}$) was estimated.

As described previously, Forster et al. (1971) have observed that the ventilatory response to hypoxia and hypercapnia were increased in lowlanders throughout their altitude at 3,100 m and none of individual had returned completely to thier prealtitude level on 45 days after return to sea level. It was found in this study that average values of the slope of ventilatory response to hypercapnia at rest before and after intermittent hypoxic exposure were 1.23 ± 0.53 and 1.32 ± 0.61 l/min, respectively. There are no significant difference not only in S, but also B, M and K as shown in Table 1. On the other hand, Table 2 indicate results of ventilatory response to submaximal exercise at sea level before and after hypoxic exposure. Average values of oxygen

Table 1. Ventilatorty response to hypercapnia at rest before (B) and after (A) intermittent hypoxic exposure by means of decompression chamber.

Subjects	S		B		M		K	
	B	A	B	A	B	A	B	A
R. I.	1.00	1.31	44.2	44.4	17.9	19.7	0.05	0.15
H. W.	0.66	0.70	37.0	40.7	26.4	17.4	0.20	0.17
W. N.	0.73	1.29	31.1	40.9	27.6	29.5	−0.09	0.03
A. M.	1.75	2.47	42.8	42.2	30.4	23.4	0.82	0.82
Y. T.	2.02	1.20	45.5	37.5	23.0	29.4	−0.09	0.21
T. I.	1.23	0.95	41.7	41.2	24.7	19.7	0.29	0.36
mean	1.23	1.32	40.3	41.2	25.0	23.1	0.20	0.29
± SD	0.55	0.61	5.4	2.2	4.3	5.2	0.34	0.28
	ns		ns		ns		ns	

ns: not sinificant

Table 2. Ventilatory response to submaximal exercise at sea level before (B) and after (A) intermittent hypoxic exposure by means of decompression chamber.

Subjects	$\dot{V}O_2$		$\dot{V}_{E(nor)}$		$\dot{V}_{E(hypo)}$		$\dot{V}_{E(hypo)}/\dot{V}_{E(nor)}$	
	B	A	B	A	B	A	B	A
R. I.	1.17	1.24	27.6	29.4	47.8	45.7	1.73	1.55
H. W.	1.15	1.09	46.9	38.0	63.7	62.6	1.35	1.64
W. N.	1.04	1.10	37.2	36.8	59.4	51.6	1.59	1.40
A. M.	1.13	1.21	34.4	35.9	55.7	49.6	1.61	1.38
Y. T.	1.07	1.04	48.3	45.5	56.8	47.2	1.17	1.03
T. I.	1.09	1.09	30.9	31.7	45.3	48.1	1.46	1.51
mean	1.11	1.13	37.5	36.2	54.7	50.8	1.48	1.41
± SD	0.05	0.08	8.4	5.6	6.9	6.1	0.18	0.19
	ns		ns		ns		ns	

ns: not significant

uptake and pulmonary ventilation during submaximal exercise for 3–5 min were 1.11 ± 0.05 and 37.5 ± 8.4 l/min for the pre-hypoxic exposure and 1.13 ± 0.08 and 36.2 ± 5.6 l/min for the post-hypoxic exposure, respectively. Pulmonary ventilation breathing of low oxygen (about 10% O_2) was decreased in the 5 out of 6 subjects after hypoxic exposure by the decompression chamber. However, there are no significant difference in the $\dot{V}_{E(hypo)}$. The ratio of $\dot{V}_{E(hypo)}$ to $\dot{V}_{E(nor)}$, which is an index of hypoxic ventilatory drive during exercise at sea level, was almost the same before and after intermittent hypoxic exposure. Our results suggest that ventilatory response to hypercapnia at rest and to hpoxia during submaximal exercise did not change by intermittent hypoxic exposure by means of decompression chamber as applied here. At present, we can not explain why ventilatory response to hypercapnia and hypoxia did not increase by the intermittent hypoxic exposure. It will be related to various factors such as altitude, sojourn time, exposure frequency etc. In other words, it is possible to assume that chemosensitivity to hypercapnia and/or hypoxia may be able to alter by the intermittent hypoxic exposure using decompression chamber by increase of altitude, sojourn time and exposure frequency, even if subject do not go to high altitude. However, the possibility mentioned above needs further investigation.

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(Received January 26, 1985)